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Technical report – DIVA

Monitoring and management of high Andean biodiversity - a study from Cochabamba, Bolivia

DIVA, Technical Report No 6

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- a study from Cochabamba, Bolivia

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Centre for Research on the Cultural and Biological Diversity of Andean Rainforests (DIVA)
The Danish Environmental Research Programme

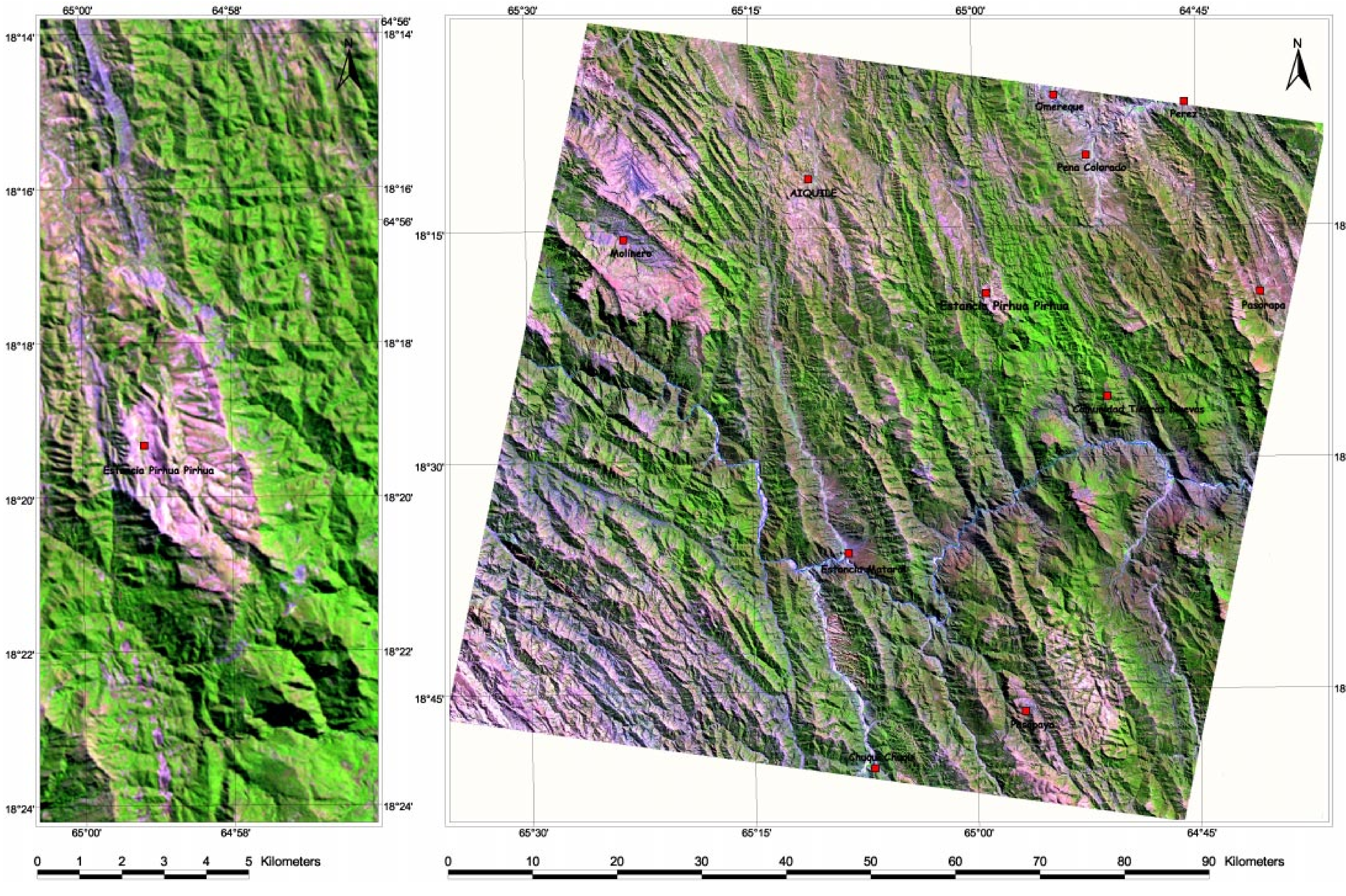

Figure 1. Colour composites of the southern study region with the raw sateillite bands : TM5, TM4 and TM3 displayed as red, green and blue. Note that TM4, loaded as green, represent the reflectance recorded in the near-infrared part of the electromagnetic spectrum.

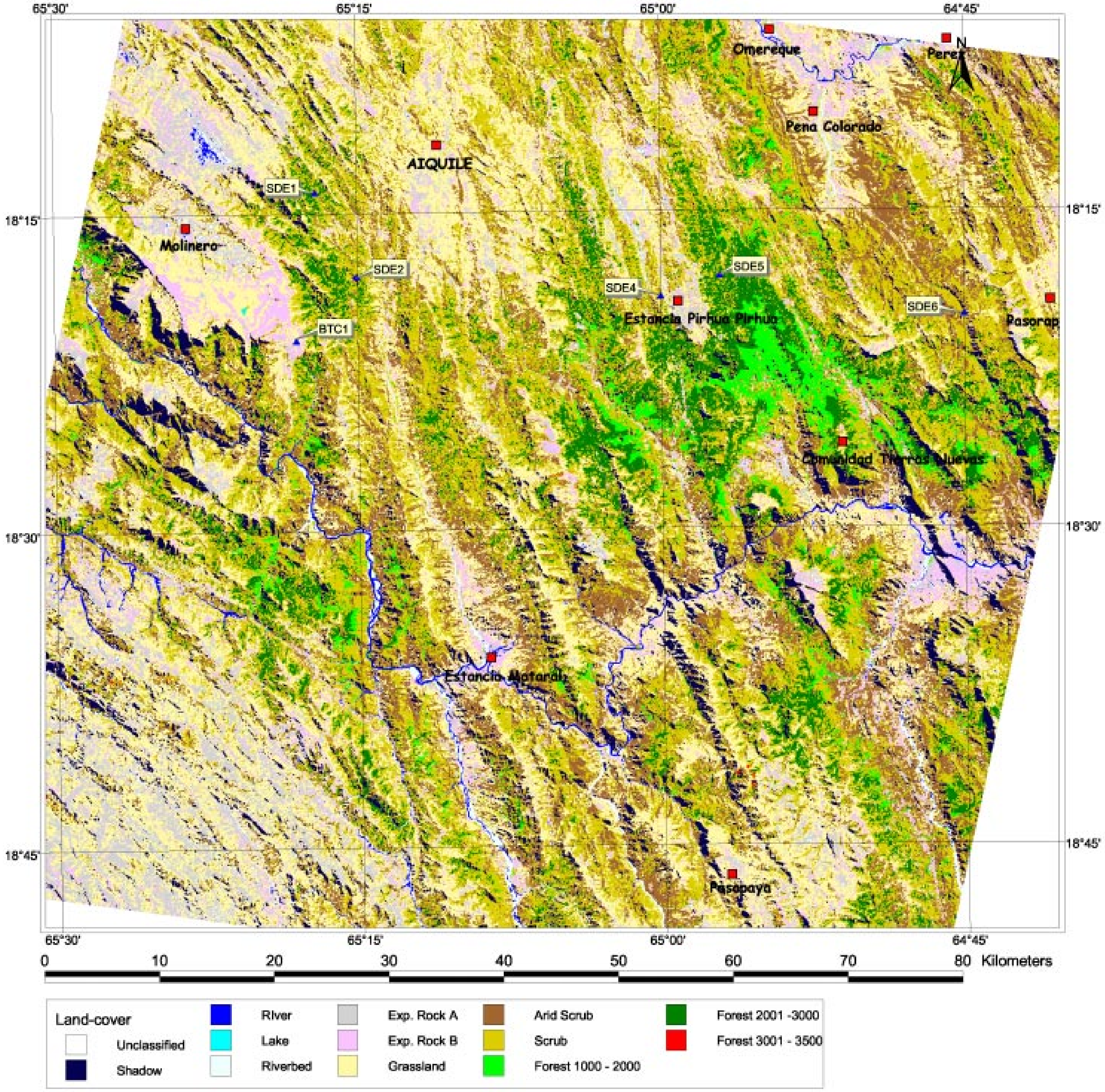

Figure 2. Land-cover map of the southern Study region. The map produced by applying the maximum-likelihood classifier has been combined with an elevation model in order to subdivide the forest into 3 elevation zones. See the legend(and Table 7) for explanation of the colour codes.

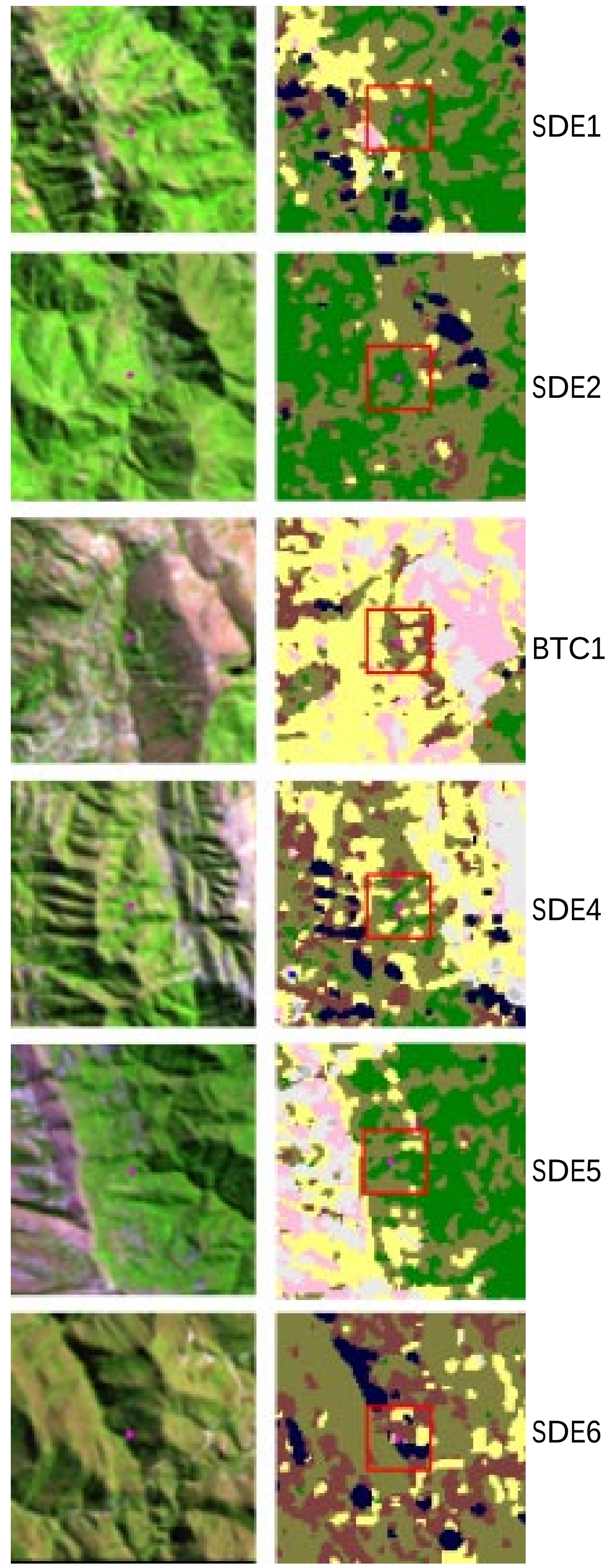

Figure 3. Detail images of the study sites SDE1, SDE2, BTC1, SDE4, SDE5 and SDE6 in the southern study area used to calculate the correlation between the heterogeneity of the landscape and the bird communities found inside the forest fragments. The images to the left are RGB-composites of the study sites with TM5, TM4 and TM3 loaded as red, green and blue. The right images are false-coloured classified images of the same sites. The red frame has a side of approximately 900 m.

Monitoring and management of high Andean biodiversity

– a study from Cochabamba, Bolivia

DIVA, Technical Report no 6

Poul Nygaard Andersen, Thor Hjarsen
and Nicholas Moray Williams

Centre for Research on the Cultural and Biological
Diversity of Andean Rainforests (DIVA)
July 1999

Data sheet

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Contents

Preface

This report contains results from two independent studies of birds in the Andes of Bolivia. The studies have been conducted in upper montane *Polylepis* woodlands and in dry deciduous forest, which are considered to be some of the most fragmented and threatened habitat types in the Neotropics. Both studies represent new approaches to the study of bird communities and species richness: The aim of the first study is to assess the effects of traditional land-use versus plantation forestry on bird species richness and thereby contribute to a better management of the remaining patches of native montane forest in Bolivia. The second study explores the usefulness of remote sensing to map land-cover, forest fragmentation and predict bird species richness.

We hope the report will find use not only for biologists who are interested in the rich bird life of Bolivia, but also for those with a general interest in biodiversity, land-use and management. An updated land-cover map of the southern part of the study region with dry decidous woodland is provided with the report. This map is also available in digital form from DIVA.

Flemming Skov
Co-ordinator, DIVA

Center for Research on the Cultural and Biological Diversity of Andean Rainforests (DIVA)

DIVA is a multi-disciplinary research centre funded since 1994 by the Danish Environmental Research Programme. The purpose of the centre is to investigate regional patterns of biodiversity, land-use, and human perception of the environment, to improve strategies and to combine the obtained knowledge with recommendations for a balanced and sustainable use of the Andean forest ecosystems and natural resources. The research is carried out in Ecuador, Peru, and Bolivia in close collaboration with local institutions and organisations. The project is divided into eight inter connected and inter disciplinary modules:

1. Establishment of project databases and a Geographical Information System.
2. Mapping environmental constraints.
3. Mapping biodiversity based on present day knowledge and new collections.
4. Development of methodologies for standardised sampling and for modelling biological distributions based on correlations with satellite imagery.
5. Studying environmental perception, local use of natural resources and land-use classification and mapping.
6. Studying the influence of different cultural pressures on biodiversity.
7. Predicting socio-economic scenarios and future development trends.
8. Providing information for better planning.

DIVA involves:

– National Environmental Research Institute, Department of Landscape Ecology.
– University of Aarhus, Department of Systematic Botany.
– Danish National Museum, Department of Ethnography.
– University of Copenhagen, Zoological Museum.
– Several collaborating institutions in Ecuador, Peru, and Bolivia.

Figure 4. The DIVA team was gathered in February 1997 in Ecuador.

Summary

This report summarises the results of two independent biological studies from the highland slopes and dry inter-montane valleys of the Valles of the Bolivian Andes in the Cochabamba department (Fig. 8). The studies were carried out in upper montane *Polylepis* woodlands ("the northern study site"), and in dry deciduous forest ("the southern study site") which are two of the most fragmented and threatened habitat types in Bolivia and the Neotropics.

The real dimensions of Bolivia's biodiversity are not yet well known due to the short history of biological research in the country. Birds are by far the most studied animal group in Bolivia and the distribution of most species has been described. With as many as 1,404 species, Bolivia is among the most diverse countries in the world. Birds are good biological indicators because they are numerous and have dispersed into, and consequently often become specialised and restricted to distinct habitat types. From this follows that many birds are sensitive to modification of their habitat and can be used as indicators of ecosystem health. Most birds are diurnal and active, so they can be inventoried fairly easily. On this background, birds were considered a very useful group to use for the studies presented in this report.

In the *northern study site*, the effects of various types of traditional land use and plantation foretry on forest biodiversity were investigated. *Polylepis* woodland is the climax vegetation in the Cochabamba highlands. The potential coverage of *Polylepis* forest in Bolivia is found to be 51,000 sq. km and only 10% of this coverage is estimated to be left. The *Polylepis* forests remain today as small, highly fragmented woodlands surrounded by grasslands, scrub or fields, and the woodlands are often restricted to steep slopes or in deep ravines. Locally, bird species richness in *Polylepis* woodlands are high and the highest densities in Bolivia are found in the mountain ranges north and west of the town of Cochabamba.

The study conducted in *the southern study site* explores the feasibility of using satellite imagery to map montane forest fragments and predict the distribution of bird species. This part of the study region is dominated by dry vegetation types, but due to the sharp gradients in altitude and humidity, small pockets of humid and semi-humid forests are found locally. Rainfall is seasonal, usually from November to February with a dry season the remaining 6–8 months, – in some areas up to 11 months. The dry vegetation cover consists of deciduous or semi-deciduous forest and scrub with many endemic plant species, and species typical of the Chaco in the eastern foothills and lowlands. No estimates of the past or present coverage of dry forest in the Valles exist but the potential cover is certainly much larger than present days. Most remaining dry forest in southern Cochabamba exists as small fragments in a landscape dominated by shifting cultivation, grazing, and erosion. Forest cover is confined to patches in bottoms of steep ravines where the vegetation is relatively protected against manmade fires. In humid ravines at 1,500–2,500 m patches exist of semi-deciduous forest up to 20–30 m in height.

In the study, the ability of mapping extensive or inaccessible areas by use of digital satellite imagery was demonstrated as an efficient methodology to identify and quantify landcover. In the southern part of the study region 10 different landcover classes were identified, and less than 9% of the area mapped was classified as forest, reflecting the fact that the region is highly degraded.

Data from the forest fragments visited in the study region showed a clear correlation between bird diversity and structural diversity of the forests. However scrub species or widespread generalists are invading the forest fragments. Edge species have been favoured, and in some areas species richness in and around the woodland fragments has probably risen due to the influx of less specialised species that are abundant in many types of habitat. When the relationship between the landscape heterogeneity surrounding the forest patches and the number of bird species recorded inside these was examined, a correlation between heterogeneity and number of scrub species present was found. No correlation between the number of forest

species and landscape heterogeneity was discovered (the landscape heterogeneity was measured in a quadrate of approximately one sq. km). Forest species richness is highest in the forest fragments situated close to the largest forest covered area in the region.

Species richness within the semi-deciduous forest communities in the southern part of the study site was low compared with the humid forests further north, which is a general situation in the Valles. The results from the study show a substantial turnover (beta-diversity) of forest species between study sites, and thus regional species richness is high. Relatively few understory and terrestrial birds remain in many of the forest fragments. Obviously forest fragmentation, overgrazing and trampling by livestock has a serious impact on the bird diversity. If the remaining forest patches were managed in a way that allowed undergrowth regeneration many species would be able to recolonise by dispersion from other patches.

Very little documentation on the effect of forest fragmentation and exotic plantation in the Andes on the bird fauna is found in the literature. In the present study it was found that exotic plantations can not support near-natural levels of bird diversity. When looking at community structure, species richness, bird densities, and abundance of restricted range species, these indicators are in all cases significantly different from the native forest vegetation habitats classified in the study as *Polylepis* woodlands and mixed woodlands of native species. Accordingly, the exotic plantations with *Eucalyptus* and *Pinus* studied can not substitute the biological richness of the native forest ecosystems.

In the study it was documented that human land-use does not threaten the endemic avifauna of the highland forests, as long as patches of native trees and bushes are allowed to remain. Such a land-use would be possible in different agroforestry systems, including those presently in use by a few communities in the highlands of Bolivia. Certain bird species, fruit and insect eaters, occurred at lower abundance in habitats with high land-use pressure, while some seed-eaters where most abundant in these habitats. An important finding was that several of the priority species occurring in the highland woodlands on the mountain fringes of the Cochabamba basin largely seemed to be unaffected by human land-use. Species dependent on dense vegetation and well-developed understory seemed to prefer habitats with low land-use pressure.

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The project team wishes to thank a number of persons and institutions for their valuable help during the field work and in the preparation of the report.

First of all we wish to thank the staff and students from Universidad Mayor de San Simón in Cochabamba for field assistance, practical help and valuable discussions: Elva Villegas Nuñez, Nelly de la Barra R., Jeanette M. Mercado, Erika Fernández (see Fig. 5), Susanna Arrazola, Gonzalo Navarro, Maritzha del Castillo, Sául Arias Cossio and Wilma Crespo.

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The southern studies (Nicholas Moray Williams and Poul Nygaard Andersen) were supported by Torben and Alice Frimodts Fond, The Frimodt–Heinike Fond, Herboms Boglegat and the Faculty of Natural Science, University of Copenhagen.

Figure 5. To the left: Elva Villegas Nuñez from CUEMAD, Universidad Mayor de San Simón and Nelly de la Barra R. from Herbario Forestal Nacional "Martin Cardenas", Universidad Mayor de San Simón, collecting flowering branches at Cerro Puca Yaku (18°20'S 64°45'W).
To the right: Jeanette M. Mercado and Erika Fernandez from Herbario Forestal Nacional "Martin Cardenas", Universidad Mayor de San Simón taking a rest at the campsite at Lopez Mendosa (17°29'S 65°24'W).

1. Introduction

by Nicholas Moray Williams, Thor Hjarsen and Poul Nygaard Andersen

Bolivia is one of the richest countries in the world in terms of ecological regions and biodiversity. It is also regarded as one of the world's poorest nations in economic terms (Ibisch 1998). For several thousand years human activities on the upper slopes and in the highlands of the eastern Andes have led to large-scale clearing of the primary vegetation cover, causing soil degradation and an irregular flow of water. Today, Bolivian highlands have some of the highest erosion rates in the World. Most major cities are situated in the dry intermontane valleys or highlands of the eastern Bolivian Andes. Approximately 86% of the population of the Valles and highlands of southern Bolivia inhabits the zone above 2,500 meters (Fjeldså & Kessler 1996) (Fig. 6 & Fig. 7).

The fauna and flora of the dry valleys – Los Valles, is underdescribed, but recent studies have shown that the remaining, highly fragmented forest habitats still contain unique ecosystems with hundreds of endemic animal and plant species. The high regional endemism with both young and old species may be due to intrinsic ecoclimatic stability leading to low extinction rates (Fjeldså & Maijer 1996; Hanagarth & Szwagrzak 1998). The Cochabamba basin in the Valles, where the studies presented in this report have taken place (Fig. 8), contains one of the most unique aggregates of endemic bird species in the Andes and it has been suggested that the region is of great importance for maintenance of continental biodiversity (Fjeldså & Rahbek 1998).

Despite the importance of the area, there are few protected areas within the Valles region (Cardozo 1988; IUCN 1992; Pacheco and others 1994; Hanagarth & Szwagrzak 1998) and administration of protected areas in Bolivia has until recently been inadequate (USAID 1986; MDSMA 1994; Ribera 1996; Lozada 1998).

However, the political process in Bolivia has moved towards regional autonomy and this raises hopes of social and economic development for the rural population. The Valles region may be managed in an ecologically sustainable way, only if political decisions include conservation as a goal of development. Thus, it is necessary to establish which forms of human land use are compatible with maintaining the biodiversity of the Valles and which habitats are most important. To do so surveys of local and regional biodiversity are necessary.

Approximately 86% of the population of the Valles and highlands of southern Bolivia inhabits the zone above 2,500 meters.

Figure 6. Most people living outside the larger cities are campesinos (peasants).

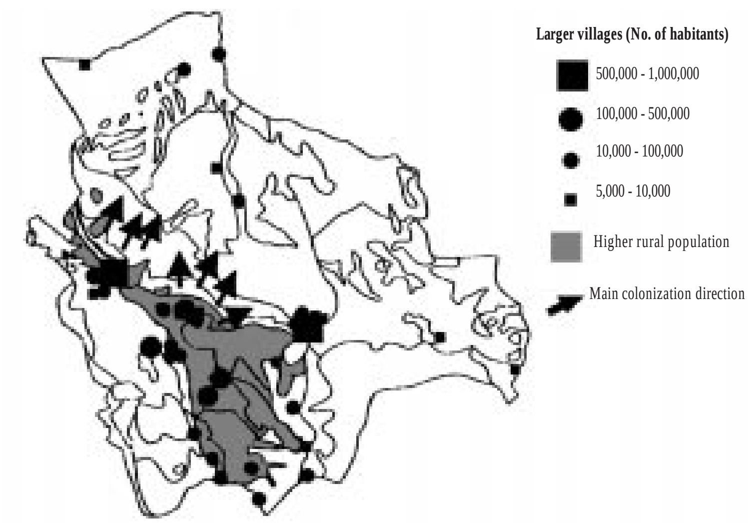


Figure 7. Larger villages, cities and regions with the highest rural population density. Population pressure is highest on the altiplano, in the Valles and on the eastern Andean slopes towards the lowlands. From Ibisch (1998).

Figure 8. The map shows the study region in the Cochabamba bassin and surrounding highlands. Locations of the northern and southern areas are indicated.

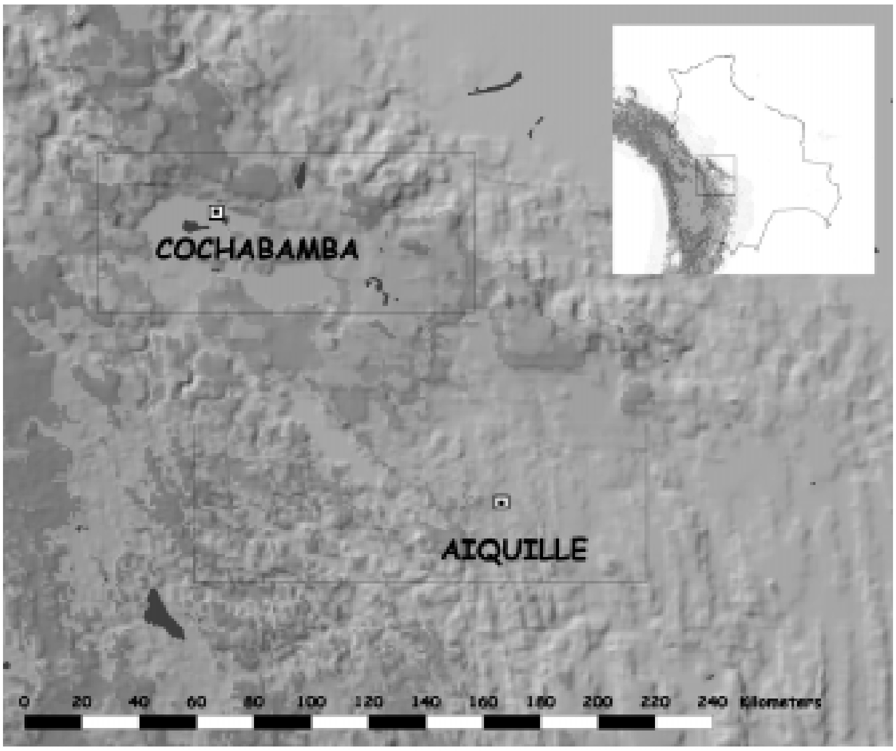


Figure 9. Tape-recording of bird sounds was an important part of the field study. Here Sjoerd Maijer is making recordings for his CD-rom "Bird Sounds of Bolivia" (http://ourworld.compuserve.com/homepages/bird_songs_international).

The real dimensions of Bolivia's biodiversity are not yet well known due to the short history of biological research in the country (Lozada 1998), but recent scientific surveys have begun to document the immense richness of species and habitats. Birds are by far the most studied animal group in Bolivia and the distribution of most species has been described. With as many as 1,404 species, Bolivia is among the most diverse countries in the world (Remsen & Traylor 1989; Armonia 1995, 1997). The species level taxonomy of most birds is better known than for any other animal or plant group of Bolivia and only few species are discovered every year as compared to for example plants, and other vertebrate groups (Anderson 1997; Beck 1998; Hutterer 1998; Köhler and others 1998). Also the ecological requirements of most bird species are known to a certain extent. Birds are good *biological indicators* because they are numerous and have dispersed into and consequently often become specialised and restricted to distinct habitat types. From this follows that many birds are sensitive to modification of their habitat and can be used as indicators of ecosystem health (ICBP 1992; Stotz and others 1996).

Most birds are diurnal and active, so they can be inventoried fairly easily. Our field experience with bird identification and the availability of identification manuals allowed us to identify most species (Figs. 9–11). Finally we were able to record a representative number of species in the study sites within a few days using standardised rapid assessment methods developed by the DIVA programme (DIVA 1997; Poulsen and others 1997). All this means that birds were considered a very useful group to use for the studies presented in this report.

Figure 10. Many Bolivian biology students from the universities in La Paz (Universidad Mayor de San Andrés) and Cochabamba (Universidad Mayor de San Simón) participated in the field work.

Topography and climate

Bolivia is a landlocked country covering 1,098,580 sq. km in the central western part of South America. The Andean highlands cover about one third of the country towards the west. They can be divided into the zones of wet Yungas forests and cordilleras La Paz and Cochabamba, the Valles which is a wide zone of ridges and rain shadow basins, and the highland plateau (Altiplano). The Valles lies on the eastern slopes of the Andean range, and the Altiplano lies towards west and south.

The Altiplano is bordered towards the west and east by mountain ranges (Cordillera Occidental and Cordillera Oriental respectively). Along the eastern slope the Valles forms a transition zone (500–3,300 m) where the Bolivian Andes is intercepted by a succession of plateaus, slopes and deep valleys stretching discontinuously from the northern La Paz Department through the Cochabamba Department and southwards into the southern Tarija Department (Killeen and others 1994).

The latitudinal variation of the Bolivian Andes produce a general north-south climatic gradient, supplemented by an east-west gradient caused by the altitude difference. The southernmost parts of the Bolivian highlands are extremely dry and experience large temperature differences between day and night, because of low cloud cower and high heat radiation during nights. The northern parts have higher annual precipitation and less extreme difference in day and night temperatures.

The topography of the Andes produces climatic changes that locally, and during the day, cause marked differences over just a few hundred meters (Fjeldså & Kessler 1996). Important in this pattern is the rain shadow effect caused by high mountain scarps towards the east (Cordillera Oriental), and elevation of heat sources above valleys and basins in rain shadow, which cause very dry local situations greatly affecting ecosystems (Killeen and others 1994; Fjeldså & Kessler 1996). The eastern slope receives generally high annual rainfalls, whereas valleys, basins and plateaus towards the west receive decreasing precipitation. Figure 12 shows major ecoregions of the country.

One large topographic depression in the Valles is the Cochabamba basin (approximately 2,500 m), located in the north-central part of Bolivia (Fig. 8). The basin is surrounded by high mountains (> 4,000 m) towards the west, north and east, and in the south, a depression with Río Caine connects the basin with the eastern slopes. The plains of the Cochabamba basin are in rain shadow of Cordillera Tunari towards the north, where annual precipitation (900–1,000 mm / yr.) may be twice as high as on the plains just 800–1,000 m below (500–600 mm / yr.).

Figure 11. Some of the shy and hidden birds in the forests can only be captured by use of mist-nets. Here Elva Villegas Nuñez from CUEMAD, Universidad Mayor de San Simón, is about to release a bird after it has been identified and registered.

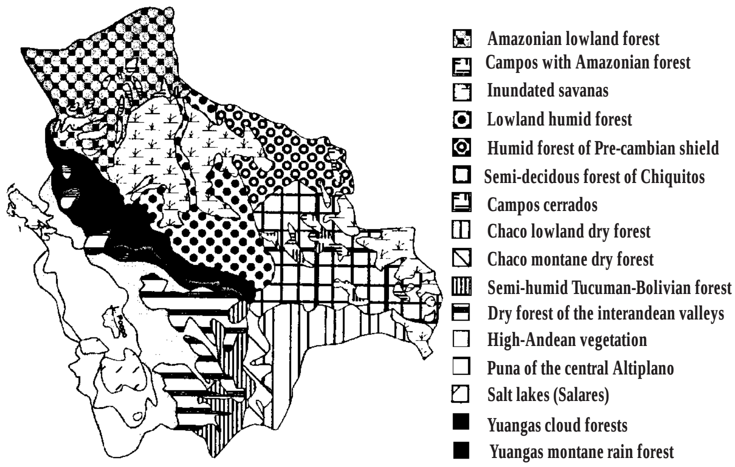


Figure 12. Ecoregions of Bolivia showing the main vegetation formations. Phytogeographically central Bolivia is situated at the junction of four main zones: Andes, Amazonia, Cerrado and Gran Chaco which are subdivided into several vegetation types determined by elevation, geomorphology and climatic condition. From Ibisch (1998).

Study areas

This report summarises the results of two independent biological studies from the highland slopes and dry intermontane valleys of the Valles of the Bolivian Andes in the Cochabamba Dpt.

Both studies were carried out in upper montane *Polylepis* woodlands (the northern study) and in dry deciduous forest (the southern study) which are two of the most fragmented and threatened habitat types in Bolivia and the Neotropics (Prado & Gibbs1993; Killeen and others 1994; Stotz and others 1996; Fjeldså & Kessler 1996; Hanagarth & Szwagrzak 1998) and were to a high extent based on the same field methods making way for comparison of results (for methods see chapters on individual studies).

Figure 13. All over the Andes fields are established where it is possible. The local farmers still use ancient methods allowing them to exploit very steep areas. The field established here can probably only be used for a short period as no measures to prevent soil erosion are taken.

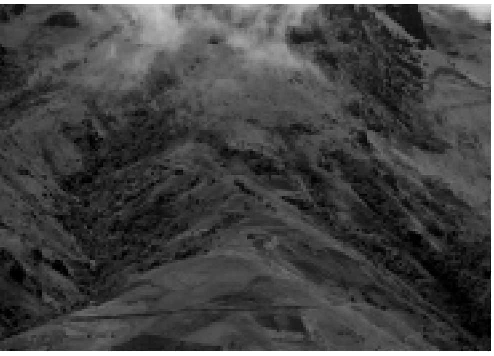


Figure 14. Typical zonation of land-use on high altitude slopes in the northern study region. At lower slopes up to about 3,000 m most fields and houses are located. Above this, pastures maintained by yearly grass burning dominate the land. The Polylepis *woodlands are found in ravines and on the deepest slopes inappropriate for agriculture and grazing. The photo is taken east of Quebrada Mojon (17°29'S 65°25'W).*

The northern study

In the northern study site, the effects of various types of traditional land use on forest biodiversity were investigated by Thor Hjarsen. The study region was situated between 2,900 and 3,700 metres above sea level within the upper Andean zone (see Figs. 13–16).

Precipitation range from approximately 500 mm / year to 1,100 mm / year. *Polylepis* woodland is the climax vegetation in the Cochabamba highlands (Ibisch 1994; Kessler 1995; Fernandez 1997). Kessler (1995) estimates the present day cover of *Polylepis* woodlands in the eastern highlands to be 5,630 sq. km. He estimated that the potential coverage of *Polylepis* forest in Bolivia is 51,000 sq. km or % of the land area.

The main threats to the remaining forest cover are burning to clear land for crop growing or pasture, and inhibited regeneration due to burning, and overgrazing of young trees by introduced livestock (Killeen and others 1994; Fjeldså & Kessler 1996, Ibisch 1998). The *Polylepis* forests remain today as small, highly fragmented woodlands surrounded by grasslands, scrub of *Baccharis* and *Escallonia* or fields. Woodlands are often restricted to the most inaccessible parts of the mountains, on steep slopes or in deep ravines. *Polylepis* often grow together with other trees of the highlands such as: *Alnus acuminata, Vallea* and *Escallonia* and thornscrub including *Baccharis, Berberis, Gynoxys, Brachyotum, Citharexylum* (Killeen and others 1994; Fjeldså & Kessler 1996). The woody vegetation in the Cochabamba basin between 3,000 and 4,000 m is naturally zoned and recent studies show that *Polylepis* occurs in specific plant community associations depending on prevailing features of altitude and humidity: *Vallea–Polylepis* association, *Woodsia–Polylepis* association, *Calamagrostris–Polylepis* association and *Berberis–Polylepis* association (Hensen 1995; Fernandez 1996). The *Polylepis* woodlands in Cochabamba contains at least 261 plant species (Fernandez 1996) of which several are of local socio-economic importance to "campesinos" (rural people / small farmers) as medicinal plants or food and fodder (Hensen 1992). For detailed information of the study sites see Appendix 1.

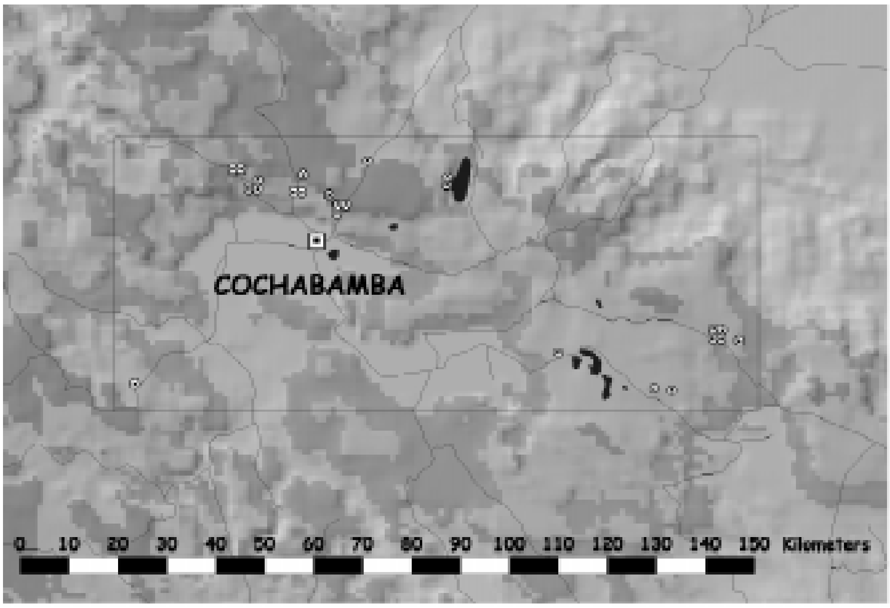


Figure 15. Map of the northern study area with the locations of the study sites indicated. A detailed description of the study sites can be found in Appendix 1.

The southern study

The study conducted in the southern part of the study region by Nicholas Moray Williams and Poul Nygaard Andersen explores the feasibility of using satellite imagery to map montane forest fragments and predict the distribution of bird species (see Fig. 1 - 2 & Fig 20).

Figure 16. In areas where larger areas of Polylepis *woodlands remain as here above Lopez Mendosa (17°29'S 65°24'W) the traditional farmers establish their fields inside the woodlands. Thereby, the crops are benefiting from a more favourable microclimate (higher temperatures and lower influence from wind and frost).*

This study region is dominated by dry vegetation types, but due to the sharp gradients in altitude and humidity, small pockets of humid and semi-humid forest are found locally (see Fig. 17 & Fig. 18). Mean annual precipitation is 500 to 600 mm, temperature range from 2–28 °C with a mean annual temperature of 12–16 °C. At 2,700 m frosts can occur at night during winter (own observations). Rainfall is seasonal, usually from November to February with a dry season the remaining 6–8 months, in some areas up to 11 months (Unzueta Q. 1975; Montes de Oca 1989). The dry vegetation cover consists of deciduous or semi-deciduous forest and scrub with many endemic plant species, and species typical of the Chaco in the eastern foothills and lowlands. Dry forest and scrub vegetation extends to high elevations, up to between 2,700 and 3,200 m (Killeen and others 1994; Navarro and others 1996).

We know of no estimates of the past or present coverage of dry forest in the Valles but the potential cover is certainly much larger than present days. Most remaining dry forest in southern Cochabamba exists as small fragments in a landscape dominated by shifting cultivation, grazing, and erosion (Killeen and others 1994; Navarro and others 1996; Williams & Andersen 1997).

Figure 17. Inside the forest found at Puca Yacu (18° 20´ 03"S 64° 45´ 07"W). The trees in the valley bottom were densely covered with Tillandsia *which is able to extract humidity from the air and thus benefit from the mist covering the valley bottom at dawn.*

Figure 18. The semi-deciduous forest found at the study sites at Puca Yacu (18° 20´ 03"S 64° 45´ 07"W). The vegetation in the deep valleys found here benefit from the mist covering these valleys in the morning.

Forest cover is confined to patches in bottoms of steep ravines where the vegetation is relatively protected against manmade fires, while the slopes and valley bottoms over extensive areas are cultivated, or dominated by scrub of *Dodonea viscosa, Baccharis dracunculifolia* or *Kageneckia lanceolata.* Typical forest trees are *Schinus molle, Jacaranda mimosifolia, Prosopis,* and *Acacia* species. Open forest (10 m) is found at 700–2,600 m again with a strong element of Chaco foothill vegetation, for example *Schinopsis haenkeana* and *Aspidosperma*

Figure 19. Quite extensive areas with arid scrub are found in the Valles. Generally, these areas are very dry and dusty and often with columnar cacti several meters high. This land-cover type is visible from the road leading from Pasorapa to Estancia Peña Colorado (18° 15´S 64° 50´W).

quebracho–blanca. Locally open forest of large columnar cacti and species of *Opuntia*–cacti is found (Fig. 19). In humid quebradas (ravines) at 1,500–2,500 m patches exist of semi-deciduous forest up to 20–30 m in height dominated by *Tipuana tipu* and *Alnus acuminata*. On mist trapping ridges in the transition zone between lowlands and arid basins patches are found of the southern Bolivian Tucuman forest, with species such as *Podocarpus parlatorei*, *Prunus tucumanensis*, *Myrica pubescens* and *Zanthoxylum coco* (Killeen and others 1994; Navarro and others 1996). For detailed information of the study sites see Appendix 1.

Avifauna of dry and highland forests

Neotropical montane dry forest avifauna is low in species richness compared to humid forests. However, since many species of the dry forests have a limited distribution and are restricted in habitat selection (Stotz and others 1996) they are vulnerable to habitat destruction. But because habitat fidelity of most species is low (maybe due to adaptations to the changeable environment) about half of all dry forest and arid scrub species can survive in other vegetation types, not being as specialised as for example humid montane forest bird species (Stotz and others 1996). In many dry forests, there is a gradient of intermixing lowland species to montane species with altitude, probably due to the intermediate position between montane and lowland forest.

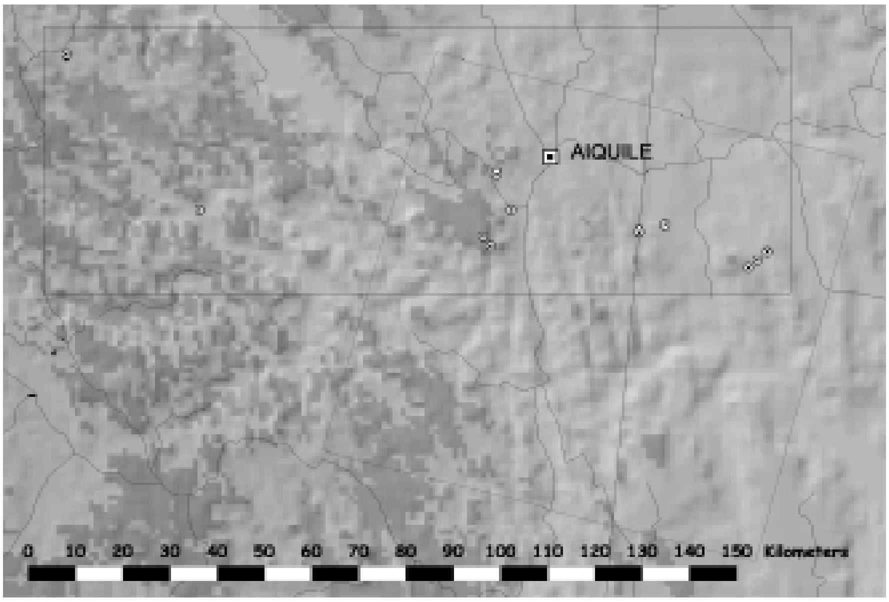


Figure 20. Overview of the southern study area with the location of the study sites indicated. The tilted frame indicate where a land-cover mapping has been made (see Fig. 1 & Fig. 2). A detailed description of the study sites can be found in Appendix 1.

Rich in lowland species

The avifauna of the southern Valles is extraordinarily rich in lowland species of semi-deciduous and evergreen habitat. They are distributed nearly continuously from the lowlands up into the Cochabamba basin (Fjeldså & Maijer 1996). For some granivorous (seed-eating) species, this could reflect human impact such as clearing of forests and the practice of fallow agriculture creating a continuously shifting mosaic of fields, tall herbs, scrub and forest (see Fig. 21). However, the morphological differentiation of many highland populations indicates that the expansion into higher altitudes took place on several time scales since long before the human presence (Fjeldså & Maijer 1996).

Alternating dry and humid climatic fluctuations in the Pleistocene are thought to have isolated highland from lowland populations long enough to evolve the differentiation observed today. Present day distribution patterns indicate that the Cochabamba basin remained climatically stable during these climatic fluctuations and thus became a major centre of evolution of new species (Fjeldså & Maijer 1996; Hanagarth & Szwagrzak 1998). The almost subtropical climate in the Cochabamba basin might be an explanation for the expansion from the lowlands of birds of the drier habitats (Fjeldså & Maijer 1996). Despite of periodical continuos montane forest cover, many humid forest species of the Yungas have been unable to spread south into the humid evergreen and semi-evergreen Bolivian Tucuman forests of the southern Valles, which does not enjoy the same seasonal climatic stability as the Yungas.

The number of specialised humid montane forest species drops from ca. 100 in the Yungas to ca. 40 mainly premontane species in the Bolivian Tucuman forests (Fjeldså 1995; Fjeldså & Maijer 1996). The lack of specialised species may have caused a competitive release allowing less specialised lowland species to colonise the forest habitats (Fjeldså & Maijer 1996) (see Fig. 22 and Appendix 2 for details of avifauna).

*Figure 21. Golden-Billed Saltator (*Saltator Aurantiirostris*) is often found in montane scrub or second growth where it feeds on insects, berries and seeds.*

Species richness in the highlands

In total, 273 land bird species occur from 3,000 to 4,000 m in the Bolivian highlands of which 265 species are breeding (Rahbek 1997). A regional assessment of species richness in 15' grids (25 x 25 km) on the eastern Andean slopes identifies 130 to 170 bird species in the grids covering the most humid forest ecotones towards the Yungas, whereas grids in drier inter-valley areas generally hold from 90 to 110 bird species (Fjeldså pers. comm.).

Locally, species richness in *Polylepis* woodlands are high and the highest densities in Bolivia are found in the mountain ranges north and west of Cochabamba (Fjeldså 1992b). McDowell & Gonzales (1994) recorded 67 bird species in semi-humid *Polylepis* woodlands and adjacent areas in Parque Nacional Tunari on the slopes just north of Cochabamba and Quillacollo. The *Polylepis* woodlands are often visited by opportunistic species from cloud forest habitats (for example, hummingbirds) or species normally inhabiting the puna vegetation (for example, *Sicalis* sp., *Catamenia* sp., and *Phrygilus* sp. (see Fig. 23) (Fjeldså 1992a). In Bolivia, 89 bird species inhabits *Polylepis* at least in part of their range (Fjeldså 1992b; Hjarsen 1997).

Box 1. Ecology of dry neotropical forest

Long term studies of dry forest ecosystems are few (Murphy & Lugo 1986) and mainly from the lowland. It is a general trait that seasonality of precipitation becomes a synchronising factor for growth and reproduction, and moisture levels act as a constraining factor for the geographical distribution of plant and animal taxa. Generally, tropical dry forests have a lower canopy layer and are less structurally complex, with one or two canopy strata as opposed to three or more in wet forests. Leaf area index is generally half of that in moist forest (Murphy & Lugo 1986). The conditions vary considerably during the year. While the forest may look uniformly green during the rainy season, many trees, herbs and lianas are deciduous in most of the dry season. The sun can penetrate to the forest floor drying up the leaf litter, inhibiting decomposition. Many streams dry out or are greatly reduced. The forest changes into a heterogeneous mosaic of different habitat types depending on soil drying rate, exposure, and successional stage, and many animals migrate to the moister areas. Many trees and shrubs flower, mature their fruits and disperse them during the dry season providing food for some animal species (Janzen 1988 and own observations).

*Figure 22. Browncapped Whitestart (*Myioborus bruniceps*). This species is normally found in the humid Boliviano–Tucumano forest, where it shows fairly narrow habitat preference. In the southern study area, it was one of the most common species found, probably due to the lower species richness in the semi-deciduous forests.*

Endemic and restricted range species

BirdLife International has identified regions with concentrations of endemic bird species, that is species with a range restricted to 50,000 sq. km or less

Figure 23. Peruvian Sierra-finch (Phrygilus punensis) *is found in open country with scattered shrubbery or grassland. It is also often found close to villages and farms.*

*Figure 24. Rufous-bellied Saltator (*Saltator rufiventris) *in the top of a* Polylepis *tree. This species is often found near* Polylepis *or* Alnus *woodlands and is possibly threatened by habitat destruction. It is a restricted range species and regarded as vulnerable in the IUCN classification system.*

Forty-nine per cent of all Bolivia's endangered bird species inhabits montane forest habitats.

(Stattersfield and others 1998). These areas are termed "Endemic Bird Areas" (EBAs). Stattersfield and others (1998) identifies five EBAs in Bolivia:

- Bolivian and Peruvian lower yungas (054): Humid forest of the eastern slope of the Andes (altitude range: 400 to 2,000 m) ranging from north of Lake Titicaca all the way to northern Argentina.
- Bolivian and Peruvian upper yungas (055): Also at the eastern slope (altitude range: 1,800 to 3,700 m) ranging from north-west of Lake Titicaca through the departments of La Paz and Cochabamba along the mountain range to extreme western Santa Cruz.
- High Andes of Bolivia and Argentina (056): Covers the highest parts of the eastern Andean slopes, and includes the inter-Andean valleys and basins (altitude range: 1,100 to 4,600 m).
- Argentine and south Bolivian yungas (057): Covers the eastern slope of the Andes in southern Bolivia and northern Argentina (altitude range: 800 to 3,100 m).
- South-east Peruvian lowlands (068): Centred on south-east Peru, but extends into Pando and northern La Paz Departments (altitude range 0–800 m).

In the high Andes of Bolivia and Argentina (EBA 056) which covers the main part of the study areas the following species with restricted-ranges are found (Stattersfield and others 1998): Red-fronted Macaw (*Ara rubrogenys*), Wedge-tailed Hillstar (*Oreotrochilus adela)*, Bolivian Earthcreeper *(Upucerthia harterti*), Maquis Canastero (*Asthenes heterura*), Berlepsch' Canastero (*A. berlepschi)*, Line-fronted Canastero (*A. urubambensis*), Scribble-tailed Canastero (*A. maculicauda*), Grey-breasted Flowerpiercer (*Diglossa carbonaria*), Grey-crested Finch (*Lophospingus griseocristatus)*, Short-tailed Finch (*Idiopsar brachyurus*), Bolivian Warbling-Finch *(Poospiza boliviana*), Cochabamba Mountain-Finch (*Poospiza garleppi*), Citron-headed Yellow-Finch (*Sicalis leutocephala*), Rufous-bellied Saltator *(Saltator rufiventris*)(Fig. 24), and Bolivian Blackbird (*Oreopsar bolivianus*). Olivaceous Thornbill (*Chalcostigma olivaceum*), Royal Cinclodes (*Cinclodes aricomae*) and Ash-breasted Tit-tyrant (*Anairetes alpinus*), occur only very patchily in Bolivia and have their principal distribution in Peru. Nearly all these species occupy *Polylepis* habitats in part of their range (see also below).

Priorities to Endemic Bird Areas

The location and range of EBAs number 055 and 056 is in accordance with the centres of endemism in southern Peru and Bolivia identified by Fjeldså & Kessler (1996). They have located specific areas with peak concentrations of endemic *Polylepis* associated species by considering evolutionary aspects (ratios of young and old species). By setting specific criteria to preserve unique genetic variation, Fjeldså & Kessler (1996) identified three specific areas in the Andes, which should receive highest conservation priorities: I: West Peruvian Andes Centre, Peru, II: Runtacocha Highlands, Abancay, Apurimac, Peru, and III: The Cochabamba Centre, Bolivia.

The Cochabamba Centre still holds some *Polylepis* woodlands (see Fig. 68), particularly towards the east, and several of the species included in EBA 056 occur in the area: Wedge-tailed Hillstar *(Oreotrochilus adela)*, Maquis Canastero *(Asthenes heterura)*, Grey-crested Finch *(Lophospingus griseocristatus)*, Short-tailed Finch *(Idiopsar brachyurus*), Bolivian Warbling-Finch (*Poospiza boliviana)*, Cochabamba Mountain-Finch (*P. garleppi)*, Citron-headed Yellow-Finch *(Sicalis leutocephala)*, Rufous-bellied Saltator *(Saltator rufiventris)*, and Bolivian Blackbird *(Oreopsar bolivianus)*. Furthermore, the Bolivian endemics: Bolivian Earthcreeper *(Upucerthia harterti)*, Grey-bellied Flowerpiercer, and Fulvous-headed Brush-Finch (*Atlapetes fulviceps)*, also occur (Fjeldså 1993).

In total, 115 Bolivian bird species are listed by BirdLife International as threatened (Stattersfield and others 1998). This is approximately 8% of all species in the country. Forty-nine per cent of all Bolivia's endangered bird species inhabit montane forest habitats (Table 1). Furthermore, of all the threatened species inhabiting montane forest habitats, 89% have restricted

Table 1. Bolivian montane forest birds covered by BirdLife/IUCN's threat categories

Species	Main habitat	Threat category
Nothocercus nigrocapillus	Humid forest, 2,000–3,000 m	Near-threatened
Penelope dabbeni	Semi humid forest and bushland, ca. 2,000 m	Least concern[r-r]
Odontophorus balliviani	Seasonally dry forest, 2,000–3,000 m	Least concern[r-r]
Ara militaris	Dry forested slopes, < 2,400 m	Vulnerable
Ara rubrogenys	Dry subtropical woodland, 1,100–2,500 m	Endangered[r-r]
Hapalopsittaca melanotis	Humid Yungas, 1,700–2,500 m	Least concern[r-r]
Amazona tucumana	Semi humid forested ravines, 1,500–2,600 m	Least concern[r-r]
*Oreotrochilus adela**	Semiarid woodland (*Polylepis*), 2,600–4,000 m	Near-threatened[r-r]
*Aglaeactis pamela***	Semi humid and humid woodland, 1,800–3,500m	Least concern[r-r]
*Eriocnemis glaucopoide*s	Humid shrubbery, 1,500–2,900 m	Least concern[r-r]
Metallura aeneocauda	Semi humid shrubbery, 2,800–3,600 m	Least concern[r-r]
*Chalcostigma olivaceum**	Puna and woodland (*Polylepis*), 4,000–4,600m	Least concern[r-r]
Andigena cucullata	Cloud forest, 2,500–3,300 m	Near-threatened[r-r]
Upucerthia harterti	Woodland and shrub, 1,500–3,050 m	Near-threatened[r-r]
*Cinclodes aricomae****	Semi humid *Polylepis*, 3,200–5,200 m	Critical[r-r]
*Leptasthenura yanacensis***	*Polylepis* woodland, 3,200–4,600 m	Near-threatened[r-r]
*Schizoeaca harterti***	Humid woodland and shrub, 2,500–3,800 m	Least concern[r-r]
Cranioleuca albiceps	Open cloud forest, 2,200–3,400 m	Least concern[r-r]
Asthenes henricae	Semi arid bushland, Inquisivi	?[r-r]
*Asthenes heterura***	Semi arid shrub and *Polylepis*, 3,000–4,150 m	Vulnerable[r-r]
Asthenes berlepschi	Arid shrubland, 2,600–3,700 m	Vulnerable[r-r]
*Asthenes urubambensis***	Semi humid *Polylepis*, 3,050–4,300 m	Near-threatened[r-r]
Asthenes maculicauda	Puna with shrub, 2,250–4,300 m	Least concern[r-r]
Simoxenops ucayalae	Humid foothill forest, <1,300 m	Near-threatened
Simoxenops striatus	Humid dense Yungas, 670–900 m	Vulnerable[r-r]
Thamnophilus aroyae	Semi humid shrubbery, 800–1700 m	Least concern[r-r]
Myrmotherula grisea	Humid foothill forest, 600–1,400m	Vulnerable[r-r]
Terenura sharpei	Humid Yungas, 1,100–1,680 m	Vulnerable[r-r]
Grallaria erythrotis	Elfin and cloud forest, 2,050–2,900 m	Least concern[r-r]
Grallaria albigula	Humid montane forest, 800–1,700 m	Least concern[r-r]
Scytalopus schulenbergi	Cloud forest, 3,100–3,200 m	Least concern[r-r]
Scytalopus superciliaris	Montane shrub and woodland 1,500–3,350 m	Least concern[r-r]
Ampelioides tschudii	Yungas, 900–2,000 m	Near-threatened
Pipreola frontalis	Humid Yungas, 1,100–2,000 m	Near-threatened
Lipaugus uropygialis	Cloud forest, 1,800–2,575 m	Least concern[r-r]
Chiroxiphia boliviana	Humid foothill forest and Yungas, 650–2,150 m	Least concern[r-r]
*Pseudotriccus simpl*ex	Cloud forest, 1,300–2,000 m	Least concern[r-r]
Hemitriccus spodiops	Humid Yungas, 800–1,600 m	Least concern[r-r]
Hemitriccus rufigularis	Humid Yungas, 800–1,450 m	Near-threatened
Zimmerius bolivianus	Humid woodland, 1,000–2,850 m	Least concern[r-r]
Elaenia strepera	Humid woodland, 1,200–2,000 m	Least concern[r-r]
*Anairetes alpinus****	*Polylepis* woodland, 4,000–4,600 m	Endangered[r-r]
Myiophobus inornatus	Humid forest, 1,400–2,500 m	Least concern[r-r]
Myiotheretes fuscorufus	Cloud forest and *Alnus*, 2,130–3,550	Near-threatened[r-r]
Cinclus schulzi	Streams near *Alnus*, 800–3,000 m	Vulnerable[r-r]
*Oreopsar bolivianus**	Open woodland, arid shrub, 2,400–3,200 m	Least concern[r-r]
*Oreomanes fraseri****	*Polylepis* woodland, 2,700–4,850 m	Near-threatened
*Diglossa carbonaria**	Semi humid woodland, 2,100–4,300 m	Least concern[r-r]
Hemispingus calophrys	Cloud forest, 2,300–3,500 m	Least concern[r-r]
Tangara argyrofenges	Humid forest, 1,300–1,700 m	Least concern[r-r]
Iridosornis jelskii	Humid tree-line forest, 3100–3650	Least concern[r-r]
Creurgops dentata	Premontane forest, 1,450–2,150 m	Least concern[r-r]
*Saltator rufiventris***	Woodland (incl. *Polylepis*), 2,750–3,800 m	Vulnerable[r-r]
Lophospingus griseocristatus	Shrub and *Prosopis*, 1,500–3,000 m	Least concern[r-r]
*Poospiza boliviana**	Arid shrub and open *Polylepis*, 1,700–3,100 m	Least concern[r-r]
*Poospiza garleppi***	Woodland (incl. *Polylepis*), 3,000–3,800 m	Endangered[r-r]

Species with restricted ranges are marked with a small "r-r" (Stattersfield and others 1998). Species marked with an asterisk are considered to inhabit* Polylepis *at least in part of their range. Species most specialised to* Polylepis *or semi-humid woodland habitats are marked **, highly specialised: *** (Fjeldså 1992b; Hjarsen 1997).*

ranges. Main threats to these species today are human-caused habitat disturbance, in combination with the restricted ranges of the species (Collar and others 1994). The highest number of endangered species is found on the eastern Andean slopes with cloud forest and yungas. In the dry zone in southern Cochabamba the lower Río Caine and Río Grande valleys contain the river valleys and dry deciduous woodlands supporting almost the entire population of *Ara rubrogenys.* The river valleys overlap the ranges of other restricted range species associated with dry forest and scrub habitat: *Upucerthia harterti, Sicalis luteocephala, Lophospingus griseocristatus, Poospiza boliviana,* and *Oreopsar bolivianus.* Both zones are used for agriculture and neither are in protected areas (for details on the species, see Appendix 2).

Fjeldså (1992b) calculated the density distribution of bird species that are established in *Polylepis* woodlands at least locally. This analysis showed that peak densities are found in the same regions that remained ice-free and which are believed to have had particularly stable conditions despite the drastic climatic changes during the Pleistocene. One peak density area is the western and northern mountain ranges of the Cochabamba basin. Thus, conservation of many threatened and near threatened bird species in Bolivia is highly dependent on the management of the remaining *Polylepis* woodlands in the Bolivian Andes. Abundance of such species in different study areas can be used for assessing the “biological importance” of the habitat covered by the study areas.

Thus, conservation of many threatened and near threatened bird species in Bolivia is highly dependent on the management of the remaining Polylepis *woodlands in the Bolivian Andes.*

Human influence on montane forests

In the Andean highlands humans have interacted with vegetation for up to 10,000 years. Nearly all regions of the highlands were more densely populated before the Spanish conquest than today (Ellenberg 1979). Causes for present lack of *Polylepis* forest cover in the High Andes of Bolivia are directly associated with land-use of the rural populations (see Ellenberg 1979, Hensen 1991, Kessler & Driesch 1993, Kessler 1995, Fjeldså & Kessler 1996). It is believed that upper tree line today is appro**x**mately 500 m below the natural potential treeline (Fjeldså pers. comm.). The suppression of the natural treeline has been caused by a number of factors (Ellenberg 1979, Kessler & Driesch 1993, Fjeldså & Kessler 1996):

- Grass fires. The farmers burn puna vegetation (grasslands) to provide their livestock with fresh green palatable grass. The burning takes place just before the rainy season, and is somewhat regarded as a traditional activity. It is generally believed that “exotic” livestock (cows and sheep) can not eat the coarse bunchgrass dominating the slopes, but unfortunately the burning may ultimately favour unpalatable grass species. The burning heavily inhibits succession and regeneration of *Polylepis* trees (Fig. 25 & Fig.26).

- Grazing pressure probably only indirectly affects the *Polylepis* woodlands. When grass is burned, or forests fragmented, because of logging or slash-and-burn agriculture, livestock can enter the woodlands and wear down ground vegetation by overgrazing and trampling. The Bolivian highlands are overstocked and communal organisation of grazing systems increasingly difficult to regulate.

- Shifting cultivation. Where larger *Polylepis* woodlands are still found, farmers favour establishment of agricultural fields inside the woodlands (own observations in Quebrada Mojon, San Miguel, and Kehuiña Pampa). Above Liriuni, it was evident that former fields were left fallow, and *Polylepis* regenerated. Alongside, clearance of forested areas took place to establish new fields. Traditionally, shifting cultivation is practised in the Bolivian Andes (Sotomayor 1995), but increasing shortage of fertile land (due to over-exploitation, erosion, and increasing population), puts higher pressure on remaining fertile areas, including forested land (Denniston

1996). Thus, fallow periods are shortened and woodlands do not get sufficient time to regenerate and naturally refertilise the soil.

- Timber extraction for local use. *Polylepis* wood is traditionally used for firewood and charcoal production, house construction and field fencing (to keep livestock away from the crops). If extraction of such timber exceeds biomass production, this will affect the natural regeneration of the woodlands, and ultimately the forest cover.

Figure 25. Polylepis *woodland near Khalani Centro (17°40'S 66°29'W). Mainly due to grass burning and livestock grazing not much regeneration is present. All trees in this woodland are of the same size.*

Figure 26. Burning of Polylepis *trees is common in the whole region.*

Traditional Andean land-use

By tradition, timber extraction of Andean highland forests seems to be regulated by the rural communities (pers. obs.*)*, and to a large extent traditional agricultural systems have been developed in accordance with prevailing ecological conditions (Sotomayor 1995). Several authors have investigated traditional use of forest resources (see for example Hensen 1992 or Kress 1994), but apparently no detailed research has been made on rural community management of forest resources in the high Andes of Bolivia. Still, what seemed to be specific timber extraction zones was observed, and local farmers at La Candelaria once explained that different parts of the natural woodlands above the village were belonging to different families. More (anthropological) knowledge on this subject may be important in future land-use planning.

Rural land-use functions under a traditional community and family based decision system called *aynokas* in Bolivia. The *aynokas* set out area specific rules for agricultural production cycles, crop diversity, and social organisation (Sotomayor 1995). In some areas, sowing was done with a wooden digging stick , and grass cover was not completely removed from field areas (Ellenberg 1979). In pre-Hispanic times (before ca. A.D. 1550), intensive agriculture was established well above 4,000 m on terraces (andenes), with irrigation systems (Fjeldså & Kessler 1996). Such terraces were often located in the regions with highest population densities near the centres of the high cultures (Cusco, Tiwanaku, Cochabamba, etc.). The slopes around Laguna Titicaca are covered with antique terraces, some of them still in use, and in several areas of the Peruvian High Andes terraces are still widely used (Inbar and Llerana Pinto 1997) (Fig. 27).

Use of terraces and low-technology irrigation systems in montane agriculture are well established in many other hilly areas of the world, for example in Nepal (Vincent 1995). In the Andes, new agricultural methods were introduced with the Spanish, like sowing on steep slopes without terracing, use of European style ploughs, and introduction of new grain crops (wheat and barley) (Fjeldså & Kessler 1996). Terraces were abandoned or levelled out because they were too narrow to plough (Ellenberg 1979). Such changes have lead to increased erosion of fertile topsoils and increased demand for remaining fertile soils, which are often covered by woodlands.

Most subsistence agriculture, also in the high Andes, is concerned with minimisation of risk (of failure). This is traditionally acquired by maintaining high crop diversity, using "well-tested" land-use systems, and integrating different dynamic components (for example use of manure for fertilisation) (Altieri and others 1987, Sotomayor 1995).

Forestry and plantation projects in the Bolivian Andes

The forestry sector is having increasing importance in the Bolivian economy, and as an instrument in rural development. It is estimated that 41% of Bolivia's land area is covered by forest (statements range from 41 to 50% depending on source), and annual deforestation rate is calculated to 1.2% or 5,331 sq. km (533,100 ha) by Harcourt & Sayer (1996). References disagree in this aspect and rates of 0.3%, 0.8%, and 1.3% can also be found in the literature. No detailed data on deforestation rates in the highlands are available, except the estimation of yearly deforestation in the hilly and montane region at approximately 920 sq. km in Harcourt & Sayer (1996). This corresponds to a deforestation rate of 0.7% if the coverage of sub-montane (61,165 sq. km) and montane forests (69,248 sq. km) given by Harcourt & Sayer (1996) is considered. The main causes of the deforestation are agricultural expansion, colonisation and commercial logging (Harcourt & Sayer 1996). The latter is still of minor ecological importance, but are contributing to the national export earnings with US$ 50.6 million (López 1996). Instead, agricultural expansion and colonisation is estimated to cause from 70 to 90% of the total deforestation (Harcourt & Sayer 1996).

If the sub-montane and montane deforestation rate of 0.7% is true also for the present clearance rate of *Polylepis* forest habitats, approximately 4.4 sq. km of the remaining 630 sq. km *Polylepis* woodland in the eastern Bolivian highlands is cleared annually (estimated cover according to Kessler 1995).

Figure 27. The Incas established terraces in large parts of their territory. Here on the banks of Lake Titicaca the terraces are still in used but not maintained. The terraces stabilise the topsoil by creating horizontal soil surfaces so water-induced erosion is reduced.

Highland reforestation

More than 80% of the timber extraction in the Bolivian Andes is for firewood (Schulte 1991), and each household may use 12–15 m^3 per year (Brandbyge & Nielsen 1991). In recognition of the shortage of firewood and construction timber in the Bolivian highlands, several international donors have initiated tree plantation projects. Furthermore, private landowners have established plantations in expectation of earnings from timber sales.

Annually, approximately 1,000 ha (10 sq. km) plantation is established in Bolivia (Fjeldså & Kessler 1996), with mainly exotic tree species (that is non-native species). *Eucalyptus* sp., *Pinus* sp., *Acacia* sp. and *Cypressus* sp. make up 90–98% of all planted trees (Burgos 1990, Schulte 1991). However, exotic species may be unsuited to local environments. In the Andes at high altitudes, periodic frost, and poor soils is reflected by low performance of several exotics (CESA 1989a). The ecological implication of relying so heavily on high-yielding exotic tree species in plantation forestry in the (Bolivian) Andes – especially *Eucalyptus* – has been questioned by several authors: Crespo (1989), Fjeldså & Krabbe (1990), Schulte (1991), Kessler (1995), Fernandez (1996), Fjeldså & Kessler (1996), and G. Navarro (pers. comm.)(Fig. 28). It has been suggested that also native tree species should be considered in highland plantation projects. Such species may not conflict with ecosystem function, and could in addition supply rural communities with traditional forest resources (Schulte 1991, Kress 1994, Kessler 1995, Fjeldså & Kessler

1996, Harcourt & Sayer 1996). The favouring of exotic trees seems even more esoteric, when it is known that the farmers do not use much construction wood (Fjeldså & Kessler 1996), and that wood from *Polylepis* is considered as higher quality for firewood and charcoal than introduced tree species. Furthermore, native species often have a much wider use (multi-purpose) than most high-yielding exotic species. In spite of the little use of native species in most forestry projects in the Bolivian Andes, several native species are available, and have already been used in reforestation projects or tested in nurseries in other projects or countries, particularly in Ecuador and Peru (see Table 2 & Fig. 29).

Experience from the Andes show that community based forestry and agroforestry may be most successful if some basic principles are followed (Hartcourt & Sayer 1996):

• Select ecologically well-adapted tree species, which provide products valued by the local people.

• Tree production as an end in itself should not be promoted, but instead integrated in the land-use and farming systems of *campesinos.*

• Flexible approach that considers diversity of needs, local organisation, and changing socio-economy.

• Avoid economic incentives or gifts to motivate peasants to participate, but link project activities to their own priorities that may pursue greater self-reliance.

Fig. 28. Large areas of former puna zone above the city of Cochabamba has been planted with exotic trees, in this example a plantation of Pinus radiata *has been made. Most concerning this is funded by the Swiss Development Cooperation (SDC/COSUDE) and mainly takes place inside Parque Nacional Tunari without considering the ecological consequences.*

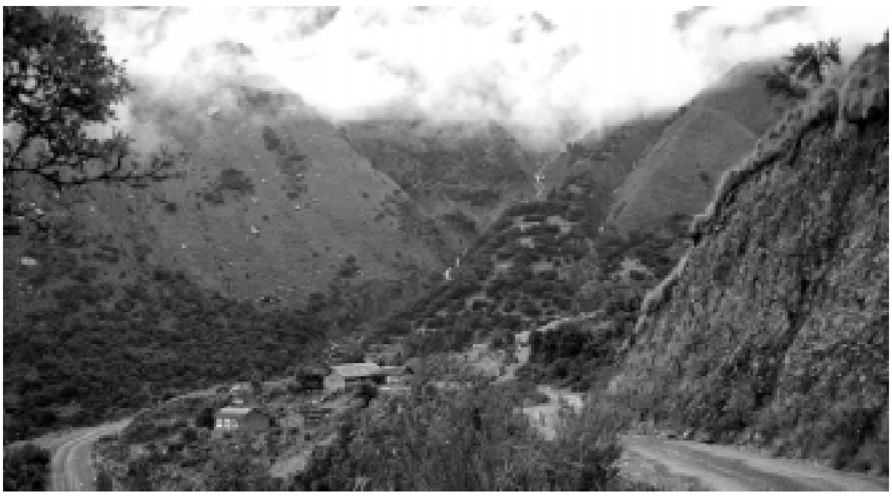


Figure 29. The woodlands at high altitudes function as sponges catching moisture from the clouds. The small-leafed Polylepis *trees have a very high surface compared to large-leafed tree species such as the exotic* Eucalyptus. *Thus, the native* Polylepis *is very important to maintain water balance at a local scale. Excessive water from the woodlands is released to the lower lying areas and is therefore important for local communities. San Miguel above Liriuni (17°16'S 66°19'W).*

Table 2. Potential tree species for reforestation

Genus species	Planting altitude(m)	Products and use	Secondary benefits	Production time in nursery	Growth and survival
Polylepis	2,800–4,000 (4,800)	Firewood, high quality charcoal, construction, fences, medicine (rheumatic and respiratory illnesses).	Protect soil-humidity, refertilise soils, frost protection, windbreaks.	12–14 months	Frost resistant, prefers organic rich soil, but grows well in different textures, 5–32% germination, 70–90% survival 6 months after germination, 0.59 m after 1 year.
Alnus acuminata	900–3,850	Firewood, fences, construction, charcoal, medicine.	Refertilisation of soil by nitrogen fixation, river stabilisation.	–	–
Gynoxys	3,200–3,700	Firewood, fences, medicine (headache).	Soil improvement, windbreaks.	10–12 months	Frost resistant, may grow in different soils, 40–95% survival 6 months after germination, 1.1 m after 1 year.
Baccharis	< 4,200	Firewood, ornamental plantations, compost, medicine (for example bronchitis)	Soil improvement, frost protection	–	Frost resistant.
Berberis	3,100–3,800	Firewood, charcoal, wool dye.	–	–	20% survival 6 months after germination. (Problem: May carry dew that infests cereal crops.)
Prosopis	< 3,000	Fodder, fruits.	Soil improvement by nitrogen fixation.	–	–
Buddleja incana	2,800–3,700	Firewood, fodder, medicine.	Windbreak.	12–14 months	Frost resistant, may grow in different soils, 92% germination, 0.86 m after 1 year.
Vallea stipularis	2,800–3,300 (2,200–3,900)	Construction, firewood, fences, dyes.	Windbreak	10–12 months	Frost resistant, may grow in different soils, 28% germination, 20–35% survival 6 months after germination.
Podocarpus	< 3,000	Construction, ornamental plantation.	–	–	65% survival 6 months after germination.
Senna	2,000–3,800	Refertilise soil by nitrogen fixation.	Windbreak.	–	–
Hesperomeles heterophylla	3,000–3,900	Construction, firewood, charcoal.	Soil protection, windbreak.	–	45% survival 6 months after germination.
Prunus serotina	2,100–3,900	Construction, firewood, charcoal, fruits.	Windbreak.	–	–
Schinus molle	2,100–3,900	Firewood, charcoal, medicine, insect repellent, ornamental use, fruits, resin.	Soil improvement, river stabilisation.	–	
Erythrina	900–3,400	Construction, forage, fruits.	Soil improvement.	–	–
Oreopanax	3,000–3,700	Firewood, handicraft.	–	18 – 24 months	Frost sensitive, prefers humid organic–rich soils, 28–63% germination, 30% survival 6 months after germination.

Sources: Chiclote and others 1986, CESA 1989b; Brandbyge & Nielsen 1991; Hensen 1992; Fjeldså & Kessler 1996; Harcourt & Sayer 1996. When no information was available, it is marked with a dash.

Box 2. Recent agroforestry in the Chorojo community

Rural populations in the Bolivian highlands rely to a large extend on natural resources. Etno-botanical studies by Isabel Hensen in the village of Chorojo have shown that many species of wild plants are used in traditional medicine, tool production, cloth manufacturing (plant dyes), house and fence construction, firewood, and fodder. A major part of these plant species are found in native woodlands, and the access to such “free” resources thus largely depends on presence of native woodlands with relative high plant diversity. Of all wild plant species identified in the Chorojo community, west of Cochabamba (Province of Tapacarí), Hensen (1992) found that 91% were used as fodder, 56% in traditional medicine (in total, the wild plants offered 103 medical treatment possibilities!), 12% as human food (for example as wild tubers), 12% as firewood, 8% for religious purposes, 6% for tool manufacture, and 3% for construction. Of the plants used for livestock fodder, twice as many species regarded by the farmers having highest forage value were found in the *Polylepis* woodlands, than on non-forested land. Furthermore, 35% of the medical plants, 27% of the plants used in religious rituals, 36% of the plants used as human food 33% of the firewood plants, and 50% of the plants used in tool manufacture, were growing only inside the *Polylepis* woodlands.

In the Chorojo village, the peasants use a traditional agro-forestry system, which has received significant attention from agronomists and biologists. The peasants maintain *Polylepis* trees inside the fields with for example potatoes, barley, wheat, oca or maize (Fig. 30). The trees are capable of maintaining soil fertility, positively affect the humus build-up, and reduce crop transpiration by reducing the daily temperature amplitude and wind influence (Hensen 1991, 1992, Romero 1992). In other communities, the farmers normally have fallow periods of 7–11 years, but a fallow period of just 4 years is possible in the “Chorojo System”. In Chorojo, Romero (1992) showed fields without trees had a top soil humidity around 8% while topsoil humidity in fields with large *Polylepis* trees had significantly higher humidity:

Distance from tree trunk:	2 m	4 m	6 m	8 m
Top soil humidity:	25%	29%	23%	20%

Hensen (1991) identifies the following advantages of the “Chorojo System”:

- Reduced temperature amplitude and risk of frost damage on crops, which increase production.
- Higher humus content, which increase the water storage capacity of the soil.
- Natural re-fertilisation of soil from decaying litter and roots.
- Lower risk of water erosion due to stabilised topsoils.
- Creation of habitats for wild plant species used in households. *Polylepis* itself is used for respiratory (the bark), and rheumatic (the leaves) illnesses.
- Production of firewood, and thus relieving pressure on natural woodlands higher up in water catchment areas. Families will also use less time on firewood collection at distant localities.
- Higher diversity of crop and natural resources minimise the risk of socio-economic collapse in the community caused by, for example, drought events or market related changes.
- Strengthening of local social structure and self-reliance in the community.

Figure 30. In Quebrada Mojon it was observed that farmers let large Polylepis *trees grow among the crops. A similar traditional agroforestry-like system is previously described from the Chorojo community by Hensen (1991, 1992).*

2. Use of satellite imagery

by Poul Nygaard Andersen and Nicholas Moray Williams

A basic assumption in terrestrial ecology is that the number of bird species is closely related to the structure of the vegetation found in an area. This means that more species are likely to be found in an area covered with forest than in an area covered with grassland. It is therefore interesting to investigate the relation between the structure of the vegetation and the reflectance submitted to a satellite with high spatial resolution. To test this relationship we used test sites located in the southern study site close to Aiquile (18°12’0’’S 65°11’0’’W, see map on page 18), where both field data (ground truth data) and satellite data was available.

Vegetation cover, ground cover and satellite data

The satellite data used was a Landsat TM satellite image from 13 May 1986 with centre co-ordinates: 18°47’18’’S 65°35’48’’W. Table 3 gives a view of the data available from the satellite. The satellite records seven different parts of the electromagnetic spectre, which are often referred to as bands.

Table 3. Wavelengths recorded by the Landsat TM satellite

TM1	TM2	TM3	TM4	TM5	TM6	TM7
450–520 Visible blue	520–600 Visible green	630–690 Visible red	760–900 Near infrared	1550–1750 Mid infrared	1040–1250 Thermal	2080–2350 Mid infrared
Separation of soil and vegetation	Detection of reflectance from fresh vegetation	Detection of chlorophyll absorption in fresh vegetation	Detection of near infrared reflectance from fresh vegetation	Detection of soil moisture	Thermal mapping	Detection of vegetation moisture

Wavelengths recorded by the sensors onboard the Landsat TM satellite with notes on usage of the bands. The wavelengths are listed in nano-meters (10^{-9} m). TM1–T5 + TM7 have a spatial resolution of 30 m, TM 6 has a spatial resolution of 120 m. Modified after Harris (1986).

Vegetation data was collected in nine study sites. In each study site the cover of the vegetation strata and ground cover (Table 4) was assessed in 25 frames of 10 x 10 m. These frames were established in areas judged to be typical of the study site. Vegetation cover and ground cover were estimated using the Braun–Blanquet scale (Oekland 1990). This estimation method is often used in vegetation studies to describe and compare vegetation communities (Ibisch & Rochas 1994). In order to apply statistical analysis an ordinal transformation of the Braun–Blanquet cover values was made resulting in values from 1 to 6 (Table 5).

For each vegetation strata and ground cover categories in each of the nine study areas, an index was made: the sum of the 25 ‘cover scores’ expressed as a fraction of the maximum possible score for all 25 frames. For each locality, these index values was summarised in a Vegetation Cumulated Index (Fig. 32) and a Ground Cover Cumulated Index (Fig. 33), and these indexes were then compared with the six satellite bands + the NDVI (a calculated band – see Box 4 and Table 6). Coverage of ephiphytes was not included in these studies.

The NDVI–band is positively correlated with the Vegetation Cumulated Index whereas none of the “raw” bands appear to be correlated with this index.

The Ground Cover Cumulated Index is positively correlated with band 1, 2 and 5 but not with the NDVI-band. This emphasises the value of using NDVI in mapping of the structurally diverse vegetation cover. As mentioned in Box 4 the NDVI furthermore is able to compensate for some of the shadow-effect caused by the mountains.

Table 4. Vegetation strata and ground cover categories

Vegetation strata	**Definition**
Mosses	Plants belonging to Bryophyta.
Herbs	Small non-woody plants with green stems.
Shrubs	Small woody plants without a main stem and branching from the base of the plant.
Understory	The vegetation layer between the shrub and canopy layer consisting of tall shrubs and young trees.
Canopy	The vegetation layer forming the "roof" or canopy of the forest.
Emergent trees	Single trees rising above the canopy layer.
Ground cover	**Definition**
Bare soil	Soil without any cover.
Gravel	Small rocks, less than 10 cm in diameter.
Rocks	Rocks greater than 10 cm in diameter.
Trunks and branches	Dead wood.
Leaf litter	Partly decomposed leaves.

The Table lists the different categories used to describe vegetation strata and ground cover at study sites. The term strata refers to the vertical division of the vegetation cover.

Table 5. Transformation of Braun Blanquet values (%)

	< 1	**1–5**	**5–25**	**25–50**	**50–75**	**75–100**
New values	1	2	3	4	5	6

In each 10 x 10 m frame the cover of the vegetation strata and ground cover was assessed using the Braun–Blanquet system.

BOX 3. Working with satellite images

Satellite images are generated as digital information onboard the Landsat TM satellite. The wavelengths or the parts of the electromagnetic spectrum recorded by the satellite are often refered to as bands. When the digital information has been stored on a computer equipped with image processing software, three of these bands can be loaded to the computer-screen as the red, green and blue colour. Such an image is often called an RGB-composite. In the present study we have worked with TM5; TM4 and TM3 loaded as red, green and blue. This combination produces an image where the vegetation turns out green. It should be noted that TM4, which is loaded to the green channel on the computer monitor, records a part of the near-infrared reflection. The rationale for loading this channel as the green colour is that fresh green vegetation reflects a high amount of this part of the electromagnetic spectrum. When the RGB-composite has been loaded to the screen, each band can be contrast-stretched individually to enhance interesting features in the image. The visual interpretation demands some experience, but is often superior compared to a computer-based classification (Fig. 31)

Figure 31. The satellite classification is based on spectral analysis of the satellite image combined with information collected in the field. Colour printouts of the satellite image was used for identification of the different landcover types on location.

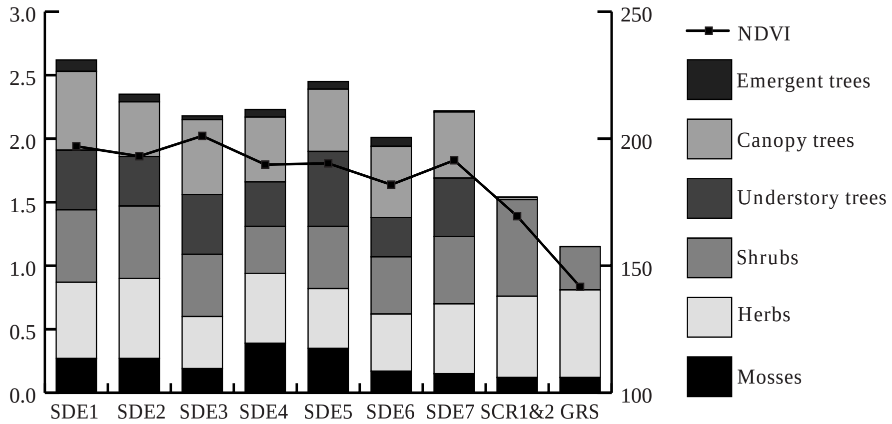


Figure 32. Cumulated indices of vegetation cover at each study site and average NDVI value for each study site. The maximal index value for each stratum is 1.

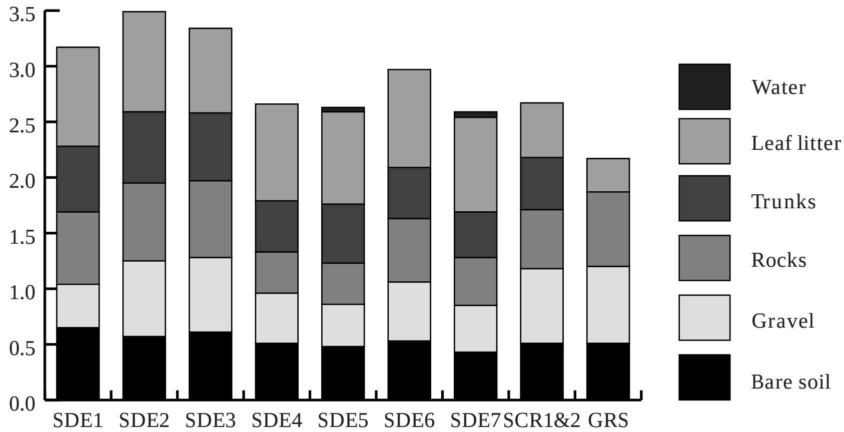


Figure 33. The Ground Cover Cumulated Indices. Each cover type has a maximum value of 1.

Table 6. Correlation between satellite data and indices of vegetation and ground cover

	NDVI	TM 1	TM 2	TM 3	TM4	TM 5	TM 7
Vegetation Cumulated Index	0.667+	–0.467	–0.317	–0.450	0.367	–0.317	–0.400
Ground Cover Cumulated Index	0.200	0.817*	0.767*	0.633	0.583	0.767*	0.667

*Spearman rank correlation coefficients between Landsat data and cover indices of vegetation strata and ground cover types recorded at the following study sites: SDE1, SDE2, SDE3, SDE4, SDE5, SDE6, SDE7, SCR1&2 and GRS. Vegetation Cumulated Index is the accumulated index of the index values of Mosses, Herbs, Shrubs, Understory, Canopy and Emergent trees. Ground Cover Cumulated Index is the accumulated index of all ground cover categories. A + signifies the correlation is significant at a level of 0.01 ≥ p ≥ 0.05 (n = 9; one-tailed). An * signifies that the correlation is significant at a level of 0.01 > p < 0.05(n=9; two-tailed). Correlation coefficients without a symbol are not significant (p>0.05).*

Box 4. Calculation and use of NDVI

To identify the vegetation cover, an artificial band, the NDVI or the "Normalised Differentiation Vegetation Index" can be calculated, and added to the series of "raw" Landsat TM bands to support the classification of the image. The NDVI index is calculated as:

$$NDVI = {}^{NIR-RED}/_{NIR+RED} = {}^{TM4-TM3}/_{TM4+TM3}$$

where NIR and RED is the measured reflectance recorded in the infrared and the red part of the spectrum respectively (Rasmussen 1993). This fairly simple index, which actually is nothing more than a band rationing, was invented in the early seventies, and a review by Ray (1994) shows that the NDVI has survived, and is still widely used, despite the fact that a number of sophisticated indexes has since been proposed. The NDVI has its origin in empirical science and is based on the spectral properties of fresh green vegetation. A healthy green leaf reflects most of the near-infrared light (NIR) but only little of the visible red light. On Fig. 34, this peak is illustrated. The shift in reflectance from red to NIR(near-infrared) can be explained by the physical properties of a single healthy plant leaf. Natural vegetation, however, most often consists of several strata with leaves of different shapes and sizes composing a combination of reflectances and shadows. A rough estimate of the difference between the reflectance from single leaf and the reflectance from a canopy mosaic is given by Campbell (1987). A single leaf reflects 10% of the visible light, a canopy mosaic reflects only 3–5%. The NIR-reflectance is 50% and 35% respectively.

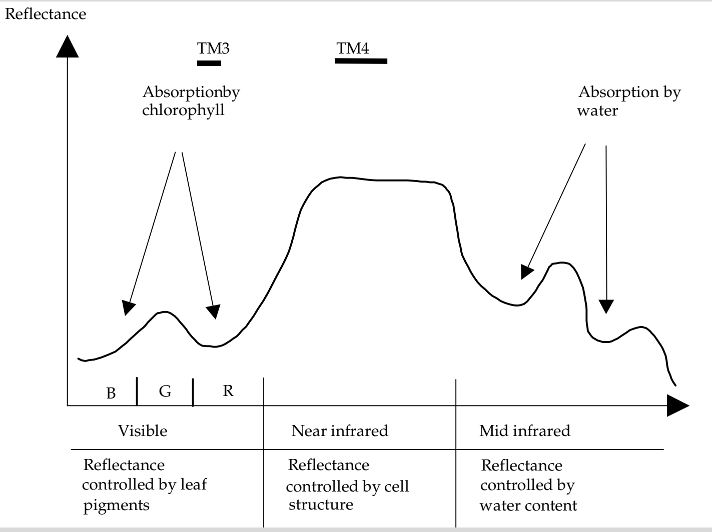
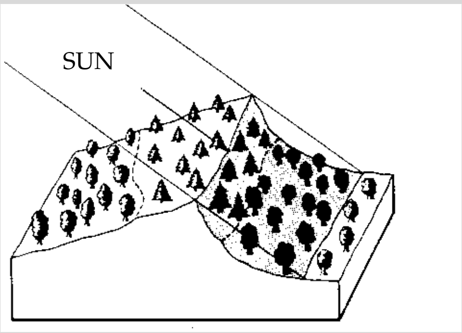


Figure 34. Major influences on spectral properties of single leaf. The approximate location of TM3 and TM4 recorded by the Landsat TM satellite is indicated on the figure. (Campbell 1987).

One major advantage by applying the NDVI to a vegetation study carried out in a mountainous area, is the ability of the index to compensate for influence of shadow effects caused by topography by rationing the TM bands. This principle is illustrated in Fig. 35. In the example shown, two different landcover types: a coniferous forest and a deciduous forest occurs on a sunlit and a shadowed side of a ridgeline. The values from both cover types are substantially lower in the shadowed part compared to the sunlit part, but the ratios of the Bands involved are nearly identical on the sunlit and the shadowed side (Lillesand & Kiefer 1994).



	Band A	Band B	Band A / Band B
Landcover			
Decidious sunlit	48	50	0.96
Decidious shadow	18	19	0.95
Coniferous sunlit	31	45	0.69
Coniferous shadow	11	16	0.69

Figure 35. Reduction of scene illumination effects by band rationing after Lillesand and Kiefer (1994).

Mapping of land-cover by satellite imagery

To study the relationship between the bird communities and the composition of the landscape an area in the southern part of the study region was mapped in detail by combining a Landsat TM satellite image and digital elevation data.

Methods

The general assumption for applying a classification to an area is that the landcover of the surface consists of discrete cover-types with well separable boundaries physical as well as spectral. This situation however, only seldom exists when it comes to natural landscapes. In fragmented landscapes, as found in large parts of the Andes, biologically diverse land-cover types such as Shrub and Forest overlaps substantially. Secondary forest and scrub vegetation intergrades constantly with forest along edges and in clearings. When applying a classification, based on distinct classes, a fuzzy border between the "Scrub" "Arid Scrub" and "Forest" classes must therefore be expected and was found.

In practise, 12 landcover classes were identified and used in the classification of the image. Most of these landcover classes could, with field-information of representative localities available, all be identified on the computer screen. See Table 7 for the definitions of the classes. To apply a computer-based classification of the whole image the procedure outlined in Fig. 35 was followed. Representative areas of the landcover classes were outlined manually on the computer screen (Training areas) and used to "train" a classification-algorithm in CHIPS (Andersen and others, 1992) to map the extension of each class. To access the accuracy of the classification "Control areas" of the landcover classes, not included in the classification, were likewise outlined on the computer-screen.

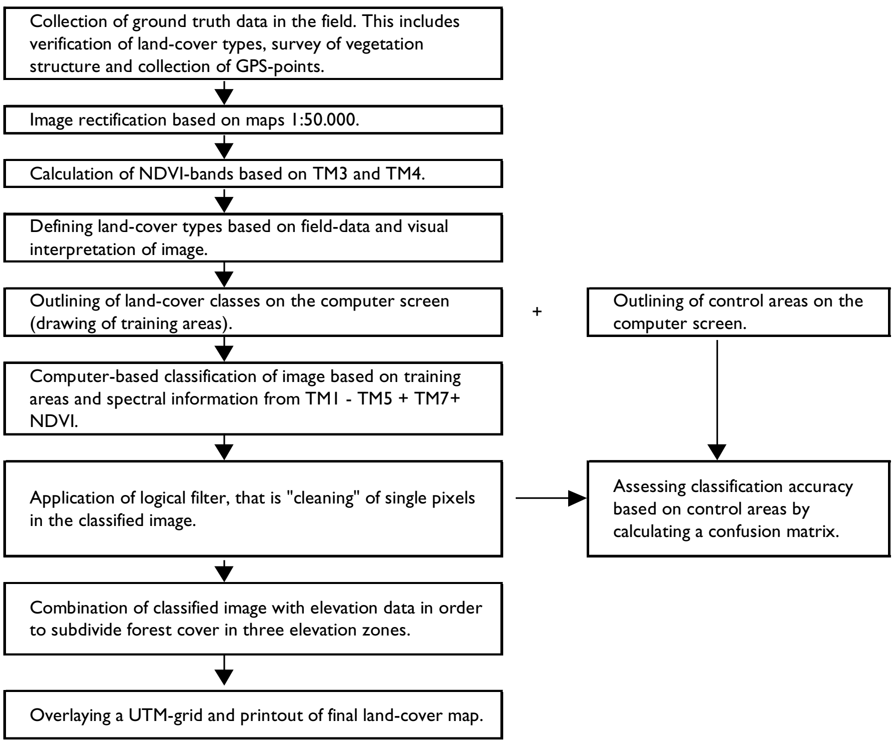


Figure 36. Diagram showing the procedure applied to map the land-cover types. "GPS"-points refers to positions read with a hand held satellite navigator (GPS) on location in the field, which are clearly visible on the satellite image.

Results

As mentioned, a fuzzy border exists between some of the landcover classes, and to access the accuracy of the image classification a "confusion matrix" can be calculated. The resulting matrix is shown in Table 8. The accuracy is assessed by evaluating how the "control areas" with known landcover turns out on the classified image. The overall accuracy of the classification: the proportion of correctly classified control pixels in relation to all control pixels, is very high. However, there are great differences in classification accuracy among the classes according to how homogenous the individual landcover classes appear on the image.

The high overall accuracy is biased because of a larger number of control pixels contained in the very homogenous landcover classes like “Shadow”, “Riverbed”, “River”, and “Grassland” areas. These surfaces are very distinct in their spectral properties and are mapped with great accuracy. The result is an overestimation of total accuracy (Rasmussen 1993). The classification of “forest” is 100% accurate because only pixels from “forest control” are found within the area on the classified image labelled “Forest”. However 30.2% of the pixels on the classified image labelled “Shrub” are from “Forest control”. This means that any pixels classified as “Scrub” has a 30.2% chance of actually being a miss-classified forest pixel. Arid Scrub displays a high degree of overlap with Scrub; Exposed Rock A has a large overlap with Exposed Rock B and to a lesser degree with Grassland and Riverbed. Exposed Rock B overlaps with Grassland. In Fig. 1 a colour composite of the study region is displayed and in Fig. 2, the final landcover map is shown. In Fig. 39 the relative distribution of the landcover classes is visualised.

Figure 37. The photo illustrates the land-cover type classified as Grassland or Puna in the classification of the satellite image. The photo is taken at Jatun Orkho, one of the two lakes identified in the image classification.

Table 7. Land-cover classes

Land-cover class	Definition
Unclassified	Areas left unassigned to any of the classes below.
Shadow	Areas with very low values of reflectance in all bands. Areas classified as “Shadow” are slopes facing towards south-west, or areas deep in ravines
River	Rivers are easily recognised on the image.
Lake	Two lakes are visible on the image.
Riverbeds	Riverbeds are easily recognised on the image and consist of sand and boulders
Bare Rock A	Bare rock exposed to the sun with absolutely no vegetation cover
Bare Rock B	Surface consisting of bare rock of a thin layer of soil andsparse vegetation.
Grassland	Grassland occasionally mixed with scattered bushes (Fig. 37).
Scrub	Second growth vegetation often highly influenced by *Dodonea* and *Baccharis* (Fig. 38).
Arid Scrub	Dry areas with sparse vegetation cover and often with bushes and cacti.
Forest	Forest or woodland of all kinds in the area. Different forest types could not be separated by the spectral information available (Fig. 41 & Fig. 42.).

Figure 38. Land-cover type identified as Scrub. Fencing efficiently prevents degradation of the Scrub land. The difference between a field heavily affected by sheep grazing on the left and a protected, fenced area on the right is clearly visible.

Table 8. Accuracy of landcover mapping

Control area	Shadow	Scrub	River-bed	River	Lake	Grass-land	Forest	Exposed Rock B	Exposed Rock A	Arid Scrub	Unclas-sified
Shadow	99.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrub	0.0	66.9	0.0	0.0	0.0	0.4	0.0	0.0	0.0	16.4	0.0
Riverbed	0.0	0.0	100.0	1.3	0.0	0.0	0.0	0.0	4.4	0.0	100.0
River	0.3	0.0	0.0	98.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lake	0.0	0.2	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Grassland	0.0	0.5	0.0	0.0	0.0	98.8	0.0	14.5	4.8	0.0	0.0
Forest	0.3	30.2	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.8	0.0
Exp. Rock B	0.0	0.0	0.0	0.0	0.0	0.8	0.0	85.5	24.4	0.0	0.0
Exp. Rock A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.5	0.0	0.0
Arid Scrub	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.8	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The confusion matrix (Users accuracy) displays the probability of an actually occurring output pixel belonging to a control area.

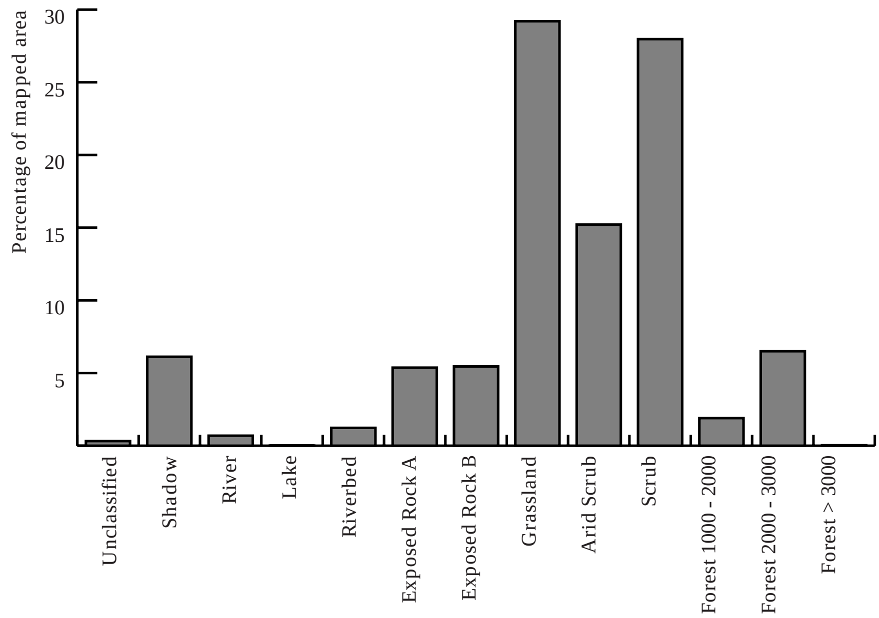


Figure 39. Different landcover types shown as percentage of the area mapped in Fig. 2.

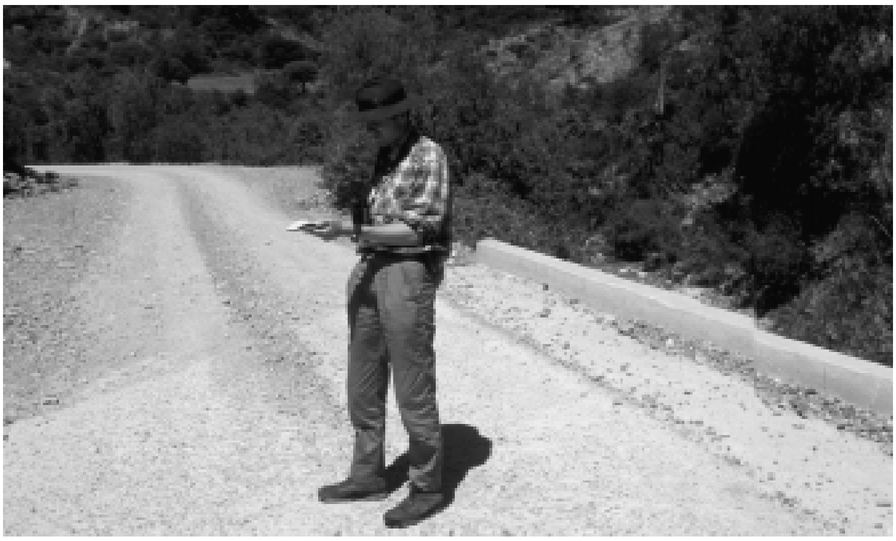


Figure 40. Geopraphic positions of features which can be recognised on the satellite image (road crosses for example) were collected with a hand-held satellite navigator (GPS). These positions were used to control the geometric retification of the satellite image.

Figure 41. The study site at Kiñi Pampa (18° 18´ 58"S 64° 57´ 54"W) was located at the edge of the biggest forest area found in the southern part of the study region. Even though extensive human activities was seen here (cultivation, cattle grazing and timber extraction), the major part of this forest area is supposed to be relatively undisturbed. The avifauna found also indicates that the forest patches here is part of a bigger coherent forest.

Figure 42. At the study site at Thipa Khasa (18° 18´ 15"S 65° 15´ 19"W) dry semi-deciduous is found. The forest is dominated by the very thorny Tipuana tipu. *The vegetation in this steep area is primarily affected by cattle grazing, paths were found all over the place. Scattered timber extraction was also registered. A substantial part of the forest has been replaced with scrub, primarily* Dodonea

Box 5. Adding a geographical reference system to the satellite Image

A Landsat TM satellite image is delivered without a geographic reference system. In order to compare positions on the image with field data, the co-ordinate system of the image has to be transformed into a predefined geographical co-ordinate system such as the Universal Transverse Mercator (UTM) system. The transformation of the image to the UTM co-ordinate system, is based on identification of ground control points GCP's. GCP's are points that can be identified on both the satellite image and on a map (Fig. 40). The list of GCP satellite co-ordinates and map co-ordinates is used to calculate a polynomium that can project the co-ordinate system of the map into the co-ordinate system of the image. The process of image rectification can be rather time consuming in order to get a reasonable rectification of the image.

By comparing the rectified image with positions read in the field by a hand-help GPS unit (Trimble Ensign GPS), we found an average deviation between these sets of co-ordinates of approximately 110 m. Locally deviations up to 400 m occurred. An important random source of deviation is the fact that the US Government still intentionally degrades the accuracy of co-ordinate reading by GPS-units. This policy known as "Selective Availability" can cause the precision of the position read to be at least +/– 100 m randomly (Rempel and others 1995).

Mapping of *Polylepis* woodland

In the study of the vegetation cover, the *Polylepis* woodland is of special concern. This landcover type was not included in the computer based image classification as only very scattered *Polylepis* woodland was encountered in the part of the study region where the satellite image classification was performed. However the spectral properties from a *Polylepis* woodland, located at the study site at POL1 (*18° 05´ 25"S 66° 08´39"W*, see Appendix 1 for a detailed description of the study site), has been compared to landcover classes used in the Maximum–Likelihood classification. The *Polylepis* woodland found at POL1 was clearly visible on the computer screen with a suitable contrast stretching, and training areas could easily be outlined. The result of this comparison is displayed in Figure 44.

It seems, according to this comparison, that if *Polylepis* woodland were to be included in an image classification of the sub-region, the greatest problem would be to distinguish *Polylepis* woodland from “Arid Scrub”.

This finding is what could be expected as *Polylepis* forest is not very dense in general (Fig. 43). This counts also for the *Polylepis* forest visited at POL. With such a vegetation type the underground of the substrate will have sustainable influence on the signals reflected to the satellite, just like what is found in areas covered by “Arid Scrub”.

A map of potential *Polylepis* woodland in the area covered by the satellite image has been produced by Navarro and others (1996). Data on humidity and elevation was in this study used to make a potential mapping of bioclimatic zones including *Polylepis* woodland with *Polylepis neglecta* (*P. neglecta* has an altitudinal range between 2,400–2,500 m and requires precipitation from 600–1,200 mm per year; Kessler 1995a; Navarro and others). When the satellite based mapping of forest above 2,500 m was compared with the mapping of potential *Polylepis*-cover made by Navarro and others, it is obvious that only very little of the potential *Polylepis* woodland remain. This finding is also true, even when it is considered that *Polylepis* could be difficult to distinguish from Arid Scrub. On Figure 45 a comparison between the *Polylepis* cover predicted by Navarro and vegetation cover higher than 2,500 m mapped by use of satellite / elevation data is seen. The conclusion that can be drawn from this comparison is that the most reliable mapping of actual *Polylepis* cover is made by a combination of satellite data and data on elevation and humidity.

Figure 43. Inside the Polylepis *forest found at Acasio (18° 05´ 25"S 66° 08´ 39"W) with* Polylepis *trees up to 15 meters tall. The picture demonstrates the fairly open structure of the woodland.*

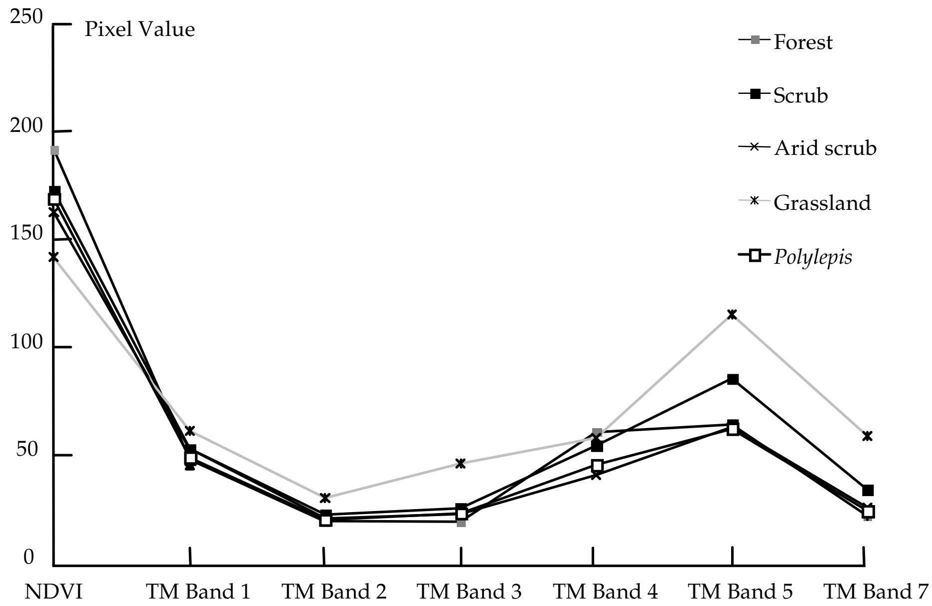


Figure 44. Comparison of the reflectance from land-cover classes in the satellite image and the reflectance from the Polylepis *woodland at POL1 near the village of Accasio.*

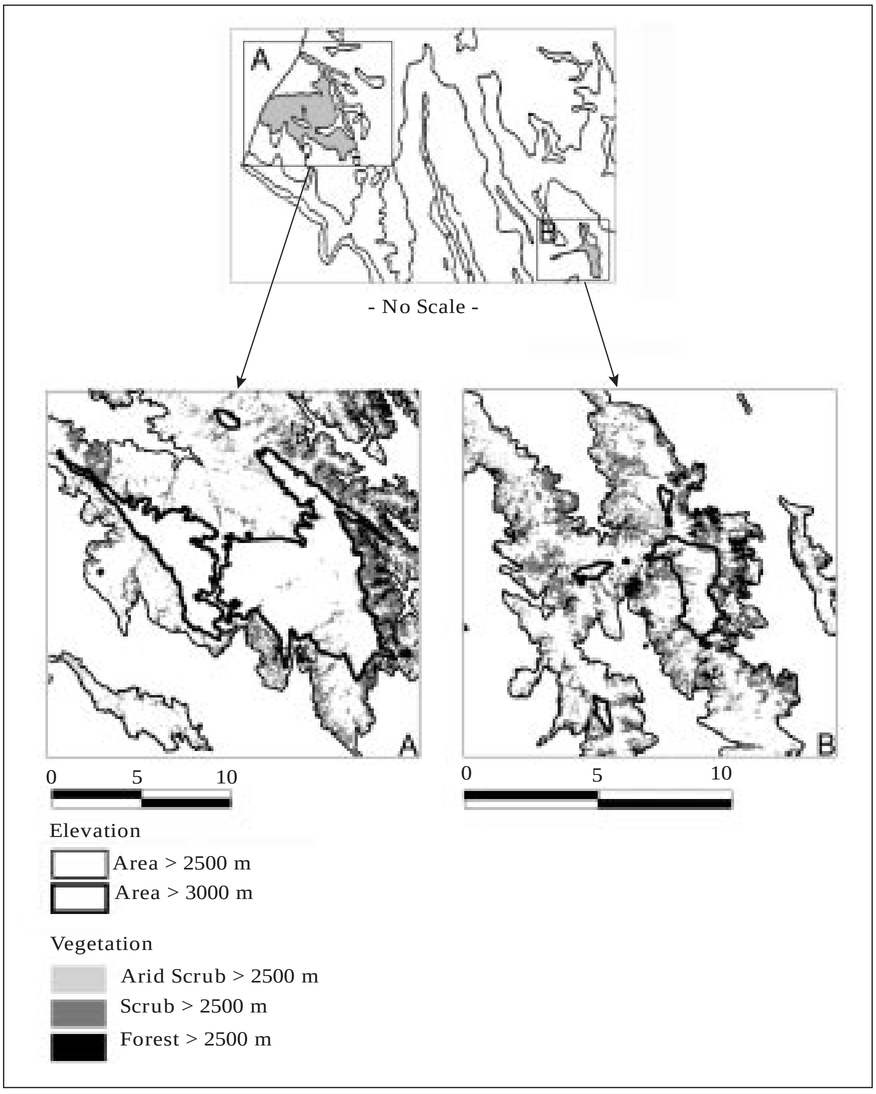


Figure 45. The gray areas on the small map on the top indicates the potential Polylepis *cover as predicted by Navaro and others (1996). The two maps A & B at the bottom shows the actual vegetation cover above 2,500 m in A & B as extracted from the Landsat satellite image.*

Part conclusion and discussion

The possibility of classifying extensive or inaccessible areas from digital satellite imagery rapidly provides increased opportunities to identify and quantify landcover. The method is not without problems when it comes to a topographically complex area like the Andean area. Examples of the difficulties of separating vegetation classes in mountain areas are numerous (Stoms & Estes 1993). Shadow effects caused by the topography makes part of the satellite image difficult to interpret. By calculating and adding a Normalised Differentiation Vegetation Index – the NDVI to the raw satellite bands, before applying a classification, these effects are diminished, and the possibility for mapping structurally diverse vegetation (forest) is enhanced. The most basic factor influencing the outcome of an classification based on satellite imagery however is field surveys (Rasmussen 1993; Craven & Haack 1994). Without ground-truthing, the image classification is more or less pure guesswork and the resulting vegetation map is likely to be very imprecise.

Without ground-truthing, the image classification is more or less pure guesswork and the resulting vegetation map is likely to be very imprecise.

Even with good field data, some vegetation classes are difficult to separate based on their spectral properties. In the present study a substantial overlap between "Scrub" "Arid Scrub" and "Forest" classes, is found, and the relatively high classification accuracy indicates that our classification of forest is conservative. That means we have preferred to exclude forest areas that might be scrub, rather than overestimating the total forested area. With above reservations in mind, the classified image represents a first attempt to map and classify the existing vegetation cover of the region in detail with respect to the vegetation types or landcover types chosen. The map produced could as such be used for further explorations of the region. It is also notable that less than 9% of the area mapped is covered with forest, reflecting the fact that the area is highly degraded.

It is also notable that less than 9% of the area mapped is covered with forest, reflecting the fact that the area is highly degraded.

Concerning the vegetation of special interest, the *Polylepis* woodland, we compared our classification of this forest type with a map of potential *Polylepis* woodland cover made by Navarro and others (1996) and found very little accordance even when the problems with separating *Polylepis* woodland and Scrub/Arid Scrub was considered.The potential vegetation map by Navaro shows where *Polylepis* could be expected to grow if it was not disturbed. In the field we did observe *Polylepis*, but only very scattered, which is also indicated by the satellite mapping.

To improve the vegetation mapping several possibilities exist. If a better temporal coverage of the area was available and we could include a Landsat TM scene of the study region from the wet season, we expect that it would be possible to distinguish areas dominated by deciduous forest. The classification could be further improved with an extended integration with other data such as humidity, elevation and soil types in a Geographical Information System (GIS). A such integration would allow us to refine the landcover mapping.

3. Bird diversity and community structure

by Thor Hjarsen, Nicholas Moray Williams and Poul Nygaard Andersen

The association of species that are found in a forest patch is assumed to be determined by the physical characteristics of the habitat. Cody (1985) states: "The number of species that pack into a habitat, defined as alpha-diversity, are directly related to structural diversity, and in turn structural diversity is related to either resource diversity or the number of ways in which resources can be partitioned". But local ecosystems should also be seen as parts of the landscape, and the diversity found within forest fragments are thus affected by a number of factors operating at various spatial and temporal scales as suggested by Ricklefs (1987) (Fig. 46). In the following chapter we examine the relationship between the bird diversity and the vegetation structure of selected localities together with the relationship between the bird diversity and the heterogeneity of the surrounding landscape.

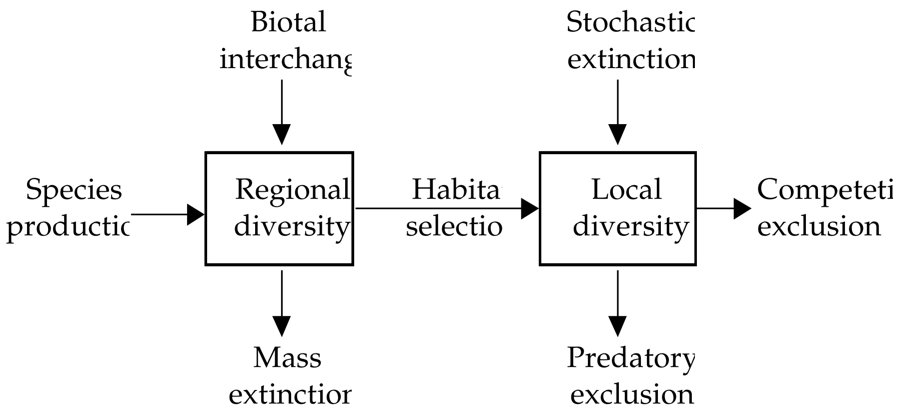


Figure 46. The influence of regional and local processes on regional and local diversity. The arrows illustrate some major factors affecting the local and the regional biodiversity. Note that these factors assert their influence on vastly different time scales (Ricklefs & Schluter, 1993).

Plantations and native woodlands

A range of data was collected from study sites in forest classified as *Eucalyptus* and *Pinus* plantations, *Polylepis* woodlands or mixed woodlands with native vegetation all located in the northern study area. Data of the vegetation structure was quantified to investigate whether bird community structure and bird diversity was correlated with such vegetation attributes.

Methods

The collection of data on the vegetation in the study areas was focused on describing the structural physiognomy of the habitat, and not on collecting qualitative data such as complete plant species lists or plant species abundance. The physiognomy of the vegetation, availability of forage plants, nesting sites and hiding places are important niche dimensions for bird communities (Weins & Rotenberry 1981, Weins 1989), and bird counts become much more valuable when they are related to factors in the habitats that influence bird abundance (Bibby and others 1992).

Previous to initiation of fieldwork, the study sites were assigned to one of the four habitat classes:

- Natural vegetation : Woodlands dominated by *Polylepis* (POL).
- Natural vegetation: Mixed woodland vegetation of native species (MIX).
- Exotic plantation: Habitats dominated by *Pinus radiata* (PIN).
- Exotic plantation: Habitats dominated by *Eucalyptus globulus* (EUC).

The following data were collected to describe the vegetation structure:

- Estimated coverage (%) and average height of emergent trees, canopy trees, understory trees, bushes, herbs, bromeliads and grasses.
- Estimated coverage (%) of mosses, lichens and lianas.
- Estimated coverage (%) of plants in flower.
- Estimated general plant species richness on a scale of 1–5, where 5 indicate the highest richness.
- Identification of the 5 (or less if 5 not possible) most abundant plant species in each plant group where coverage and height have been established.
- Density measure of trees by *Point-centred quarter method* (Shimwell 1971), where values approaching 1.0 express lowest distance between individual trees (see below).
- Trunk diameter of trees measured as diameter at breast height (DBH). Each trunk was measured and in multi-trunked trees the measurement of each trunk were summed up. Averages for each study area were then calculated.
- Number of vegetation layers / strata in the habitat; ground vegetation layer, bush layer, canopy layer(s) (epiphytes were not included in this estimation).
- Estimated influence from other vegetation life zones on a scale of 1–5. A value of 5 indicate strong influence from for example the puna zone (grassland). Habitats with high scores were often highly fragmented.

The Point-centred quarter method is a very efficient tool to quantify tree stand density (Shimwell 1971). The method implies selection of a number of sampling points in the habitat from where four perpendicular lines are erected. These lines give four quarters and the next step is to measure the distance from the point-centre to the nearest tree in each quarter. Thus, for each point four distance measures are obtained.

Tree density, *D*, is defined as the number of individuals per areal unit. The mean area, *A*, is defined as $1/D$ where A is the square of the mean of the four distance measures (*d*) from each point. Each tree measured was identified, making it possible to calculate relative abundance of trees and a tree diversity index assuming that this abundance reflected the overall tree abundance and diversity in the habitat.

A vegetation heterogeneity index for each study area is used to quantify relative complexity of the vegetation in terms of the number of strata and height of each of these. Weins & Rotenberry (1981) used a vegetation heterogeneity index based on the height of each strata for North-American shrub steppe habitat.

The following vegetation heterogeneity index, V_H, based on the height and presence of vegetation strata quantifying vertical vegetation heterogeneity is introduced: $V_H = 1 - (Sh_n/h_{max})^{(Sobs/Smax)}$. In this index h_n is the recorded height of each stratum, h_{max} is the maximum recorded height of all strata, ^{Sobs} is the recorded number of strata in the area, and ^{Smax} is the maximum possible number of strata recorded in the natural forest ecosystem. Thus, a habitat with low vegetation heterogeneity (few strata) gets a score towards 0, while very stratified habitats get scores approaching 1. Empirically, the indices calculated fits the observed complexity in the study areas.

A few values exceed 1 in habitats where the sub-canopy vegetation strata heights are similar to the canopy height.

Tree-species diversity index for each study area is actually the formula of the Shannon diversity index (*H'*), where the tree species frequencies from the species identification in the Point-centred quarter method are used. Data on diversity of trees and plant species richness of habitats are important attributes to consider when investigating factors influencing bird communities (see Weins 1989).

Results

Table 9 shows for all study areas the calculated tree density index (from the Point-centred quarter method), average DBH, score for general plant species richness, vegetation heterogeneity index (V_H), number of strata recorded and coverage of plants in flower. The data collected on coverage and height of each strata in all study areas, is included in Appendix 2.

Table 9. Vegetation structure on northern study sites

Area code	Tree density	DBH	Flower (cm)	V_H	Species richness	Strata
Eucalyptus plantation						
CA1	0.186	24.4	7	0.07	3	4
KP4	0.704	9.0	5	0.12	1	5
LI1	0.175	15.9	5	0.02	1	4
MO3	0.859	6.2	5	0.62	1	5
MO5	0.348	10.9	5	0.05	1	4
PO1	0.177	15.0	2	0.01	1	3
PO3	0.147	16.6	9	0.04	1	5
TI2	0.106	9.8	8	0.18	1	4
TU10	0.229	11.0	5	0.05	1	4
TU3	0.261	15.7	5	0.03	1	3
Means	0.319	13.4	5.6	0.12	1.2	4.1
Pinus plantation						
CA2	0.373	33.6	5	0.04	2	4
CU1	0.194	7.2	7	0.09	1	4
CU2	0.213	11.8	10	0.84	2	6
LI2	0.150	2.5	8	0.14	1	4
TI3	0.358	17.0	10	0.44	1	5
TI4	0.366	13.2	9	0.18	1	5
TU1	0.084	29.0	5	0.02	1	3
TU6	0.142	20.8	2	0.10	1	4
TU7	0.055	19.8	5	0.33	3	4
TU8	0.171	19.9	5	0.16	2	5
TU9	0.178	15.9	5	0.02	1	3
Means	0.208	17.3	6.5	0.21	1.5	4.3
Polylepis woodland						
CA3	0.103	32.7	7	0.34	4	4
CK1	0.480	nn.	8	0.69	2	3
CU3	0.414	7.1	15	0.42	3	4
KH2	0.049	24.6	5	0.55	2	3
KH3	0.074	25.3	5	0.55	2	3
KP2	0.186	19.8	8	0.67	4	4
LM3	0.185	22.2	10	0.60	2	4
MO1+2a	0.413	12.0	8	0.26	3	4
MO1+2b	0.542	17.9	8	0.67	3	4
MO4	0.241	20.5	10	0.67	2	4
OR2	0.243	8.0	15	0.51	2	3
SM1	0.165	14.3	6	0.78	2	5
SM2	0.342	8.4	5	1.20	2	5
SM3	0.098	15.0	12	0.42	3	5
SM4	0.094	15.3	8	0.36	3	4
SM5	0.066	10.3	10	0.53	3	4
TI1	0.179	7.9	6	0.42	2	4
TU4	0.266	13.5	5	0.42	2	3
TU5	0.184	17.8	2	0.78	2	3
Means	0.228	15.4	8.1	0.57	2.5	3.8
Woodland with mixed native vegetation						
KH1	0.089	20.5	10	0.30	2	4
KP1	0.357	3.7	5	0.87	5	5
KP3	0.744	8.2	5	0.26	3	5
LI3a	0.097	17.8	15	0.55	2	5
LI3b	0.097	17.8	15	0.42	2	5
LM1	0.220	17.8	8	0.41	5	6
LM2a	0.174	17.1	6	0.42	5	5

LM2b	0.219	15.7	5	0.42	1	5
OR1	0.087	34.4	10	0.63	2	4
PO2	0.371	6.3	15	0.22	3	3
PO4	0.604	0.0	15	0.29	2	3
TI5	0.083	14.7	7	1.23	2	6
TU2	0.139	25.7	7	0.04	3	4
Means	0.252	15.3	8.8	0.47	2.8	4.6

Tree density = Tree density index by point-centred quarter method corrected to horizontal level. DBH = Average measure of diameter at breast height, trunk diameter in centimetres measured approximately 1 m above ground on 40–80 trees. FLOW = Estimated coverage of plants in flower. V_H = Vegetation heterogeneity index, sensitive to large differences in strata heights and number of strata. Habitats with high values have highest heterogeneity. Species richnes = Estimated general plant species richness on a scale from 1–5, where 1 is lowest species richness (that is, near-monoculture). STRATA = Number of vegetation layers recorded. The maximum score is 7(see main text).

Kolmogorov–Smirnov one-sample test testing both medians and distributions showed significant difference of the vegetation data listed in Table 9 between the plantation habitats and natural vegetation habitats only for vegetation heterogeneity index (V_H) and estimated general plant species richness with $P < 0.05$. For all other data series no significant difference between the habitat classes could be found.

The data in Table 9 was then tested for correlation with the bird community data from all study areas: Species richness (S), number of individuals (N), rarity-score (R) and Shannon index (H') by Spearman rank correlation analysis. The test result is shown in Table 10. See Chapter 5 for an explanation of how bird data was made.

Table 10. Correlation of vegetation and bird data

	Rarity score	**Bird diversity**	**Bird species richness**	**Number of bird individuals**
Tree density	–0.245	–0.254	–0.266	–0.139
DBH	0.194	0.036	–0.010	–0.048
Flower	*0.351	***0.489	**0.436	**0.389
V_H	***0.495	***0.540	***0.513	***0.551
Species richness	***0.619	***0.513	***0.530	***0.576
Strata	0.082	–0.039	0.017	0.060

Asterisks mark where probabilities for correlation obtained by chance is: < 0.005 (*), < 0.001 (**), or < 0.0005 (***), and thus in all cases statistically highly significant with n = 53.

The result of this comparison can be summarised as follows:

- There is a modest positive correlation between all four bird community indicators and vegetation heterogeneity (H_V) and estimated general plant species richness.
- There is a modest positive correlation between both bird species richness and bird diversity (Shannon) and estimated coverage of flowering plants.
- There is a modest positive correlation between bird rarity-score and tree species diversity.

These results show that, in general the bird community responds to the complexity of the vegetation structure and food availability. Vegetation with several strata of different heights, several different species of trees and bushes, and high coverage of flowering plants holds the richest bird fauna. Furthermore, the habitats with the highest tree diversity hold the rarest bird communities. This analysis does not show higher bird diversity in near-monospecific *Polylepis* woodlands than in the (near-) monospecific *Pinus* and *Eucalyptus* habitats.

Dry semi-deciduous forests

Methods

Within all forest study sites in the southern study area, data on vegetation structure and ground cover was collected by applying the Braun–Blanquet method as described on page 28. These data were, together with data on the total number of lianas found estimated in the study sites, correlated with the bird diversity of the semi-deciduous forests.

Bird diversity was described in two indexes:
• The total number of bird species found.
• The total number of forest associated birds found.

Results

The number of forest species is strongly correlated with cover of understory trees, cover of emergent trees, and cover of epiphytes on trees. There is a modest positive correlation between number of forest species and the summed index of vegetation cover, however due to the small sample size this correlation is not significant (Table 11). These results indicate that the bird community responds to the complexity of the vegetation structure and food availability. In chapter 2 we have shown that it is possible to identify areas with high Vegetation Cover Index (VCI) using satellite imagery suggesting that it is possible to point out areas supporting the richest forest bird communities. The results are displayed in Table 6.

The number of forest species is strongly correlated with cover of understory trees, cover of emergent trees, and cover of epiphytes on trees.

Table 11. Correlation between bird species richness and vegetation cover

	Total no. of species	**No. of forest species**
Vegetation Cover Index (VCI)	0.270	0.679
Mosses (ground)	0.091	0.144
Herbs	–0.396	–0.143
Shrubs	0.200	0.577
Understory trees	0.216	*0.714
Canopy trees	0.072	0.107
Emergent trees	0.378	*0.730
Epiphytes	0.468	*0.750
Lianas	0.100	0.541
Trunks and branches	0.100	0.505
Leaf litter	0.036	0.393

Spearman rank correlation coefficients between bird species richness and cover indices of vegetation strata and ground cover types recorded at the following study sites: POL1, SDE1, SDE2, BTC1, SDE4, SDE5, and SDE6. An (*) signifies the correlation is significant at the level of 0.01< p < 0.05 (n =7; one-tailed). Correlation coefficients without a symbol are not significant (p > 0.05). Vegetation Cover Index (VCI) is the sum of the cover indices of Mosses, Herbs, Shrubs, Understory, Canopy and Emergent trees.

Landscape heterogeneity and bird diversity

As presented in the map in Fig. 2 the landscape of the southern study area is a mosaic of different land-cover types, and most of the study sites with forest found here are highly fragmented. As mentioned in the beginning of this chapter, the fragmentation of the forest habitats is supposed to influence the bird communities found in these habitats.

Bird species express different levels of tolerance in habitat conditions and fragmentation and disturbance of forest can cause the loss of many species, which are not tolerant to the changes (Begon and others 1990; Wiens 1995; Arangovelez & Kattan 1997). Birds species associated with Scrub or species, which are widespread generalists, may invade forest fragments. Edge species are likely to be favoured by increased forest fragmentation, and species richness in and around the woodland fragments may rise due to influx of less specialised species which are abundant in many types of habitat. This implies that different fragments may support different community set-ups even if these fragments seem structurally similar.

Methods

Data extracted from the satellite image was used to examine the relationship between the heterogeneity of the landscape surrounding the forest fragments and the bird communities observed within the forest fragments.

In the classified image all pixels (the smallest unit on the image) were assigned to one of twelve different land-cover classes. Each land-cover type has its own colour. The land-cover classes were not weighted in relation to each other, this means that a pixel classified as "Forest" was not considered more valuable to the birds than a pixel classified as "Bare Rock". Each pixel has the size of 30 m by 30 m. To calculate an index of the landscape heterogeneity, a Shannon index was applied to six study sites (See Fig. 3). The Shannon index has been widely used as a measure of species diversity (Krebs 1989) but has also been used as a measure in landscape ecology (Forman 1995). The index was calculated in a predefined frame as:

$H' = -S(P_i * \ln P_i)$ (Magurran 1988). ($P_i = P / S$ = the number of pixels of the one colour in the sample grid divided with the total number of pixels in the sample grid).

Landscape mosaics can be studied at different scales, according to the home range and dispersion of the organisms in question. The significance of the index employed must be evaluated with the perspective of particular species or ecological processes in mind (Griffiths and others 1993). Detailed information on the behaviour of most of the species found is not available, but all species observed can fly and the general assumption that they are potentially able to move within a few square kilometres was made. Therefore, it was chosen to investigate the relationship between the study sites and the surrounding landscape in frames ranging from 90 m (3 pixels) up to 2,430 m (81 pixels). When the heterogeneity indices for all frame sizes on each locality had been computed, the correlation coefficient for these indices and the number of bird species present in each study area were calculated using a product moment correlation (Fowler & Cohen 1990).

Four different series of correlation coefficients based on bird data and heterogeneity data from six study sites were produced:

- Correlation between the Shannon index and the total number of bird species.
- Correlation between the Shannon index and number of Forest species.
- Correlation between the Shannon index and number of Scrub species.
- Correlation between the Shannon index and number of Grassland species

The information of primary habitats for the bird species were extracted from "Neotropical Birds, Ecology and Conservation" (Parker and others 1996) (see Box 7).

Results

The correlation between the Shannon index applied to the coverage of land-cover classes in ascending frame-sizes is displayed in Fig. 47. No correlation between the Shannon index and total number of bird species or between the Shannon index and the number of Forest birds is found. When the heterogeneity index is measured in frames with sides of 25 to 36 pixels a significant correlation (p=0.05) is found between the landscape heterogeneity and the number of Scrub bird species. The interpretation of this pattern is that the Scrub species are generalist able to exploit the different land-cover types. An obvious weakness of the study however is that data on bird communities located at study sites with extensive forest cover is not included in the study. Such study sites could serve as valuable reference-sites.

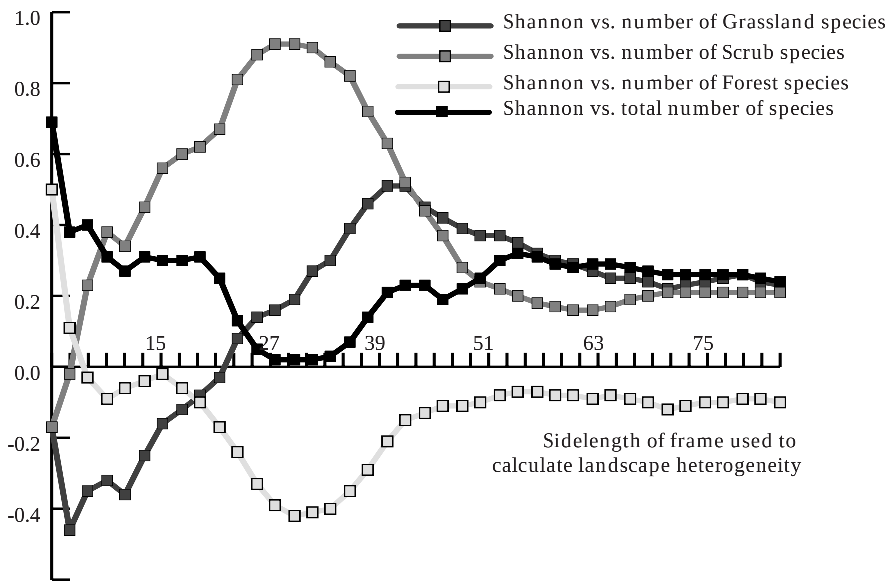


Figure 47. Correlations between the number of bird species present in the study areas and the Shannon index calculated in ascending frame sizes. A positive correlation between the Shannon index and the number of Scrub species is found with an approximate frame-size of one sq. km.

Part conclusion and discussion

The total number of bird species present in the study sites located in plantations and in *Polylepis* woodlands are found to be correlated with the structure of the vegetation. A similar relationship is found between the Forest species and vegetation parameters of the dry forest. When the relationship between the bird communities and the landscape heterogeneity is examined a positive correlation is found between the number of Scrub species present and the heterogeneity of the surrounding landscape, when the landscape heterogeneity is calculated in a frame of approximately 1 sq. km. No correlation was found between the number of forest species and the landscape heterogeneity. This could indicate that the degree of fragmentation found in the dry valleys does not seriously reduce the avian diversity of the forest fragments.

Figure 48. On most study sites in the southern study region, cattle trampling and grazing heavily affected the vegetation. The cattle create paths in the vegetation, which open and expose the forest. The picture is taken at the study site at Kiñi Pampa (18° 18´ 58"S 64° 57´ 54"W) where also sign of timber extraction and burning can be seen.

4. Birds of dry forest fragments

by Nicholas Moray Williams and Poul Nygaard Andersen

Present day vegetation cover of the dry Valles region of Cochabamba between 2,000 and 3,000 is a complex mosaic of semi-deciduous forest, primary and second growth arid scrub, and crop land. The remaining forest cover is very fragmented and disturbed by agriculture, and by burning to maintain pasture and livestock grazing (Fig. 48)

We present the results of bird surveys in various habitat types in the region. We found that the semi-deciduous forest fragments still support high species numbers but that there are few species foraging in the lower vegetation strata. Regional species richness was found to be much higher than local richness. This fact indicates that there is a high potential turnover of bird species between localities maybe because forest species have disappeared from some fragments. The results indicate that most forest fragments in the region could easily support a higher bird diversity if structural diversity was allowed to regenerate.

Methods

Fieldwork took place from medio March to ultimo May 1995 in southern Cochabamba. Study sites were situated between 2,200 and 3,500 meters above sea level (Table 12). We camped at the edge of the study areas or up to ca. one km away. Notes were taken during the day of all bird species observed at campsites and along roads. Only species recorded within 500 meters of study areas are presented in this report apart from threatened and restricted range species for which all observations are mentioned. We applied a modified version of the MacKinnon 20–species list method (MacKinnon & Phillips 1993) to estimate local species richness. The method, described by Poulsen and others (1997), was used to rapidly assess if the presence of most species in the study area had been determined. We recorded species seen or heard within the study site. We added owls heard during the night to the current list. Playback of tape recordings was used to attract some species for identification. Because of low species richness in most sites 10–species lists were used, of which 20 were accumulated. At SDE5, more lists were collected because we still found new species after collecting twenty 10–species lists. As a rule, we conducted bird surveys from the first hour of dawn until noon when most species were active.

The number of observers taking part in the daily bird surveys varied from one to three. We surveyed each study area between two and five mornings. Mist netting was carried out using two to eight nets at SEC1, POL1, SDE1, and SDE4. The main objective was to record secretive undergrowth species but we did not catch any species not observed in the field.

Table 12. Habitat classification and number of study areas

Vegetation habitat classes	Number	Code
Semi-deciduous Forest	6	SDE
Polylepis Woodland	1	POL
Boliviano Tucumano Forest	1	BTC
Arid Secondary Scrub	1	SEC
Secondary Scrub	2	SCR
Grassland	1	GRS

The codes are used in the following text. Details of study areas are found in Appendix 1.

Statistical methods

Similarity of species composition between study sites was analysed using the Sørensen similarity coefficient (C_s): $C_s = 2j/(2j+a+b)$ where j = the number of species shared between sites, a = the number of species only found in site A and b = the number of species only found in site B (Krebs 1989).

The Sørensen coefficient is regarded as one of the best performing indexes of similarity based on presence/absence data (Smith 1986 in Magurran 1988). Compared with other similarity coefficients C_s weights matches in species composition between communities more heavily than mismatches (Krebs 1989). This is preferable because the absence of species at study sites could be due to our failure to detect them. As we did not standardise our sampling effort the absence of species does not provide any information for comparing sites (Conroy & Noon 1996).

The Sørensen coefficient is regarded as one of the best performing indexes of similarity based on presence/ absence data.

To express the dissimilarity in species compositions between sites we use the expression ($1–C_s$). Besides testing if dissimilarity in species compositions between study sites can be related to habitat type and habitat quality it is important to rule out independent factors such as the geographical and elevational distance. We tested if the observed dissimilarity in species composition was associated with these two factors using the Mantel test (Sokal & Rohlf 1995, Box 6).

Box 6. The Mantel Test

The Mantel test is a non-parametric randomisation test used to test whether observed differences in datasets can be explained by simple factors such as geographical distance between data points rather than other factors (Sokal & Rohlf 1995). It considers an observed sample of dissimilarities as one of many possible, equally likely outcomes that could all have arisen by chance. Comparing independent values in two matrixes, the Mantel coefficient Z is computed as the sum of the products of each pair of corresponding dissimilarity measures. The test procedure then consists of randomly re-arranging the variables within one sample and computing Z again. This is repeated many times and the original Z is compared with the distribution of randomly generated Z values to decide if it is sufficiently deviant from these to reject the null hypothesis, that is, if the probability of obtaining an observation as deviant as or more deviant than the observed is less than the desired significance level (Sokal & Rohlf 1995). In order to obtain a measure of the correlation between the two datasets we calculated the product-moment correlation coefficient for each randomised set of variables. By comparing the distribution of correlation coefficients with the “original” correlation coefficient and accepting it if it is sufficiently deviant after the same principle as Z.

Community structure in study areas

Most smaller bird species are assumed to prefer different vegetation types and structural features within the vegetation strata for example canopy, understory and trunks to which they are adapted morphologically and behaviourally (Cody 1985). Species assemblages within a habitat are normally viewed as belonging to the same *community*. Within the community species specialised for feeding in a certain strata of the vegetation are regarded as belonging to the same *guild*. The number of species in each guild is a rough indicator of habitat quality. However some species recorded in the forest fragments primarily live in the surrounding habitats and would probably be able to survive without forest being present. This means that community species richness in the study areas is not necessarily a good measure of habitat quality as far as forest birds are concerned (Remsen 1994). Therefore we chose

The number of species in each guild is a rough indicator of habitat quality.

to focus on species known to be forest dependent by relating forest species richness to the observed habitat heterogeneity. Furthermore, we summarised information for preferred foraging strata of all forest species present. This allows us to assess if disturbance affects guilds differently.

Box 7. Habitat preferences for birds

All species observed and identified has been assigned to the primary habitat and main foraging strata recorded in Parker and others (1996). In this database and the associated book (Stotz and others 1996) the vegetation of the Neotropics is divided into 29 vegetation types (15 forest and 14 non-forest) (Stotz and others 1996). We define the primary habitat as the vegetation type the species uses most commonly over most of its range (Stotz and others 1996). Some species are less habitat restricted than others and up to seven choices of habitat are recorded for each species in decreasing order of importance. In this analysis, we used the second preferred habitat recorded for 14 species because the primary habitat clearly was not present in the region. When we refer to a species as belonging to a certain vegetation type, we base it on the primary habitat. Forest species are defined as species with any natural forest type as primary habitat. Forest Edge species are defined as species occurring mainly at the edges of forest but thought to depend on the existence of the forest itself (Fig. 50). Secondary Forest species are defined as species, which can survive permanently in forms of second growth consisting mainly of trees. Scrub species includes species whose primary habitat is dry or humid areas dominated by shrubs, scattered small trees, cacti, etc. This category also includes second-growth scrub. Grassland / Agricultural area species includes species from the upper montane Puna zone.

Results

Species richness

A total of 133 species was identified in and near the study areas

A total of 133 species was identified in and near the study areas (Table 13). The semi-deciduous forest patches had the highest species richness and the highest share of forest species. We recorded many species that are not normally found at such high altitudes, which is typical of the avifauna in the Cochabamba basin (for example Fjeldså & Maijer 1996). The most notable altitude extension was a flock of the parrot *Forpus xanthopterygius,* which was recorded at BTC1 at ca. 2,750 m.

As mentioned in chapter three all species observed within 500 m from the study areas were assumed to be associated to the forest patch. Fig. 49 displays the primary habitat of all identified species observed at each study area. Highest number of Forest / Forest Edge species was recorded in the semi-deciduous forest patches east of Río Novillero and the lowest number was recorded in the second growth scrub habitat. Scrub species were dominant in SEC1 and in upper montane POL1 and BTC1. POL1 had five species that are habitat restricted to *Polylepis* woodlands (Table 14). Presence of threatened and endemic species are treated in chapter 7.

In the following, only species belonging to the Forest and Forest Edge communities are compared. The Sørensen similarity coefficients indicate that distinctive communities exist in the forest types SEC, POL, and SDE (Table 15).

However, the Mantel test showed that the dissimilarities (1–C) in species composition between study sites can be explained both by distance and elevational difference between sites when all habitat types are compared (Table 16). The turnover of species between the semi-deciduous forest patches could not however be explained by either distance or elevation.

Table 13. Number of species recorded at each study site

	SEC1	SDE1	POL1	SDE2	BTC1	SDE4	SDE5	SDE6	Total
No. of species in study area	36	46	42	45	40	44	60	52	–
No. of unidentified species in study area	9	3	1	5	6	3	7	4	–
No. of Forest Edge species within 500 m	14	29	15	25	23	26	39	37	60
No. of identified species within 500 m	40	57	45	46	58	52	60	60	133

All forest/edge species recorded within 500 m distance are used in the following calculations. Study sites codes: See Table 12, page 46.

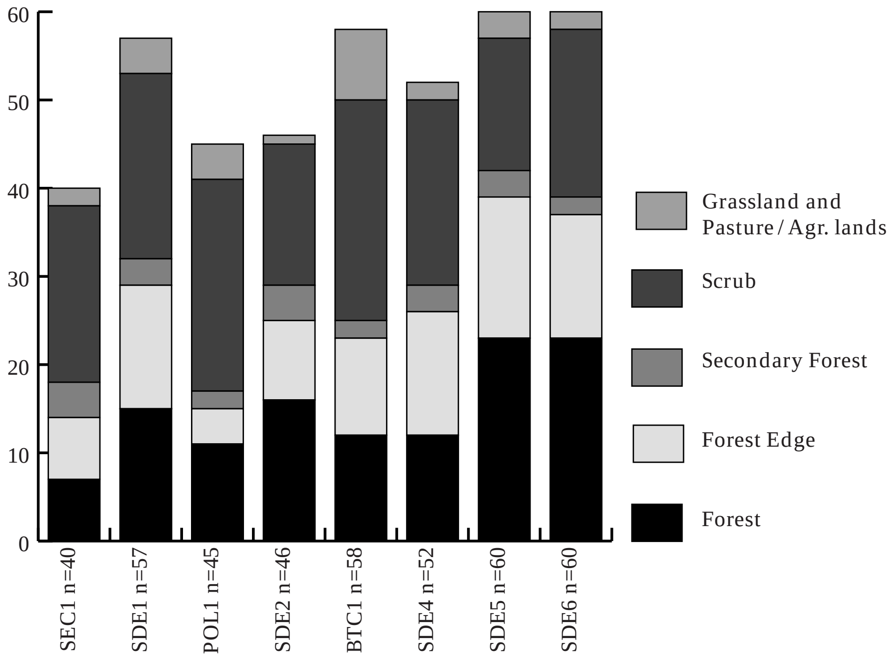


Figure 49. Number and primary habitat of all bird species identified in the study areas (n = number of species). Habitat preferences are listed in Parker and others (1996) (see Box 7). Species lists for all study sites are found in Appendix 2.

Figure 50. To the left: Red-tailed Comet (Sapho sparganura*) was quite common found at the edge of* Polylepis *forests.*
*To the right: White-browedTyrannulet (*Mecocerculus leucophrys*). This species is found inside* Polylepis *forests where it feeds on insects.*

Guilds

Canopy species constitute half of all forest species recorded in the region and this guild was the largest in all study sites excepting the upper montane *Polylepis* woodlands at POL1. These woodlands consisted mainly of low trees (< 8m) with dense cover only found in narrow ravines. Understory or Terrestrial species were most numerous in the study sites east of Río Novillero (Table 17, Fig. 49 & Fig. 50).

Table 14. Primary habitat of all species recorded in the study areas

Primary habitat	**SEC1 (14)**	**SDE1 (29)**	**POL1 (15)**	**SDE2 (25)**	**BTC1 (23)**	**SDE4 (26)**	**SDE5 (39)**	**SDE6 (37)**	**Total number observed**
Tropical Lowland Evergreen Forest	1	2	1	3	1	1	5	4	6
River Edge Forest	0	0	0	1	1	0	1	1	3
Montane Evergreen Forest	1	9	3	6	5	6	11	8	13
Polylepis Woodlands	0	0	5	0	1	0	0	0	5
Tropical Deciduous Forest	5	4	2	6	4	5	6	10	14
Tropical Lowland Evergreen Forest Edge	3	4	2	3	3	4	4	3	6
Montane Evergreen Forest Edge	4	10	2	6	8	10	12	11	13
Secondary Forest	4	3	2	4	2	3	3	2	7
Arid Lowland Scrub	5	3	1	3	4	5	5	5	8
Arid Montane Scrub	5	11	18	6	16	9	6	10	33
Semi-humid / humid Montane Scrub									
Second growth Scrub	8	5	2	5	2	5	3	4	10
Puna Grassland	1	2	4	1	7	1	2	1	9
Pastures / Agricultural Land	1	2	0	0	1	1	1	1	2
Total number of species in study area	40	57	45	46	58	52	60	60	133

Number of forest/edge species is indicated in brackets under each locality code. Locality codes: See Table 12, page 46. Primary habitat source: Parker and others (1996).

Table 15. Similarity of forest and forest edge species composition

	SEC1 (14)	**SDE1 (29)**	**POL1 (15)**	**SDE2 (25)**	**BTC1 (23)**	**SDE4 (26)**	**SDE5 (39)**	**SDE6 (37)**
SEC1	1.00							
SDE1	0.47	1.00						
POL1	0.21	0.36	1.00					
SDE2	0.56	0.74	0.30	1.00				
BTC1	0.43	0.62	0.47	0.54	1.00			
SDE4	0.55	0.69	0.39	0.63	0.57	1.00		
SDE5	0.45	0.71	0.26	0.63	0.48	0.71	1.00	
SDE6	0.39	0.61	0.23	0.52	0.50	0.73	0.76	1.00

Sørensen similarity coefficient (C_s) for forest and forest edge species composition. Number of forest/edge species is indicated in brackets under each locality code. Total number of forest/edge species = 60.

Table 16. Mantel test of association between dissimilarity coefficients against distance and elevation

	Distance	**Elevation**
All study sites	r=0.74 significant	r=0.81 significant
Semi-deciduous forest	r=0.50 not significant	r=0.52 not significant

The test was carried out using random distribution with 720 random iterations. Significance level: p=0.05 (two tailed). Test software designed by Liedloff and others (1995). Dissimilarity = (1–C_s) in Table 15.

Table 17. Number of species in four guilds recorded in forest localities

	SEC1	SDE1	POL1	SDE2	BTC1	SDE4	SDE5	SDE6	Total
Canopy	8	17	2	13	11	9	18	18	30
Midstory	1	6	5	4	4	6	8	6	9
Understory	3	4	7	5	5	7	9	9	15
Terrestrial	2	2	1	3	3	4	4	4	6
Total	l14	29	15	25	23	26	39	37	60

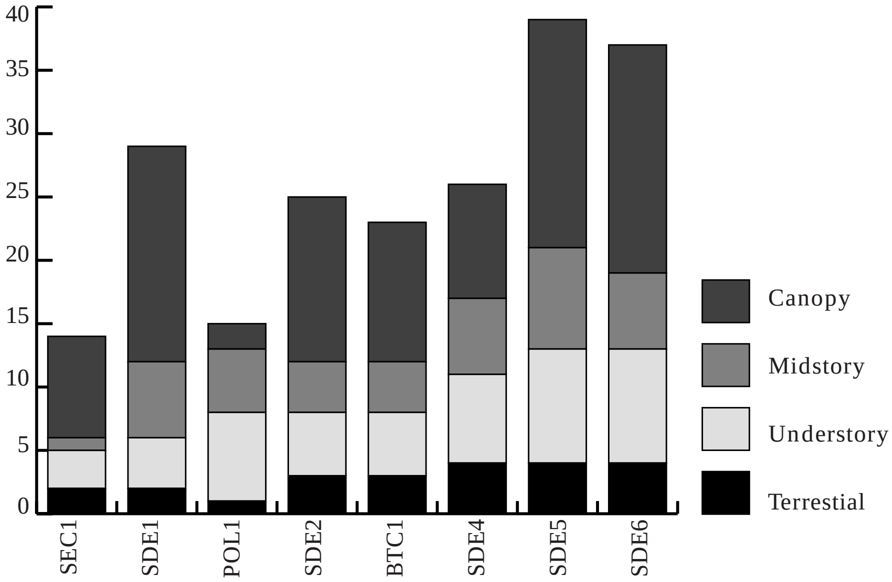


Figure 51. Representation of the main forest bird feeding guilds at study sites. Total number of species recorded is 60. Strata preferences are adapted from Parker and others (1996).

Part conclusion and discussion

Species richness within the semi-deciduous forest communities was low compared with the humid forests further north which is a general situation in the Valles (Fjeldså & Maijer 1996). Our results show a substantial turnover (beta-diversity) of forest species between study sites, and thus regional species richness is high. This turnover is not explained by differences in distance, elevation or habitat complexity. The fact that relatively few understory and terrestrial birds remain in many of the forest fragments indicates that forest fragmentation, overgrazing and trampling by livestock has a serious impact. It is known that these guilds along with larger frugivores with low abundance are the first to be negatively affected by disturbance and fragmentation of forest habitat (for example Arangovelez & Kattan 1997; Danielsen 1997).

The effects of habitat fragmentation in the region have been that scrub species or widespread generalists are invading forest fragments. Edge species have been favoured and in some areas species richness in and around the woodland fragments has probably risen due to the influx of less specialised species that are abundant in many types of habitat. Forest species richness is highest in the forest fragments SDE5 and SDE6 situated close to the largest forest covered area in the region (Fig. 2). Probably this area has the highest richness of forest birds in the region and functions as a source of dispersing individuals to the smaller fragments. If the remaining forest patches were managed in a way that allowed undergrowth regeneration many species would be able to recolonise by dispersion from other patches.

If the remaining forest patches were managed in a way that allowed undergrowth regeneration many species would be able to recolonise by dispersion from other patches.

5. Birds, forests and plantations in the highlands

by Thor Hjarsen

Figure 52. Many exotic tree species such as Pinus *and* Eucalyptus *are used in afforestation projects. The picture shows a* Pinus *plantation, planted around Laguna Corani (17°16'S 65°55'W) which is dying either due to infection or environmental stress.*

Lately, development agencies and authorities have initiated forestry activities in the Bolivian Andes to re-establish the forest cover and to provide timber. These projects are mainly relying on tree species that do not belong to the Andean flora such as *Eucalyptus* spp., *Pinus* spp. and *Cypressus* spp. (see Fig. 52). Today, annual afforestation rate in the Andean region of the department of Cochabamba alone is approximately 1,000 hectares. Still, this figure is low compared to what has been lost of natural forest. There has never been a systematic biological assessment of the exotic forestry in the Bolivian Andes. Considering the importance to threatened bird species of the region (Stattersfield and others 1998) it becomes relevant to ask: How important is the natural forests to the Andean bird fauna? What are the effects on the bird fauna of the exotic plantations? The following chapter explores these questions.

Methods

This study (the northern study) is based upon 5 months of field study in 1996 of 53 different study areas between 2,900 and 3,700 metres above sea level. All study areas were inside a 200 km radius of the city of Cochabamba (17°18'S 66°08'W) in north-central Bolivia. The study areas were subdivided in habitat classes based on dominating tree species, accordingly: *Polylepis* woodlands are study areas dominated by *Polylepis* spp., mixed woodland vegetation of native species are study areas with vegetation of mixed tree and bush species (such as *Polylepis* spp., *Baccharis*, *Gynoxus* and *Alnus acuminata*) (Fig. 53). *Eucalyptus* plantations are study areas with planted trees of *Eucalyptus globulus*, which do not naturally belong to the South American flora, just as *Pinus* plantations of *Pinus radiata*. Table 18 shows the grouping of all 53 study areas in each of these habitat classes.

Inside each study area of 3 hectares a complete census of the birds was made. The study areas are small simply because the small size of the habitats surveyed. The bird counts were initiated just after dawn and continued until all birds present were recorded. This generally took 4–6 hours in the native forest habitats, but very often just 1–2 hours in the plantation habitats (this difference in time consumption roughly reflects the low amount of birds in the plantations). All species and individuals present were noted down while slowly moving through the vegetation inside 3 hectare limits. The areal limit of each study on 3 hectares was found to be a reasonable area where all birds can be recorded without double-recording. When it was estimated by the observer that all bird individuals present inside the 3 hectares were recorded, the count ended. The same person did all bird counts throughout the field work. Only birds that were physically inside the study areas were included, thus leaving out birds passing in the air above, or heard singing from outside the area. Frequency distribution graphs were made to assess differences in bird community structure in the habitat classes. The method is appropriate to reveal any changes in species abundance (Magurran 1988) and for displaying more fundamental ecological patterns of the habitats (Kempton 1979). The graphs cover one habitat class each and include abundance of individuals in the species lists from each area belonging to this habitat. It was possible to calculate bird density due to the modification made in the sampling procedure, by working in a fixed area and only including individuals not earlier recorded. The average size of the study areas was 3 hectares and thus it was possible to extrapolate the observed density to a "type habitat" of 1 sq. km for each species.

Shannon index (*H'*) for the avifauna was calculated for each study area by entering the data in the *PC-Ord* computer programme (MjM Software Design 1995). A diversity index is less sensitive to sample size and is used for comparisons between habitat classes. The calculation follows Magurran (1988). Rarity score assigned to each bird species was calculated as the reciprocal number of 1° grids covered by the species in the *WorldMap database* on Neotropical bird distributions, at the Zoological Museum in Copenhagen. Each study area was given a total rarity score by summing the species scores of each individual recording. Rarity scores for each bird species can be found in Appendix 2.

Table 18. Habitat classification of study areas

Forest habitat classes	Number of study areas	Total area of study areas	Code
Eucalyptus plantations	10	30 ha	EUC
Pinus plantations	11	33 ha	PIN
Polylepis woodlands	19	57 ha	POL
Mixed woodland of native species	13	39 ha	MIX

The Table shows the number of study areas and their total area for each of the forest habitat classes. Codes stated in the last column are later used in figures and tables.

Results

Forest cover and bird community structure

Biological community structure can be described in several ways, but for conservation purposes information on the relative abundance of species is important (Wiens 1989. A widely used method is to construct rank-abundance diagrams to discern any difference in observed data (Magurran 1988). The graphic results are shown in Fig. 54.

The bird community structure of the native forest habitats (*Polylepis* and mixed woodland vegetation with native species) and the exotic plantation habitats (*Eucalyptus* and *Pinus* plantations), are clearly different. The native forest habitats hold generally more species occurring at low frequencies ("long-tailed" graphs), while the avifauna in the exotic plantations is dominated by a few abundant species, and not many rare species ("short-tailed" graphs). This difference in the results is confirmed by a statistical test which only showed significant difference in bird community structure between the group of native forest vegetation and the exotic plantations – see Table 19.

*Figure 53. Alder trees (*Alnus acuminata*) are found in streambeds. The Alder is the first tree to invade areas after landslides. The roots contain nitrogen-fixating bacteria making the tree important in natural soil regeneration. New research even indicate that the Incas actively used Alder in reforestation in the Cusco area, Peru (Chepstow–Lusty and others 1998). Unfortunately, the tree is overlooked in forestry programmes in the Bolivian Andes. Oropeza south-west of Incallajta (17°36'S 65°29'W).*

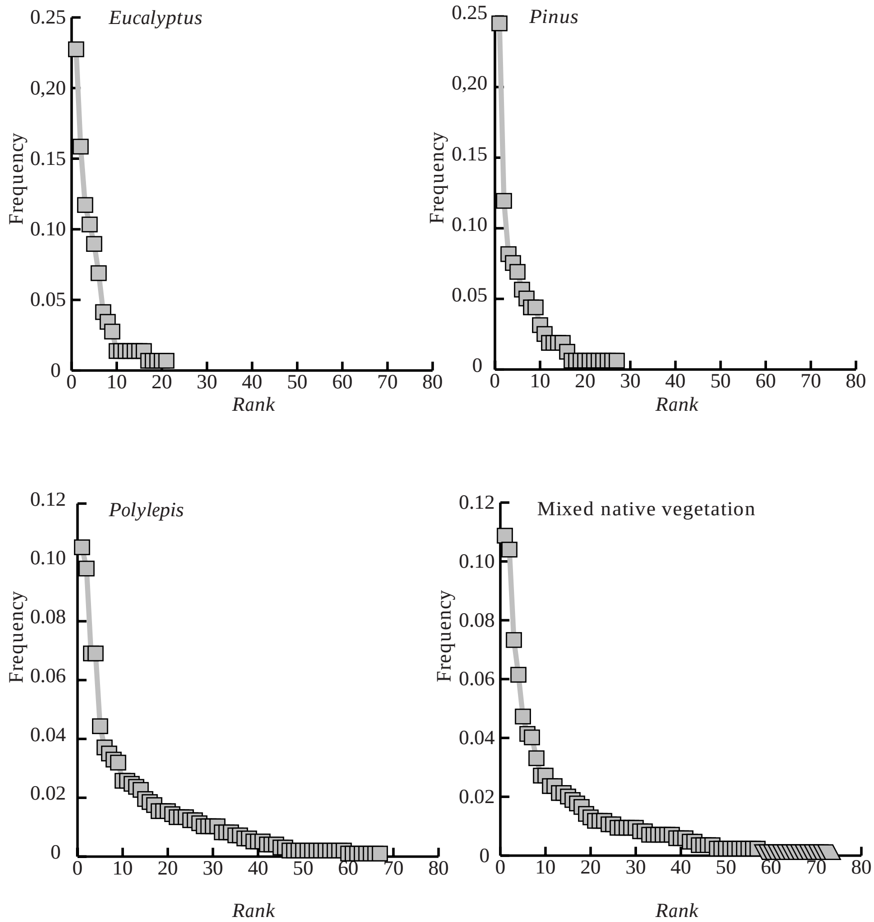


Figure 54. Rank-abundance diagrams (normal plots) showing the frequency distributions of the bird community in the four forest habitat classes.

Table 19. Probabilities for differences between observed bird distributions

	EUC	PIN	POL	MIX
EUC	–	0.323	*0.001	*0.013
PIN	–		*0.013	*0.013
POL	–	–	–	0.454

*The probabilities for significant differences between the observed bird distributions in all habitat classes were tested by Kolmogorov–Smirnov's two-sample test. * = Significant difference (P < 0.05) between habitat classes.*

Bird diversity in relation to forest and plantation habitats

The richness of the avifauna in this study is expressed by a number of indicators: The number of species (*S*), the number of observed individuals (*N*), the range size rarity-score (*R*), the Shannon diversity index (*H'*), and the a diversity (a) (Magurran 1988, Fjeldså & Rahbek in press). For each habitat class Table 20 shows the average of S, N and R found (the a diversity is calculated by the log series and is only valid for the whole class as such). Due to restrictions caused by the ordinal scaling of the Shannon diversity index, averages of this index for each habitat class can not be made (Fowler & Cohen 1990). In Appendix 2 Shannon indices are given for each study area.

The results in Table 20 show two levels of a diversity. The lowest level (a < 10) covers the exotic plantation habitat classes with *Eucalyptus* and *Pinus*, while the highest level (a > 15) covers the natural vegetation classes. A comparison between the values of S, N, R and H' of each study area by a Kolmogorov–Smirnov two sample test shows in all cases a significant difference (P < 0.05) between the plantation and natural vegetation classes. The results in Table 20 also show how selection of a biodiversity indicator (*S* or *R* in this case) may influence conservation priorities: When relying on average species richness (*S*) in a habitat it is found that the mixed woodlands of native species hold most species (19.8). However, when looking at the inverse size of the species´ distribution ranges of each habitat class, or the range-size rarity scores (*R*), the *Polylepis* woodlands become most important.

Table 20. Bird fauna indicators of the habitat classes

Habitat class	**Average S**	**Average N**	**Average R**	**a diversity**
Eucalyptus plantations	6.1	14.7	0.265	6.7
Pinus plantations	6.7	14.9	0.263	9.3
Polylepis woodlands	17.6	55.9	1.732	16.3
Mixed native vegetation	19.8	65.0	1.506	18.8

For each habitat class the Table shows the average of S, N and R found (the a diversity is calculated by the log series and is only valid for the whole class as such). Due to restrictions caused by the ordinal scaling of the Shannon diversity index, averages of this index for each habitat class can not be made (Fowler & Cohen 1990). Legend: S = species richness, N = number of individuals, R = range size rarity-score, and a = a diversity index (calculated from log series distribution).

Table 21. Total number of species recorded in habitat classes

	***Eucalyptus* plantations**	***Pinus* plantations**	***Polylepis* woodlands**	**Woodlands of mixed native vegetation**
Number of species	21	27	67	72

The native tree habitats (woodlands with *Polylepis* and mixed native vegetation) hosted together 87 species, which are all species recorded during the field work except three (see Table 22): *Acestrura mulsant, Oreopsar bolivianus* and *Sicalis flaveola*. These were only observed in the plantation habitats. The two latter species inhabits open land, but the lack of the first species is unexpected. *Acestrura mulsant* is normally distributed in the study region and inhabits mixed native vegetation and along forest edges (Fjeldså pers.comm.). Twelve of all 13 conservation priority species in the region (that is, those species red-listed by IUCN, and those species which were identified as species with range size less than 50,000 sq. km) were recorded in the native forest habitats: *Oreotrochilus adela, Aglaeactis pamela, Leptasthenura yanacensis, Schizoeaca harterti, Asthenes dorbignyi, A. heteura, Oreomanes fraseri, Diglossa carbonaria, Saltator rufiventris, Atlapetes fulviceps* and *Poospiza garleppi*. One priority species, *Oreopsar bolivianus*, was not recorded in any study areas with native forests, but only once inside an *Eucalyptus* plantation. All study areas were generally outside the habitat regime of this species.

Twelve of all 13 conservation priority species in the region (that is, those species red-listed by IUCN, and those species which were identified as species with range size less than 50,000 sq. km) were recorded in the native forest habitats.

Six out of all 13 conservation priority species were lacking in the *Eucalyptus* and *Pinus* plantations (Table 22): *Oreotrochilus adela, Aglaeactis pamela, Leptasthenura yanacensis, Schizoeaca harterti, Oreomanes fraseri* and *Poospiza garleppi*. In the plantations, 36 species were recorded in total, all common and widespread. Only two species, *Colibri coruscans* and *Carduelis magellanica*, were abundant in plantations. Apparently, *Colibri coruscans* is attracted by the large flowers of *Eucalyptus*, and *Carduelis magellanica* was often observed roosting in the tree tops. *Sappho sparganura* was also recorded several times in *Eucalyptus*, where birds often foraged opportunistically on the flowers. *Scytalopus magellanicus* occurred at several locations in mature *Pinus* plantations, but only in association with dense vegetation at clearings, or in piles of branches cut from logged trunks.

Table 22. Occurrence of birds in natural vs. plantation habitats

Bird species	Records in native forest vegetation	Recorded in exotic plantation
Rhynchotus maculicollis	yes (1)	no
Nothoprocta pentlandii	yes (15)	yes (6)
Nothura darwinii	yes (1)	no
Geronaetus melanoleucus	yes (1)	no
Buteo polyosoma	yes (3)	no
Buteo poecilochrous	yes (2)	no
Phalcoboenus megalopterus	yes (1)	no
Falco femoralis	yes (1)	no
Falco sparverius	yes (1)	no
Columba fasciata	yes (2)	yes (1)
Columba maculosa	yes (6)	no
Zenaida auriculata	yes (1)	no
Metriopelia ceciliae	yes (3)	no
Metriopelia melanoptera	yes (7)	yes (1)
Bolborhynchus aymara	yes (15)	yes (1)
Bolborhynchus orbygnesius	yes (1)	no
Glaucidium bolivianum	yes (2)	no
Caprimulgus longirostris	yes (2)	no
Colibri coruscans	yes (19)	yes (11)
Oreotrochilus estella	yes (1)	no
Oreotrochilus adela	yes (1)	no
Patagona gigas	yes (11)	yes (1)
Aglaeactis pamela	yes (7)	no
Pterophanes cyanopterus	yes (2)	no
Sappho sparganura	yes (13)	yes (4)
Metallura tyrianthina	yes (7)	yes (1)
Acestrura mulsant	no	yes (1)
Colaptes rupicola	yes (2)	no
Colaptes melanochloros	yes (4)	yes (2)
Upucerthia andaecola	yes (2)	yes (1)
Upucerthia ruficauda	yes (3)	no
Cinclodes fuscus	yes (3)	no
Cinclodes atacamensis	yes (1)	no
Furnarius rufus	yes (2)	no
Leptasthenura fuliginiceps	yes (7)	yes (1)
Leptasthenura yanacensis	yes (7)	no
Synallaxis superciliosa	yes (2)	no
Schizoeaca harterti	yes (2)	no
Asthenes dorbignyi	yes (18)	yes (2)
Asthenes heterura	yes (9)	yes (1)
Asthenes sclateri	yes (1)	no
Phacellodomus striaticeps	yes (17)	yes (4)
Melanopareia maximiliani	yes (6)	no
Scytalopus magellanicus	yes (17)	yes (6)
Ampelion rubrocristatus	yes (14)	yes (1)
Elaenia albiceps	yes (5)	no
Mecocerculus leucophrys	yes (9)	no
Serpophaga munda	yes (1)	no
Stigmatura budytoides	yes (1)	no
Anairetes parulus	yes (18)	yes (4)
Ochthoeca rufipectoralis	yes (1)	no
Ochthoeca oenanthoides	yes (5)	no
Ochthoeca leucophrys	yes (12)	yes (1)
Myiotheretes rufipennis	yes (4)	no
Agriornis montana	yes (1)	no
Muscisaxicola alpina	yes (2)	no
Knipolegus atterimus	yes (4)	yes (2)

Satrapa icterophrys	yes (1)	no
Hirundinea ferruginea	yes (1)	no
Myiarchus tuberculifer	yes (1)	no
Notiochelidon murina	yes (2)	no
Notiochelidon cyanoleuca	yes (1)	no
Hirundo andecola	yes (3)	no
Troglodytes aedon	yes (4)	yes (2)
Mimus dorsalis	yes (1)	no
Turdus chiguanco	yes (29)	yes (12)
Molothrus badius	yes (10)	yes (5)
Oreopsar bolivianus	no	yes (1)
Myioborus brunniceps	yes (7)	no
Conirostrum cinereum	yes (1)	no
Oreomanes fraseri	yes (7)	no
Diglossa sittoides	yes (5)	yes (1)
Diglossa mystacalis	yes (1)	no
Diglossa carbonaria	yes (17)	yes (1)
Thraupis bonariensis	yes (3)	no
Chlorospingus ophthalmicus	yes (6)	no
Saltator aurantiirostris	yes (25)	yes (9)
Saltator rufiventris	yes (19)	yes (6)
Catamenia analis	yes (8)	yes (3)
Catamenia inornata	yes (3)	yes (1)
Sicalis olivascens	yes (6)	no
Sicalis flaveola	no	yes (2)
Phrygilus atriceps	yes (13)	yes (2)
Phrygilus unicolor	yes (5)	yes (3)
Atlapetes fulviceps	yes (5)	yes (1)
Zonotrichia capensis	yes (29)	yes (11)
Poospiza hypochondria	yes (8)	no
Poospiza erythrophrys	yes (1)	no
Poospiza garleppi	yes (5)	no
Carduelis magellanica	yes (21)	yes (15)

The numbers in brackets refer to the number of study sites in which the species were recorded. See also Appendix 2 for detailed notes on distributions.

Box 8. Number of species in habitat classes

When testing accumulation of species with growing area of each habitat class by adding study areas and counting new species, accumulation of species stops well before maximum area of all habitat classes is reached. This means that the total species number of each habitat class reflects the maximum possible species richness of the habitat. Fjeldså (1991b, 1993) earlier found from 20–39 species in fragmented *Polylepis* woodlands above 3,500 m in Bolivia and Peru. In Cordillera Blanca, Peru at 3,500 m Frimer &Nielsen (1989) found 50 species in the most species rich woodland localities. The number of species in *Polylepis* habitat class in this study is considerably larger due to high local influx of lowland species occurring in the Cochabamba basin and adjacent valleys (Fjeldså 1987). By coincidence, McDowell & Gonzales (1994) also found 67 bird species in *Polylepis* woodlands in Parque Nacional Tunari which is also included in this field study.

Density of birds in relation to forest cover

A Spearman rank correlation analysis shows that the species richness is highly correlated with the recorded number of individuals (Spearman rank correlation: $r_s = 0.921$, $n = 85$, $P < 0.0005$) which is also seen on Fig. 55. Thus, the most species-rich habitats also contain the highest densities of birds.

The bullet symbols of Fig. 55 illustrate clearly that the most species-rich habitat is the study areas with native forest vegetation (woodlands covered with *Polylepis* or a mixed native tree vegetation).

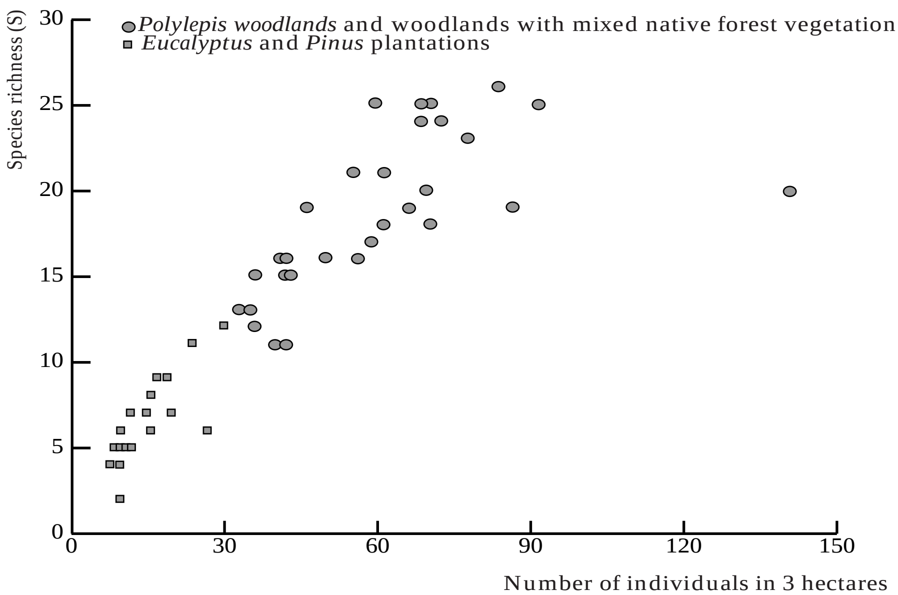


Figure 55. Correlation plot showing correlation between the number of bird individuals and the species richness in each study area. The bullets show the study areas with native forest cover with either Polylepis *or mixed forest vegetation, whereas squares show the study areas with either* Pinus *plantations or* Eucalyptus *plantations.*

The difference in density of the species between the native forest habitats and exotic plantations observed in this study indicate variations in available resources used by those specific birds (Remsen 1985). Based on the field data the overall bird densities are: *Polylepis* woodlands – 1,770 birds per sq. km, Mixed woodlands of native species – 2,169 individuals per sq. km, *Eucalyptus* plantations – 483 birds per sq. km, and *Pinus* plantations – 482 birds per sq. km. The species richness provides a similar pattern (Table 23). Again, we see that the *Polylepis* woodlands (POL) and the mixed woodlands (MIX) support the highest densities of birds, while the plantations almost completely lack the conservation priority species.

Table 23. Bird densities in forest and plantations

Species	***Eucalyptus* plantations**	***Pinus* plantations**	***Polylepis* woodlands**	**Woodlands of mixed native species**
Priority species				
Aglaeactis pamela	0	0	26	15
Leptasthenura yanacensis	0	0	26	5
Asthenes heteura	0	3	33	23
Oreomanes fraseri	0	0	32	0
Diglossa carbonaria	7	0	56	72
Saltator rufiventris	7	21	44	51
Poospiza garleppi	0	0	14	5
Widespread species				
Colibri coruscans	43	58	44	90
Scytalopus magellanicus	0	36	60	46
Turdus chiguanco	57	33	118	133
Saltator aurantiirostris	50	27	118	159
Zonotrichia capensis	77	39	179	236
Carduelis magellanica	110	118	167	226

The densities are calculated by extrapolating the observed densities to number of individuals per sq. km. (all densities appear in Appendix 2).

Forage guild abundance

The abundance of various species provides a profile of the resource availability in the habitat. With a guild analysis of the bird community we assess the abundance of species having similar requirements in food or habitats (Wiens 1989). Only species recorded at least ten times were included to avoid stragglers. The analysis also only included species identified as habitat specialists according to Fjeldså (1992, 1993), Fjeldså & Kessler (1996) and Stotz and others. (1996). The guilds used are the *terrestrial guild* (bird species inhabiting or foraging in the ground vegetation and on bare soil), the *understory guild* (bird species inhabiting or foraging in the lowest parts of shrubbery and bushes), the *midstory guild* (bird species occupying the bush layer and lowest trees), and the *canopy guild* (bird species occupying the tree canopy. Note, the altitude of this layer varies from 3–4 m in degraded *Polylepis*, to more than 30 m in mature *Eucalyptus* stands).

Several species have been assigned to more than one guild reflecting the broad selection of forage strata. Twenty-nine species are assigned to the terrestrial guild, 36 to the understory guild, 24 to the midstory guild and 28 to the canopy guild. The number of species restricted to any of these guilds are: 13, 3, 0 and 10 species respectively.

Fig. 57 shows that the midstory guild in all habitat classes is the least abundant guild. The natural vegetation classes (*Polylepis* and native woodlands with mixed vegetation) are all very alike in availability of foraging strata. The major difference in guild abundance is that the canopies of *Eucalyptus* and the lower strata of the *Pinus* plantations are not very attractive forage areas to the birds, probably because of limited food availability. Looking at these diagrams it is important to remember that they are based on very different total numbers of birds. The bird faunas of the exotic plantations were dominated by a few but very abundant species. In the *Eucalyptus* plantations these species were mainly ground feeders such as *Turdus chiguanco* and *Zonotrichia capensis* (see Fig. 56 & Fig. 58)

*Figure 56. White-browed Chat-tyrant (*Zonotrichia capensis*). This species is very common all over the Andes from sea level to higher than 5,000 m. The bird is often found around human habitation.*

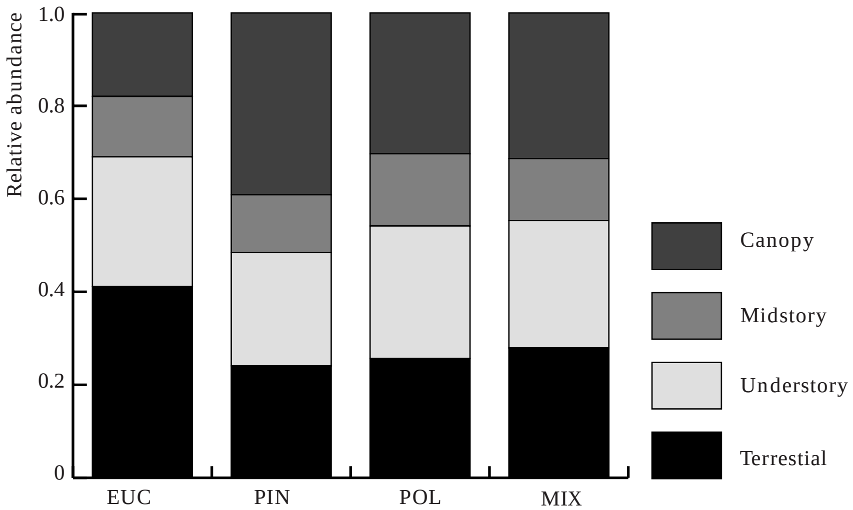


Figure 57. Relative abundance of forage strata guild in forest habitats. The result is based on number of bird individuals of species assigned to the different foraging strata. EUC = Eucalyptus *plantations, (number of individuals = 323; PIN =* Pinus *plantations, number of individuals = 386; POL =* Polylepis *woodlands, number of individuals = 1471; MIX = Mixed Woodlands with mixed native vegetation, number of individuals = 1,675.*

Effect of plantation succession on bird fauna

Stand age of plantations or succession stage of forest ecosystems has earlier been found to have effect on bird community diversity (Joensen 1965, Petty & Avery 1990). During succession of *Eucalyptus* and *Pinus* plantations vegetation cover are changing along with abiotic factors such as light conditions, humidity and top soil texture (Bargali and others 1993, FAO 1989, Gilmour and others 1987, Kardell and others 1986, May & Ash 1990, Michelsen and others 1993).

Succession stage and bird community diversity correlation was assessed by tree canopy height of each plantation area and bird species richness

Figure 58. Rows of exotic Pinus radiata *planted by Profor near Liriuni. The area has been designated as a key-area for bird protection by BirdLife International because of the occurrence of Cochabamba Mountain-Finch (*Poospiza garleppi) *and Rufous-bellied Saltator (*Saltator rufiventris).

recorded. As shown in Fig. 59 height of *Eucalyptus* was not correlated with number of species (Spearman rank correlation: r_s = 0.375, n = 10, P > 0.05), and neither was average height of *Pinus (*Spearman rank correlation: r_s = –0.321, n = 11, P > 0.05). Increasing age *Eucalyptus* or *Pinus* stands in the Bolivian Andes do not seem to create a more favourable environment for the bird fauna. This indicates that even mature plantations can not replace native forest ecosystems in terms of avian diversity. This may reflect the low botanical and overall biological diversity of these habitats (Crespo 1989, Poore & Fries 1989, Sawyer 1993, Sousa & da Gama 1994, Deharveng 1996).

Part conclusion and discussion

There are only very few other data documenting effects of forest fragmentation and exotic plantation in the Andes. Fjeldså & Krabbe (1990) expressed concerns about the ecological effects of larger plantations of *Eucalyptus*. Fjeldså (1993) found highest number of bird species (> 40 species) in forest types above 3,500 m in either: Large isolated *Polylepis* woodlands, or small and dense *Polylepis* woodlands in districts with numerous patches. Small (< 1 sq. km) isolated *Polylepis* patches, scattered *Polylepis* stands, and planted *Polylepis* hedges, had all lowest species richness (< 29 species). Bloch and others (1991) found very low species richness in two plantations with mature *Eucalyptus* spp. near Quito, Ecuador. Clearly, the exotic plantations can not support near-natural levels of bird diversity. This applies also to young stands with exotic trees. When looking at community structure, species richness, bird densities, and abundance of restricted range-sized species, these indicators are in all cases significantly different from the native forest vegetation habitats classified in this study as *Polylepis* woodlands and mixed woodlands of native species. Accordingly, the exotic plantations with *Eucalyptus globulus* and *Pinus radiata* studied can not substitute the biological richness of the native forest ecosystems (Fig. 60).

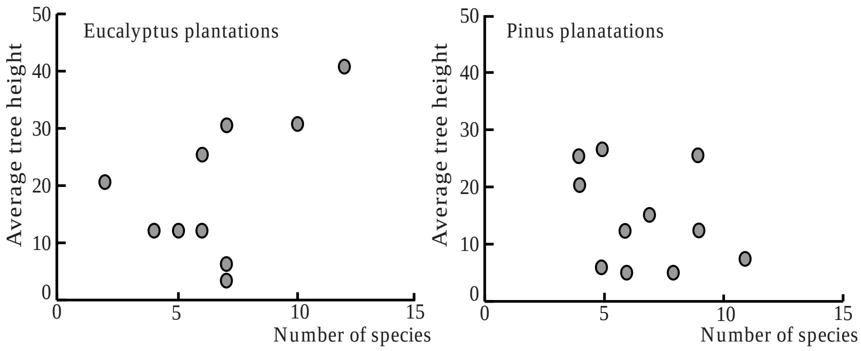


Figure 59. Correlation of bird species richness, and tree canopy height in plantations of Eucalyptus globulus *(Spearman rank correlation: r_s = 0.375, n = 10, P > 0.05), and* Pinus radiata *plantations (Spearman rank correlation: r_s = –0.321, n = 11, P > 0.05).*

Figure 60. Due to allopathic effects of the Eucalyptus *leaves ground vegetation just below the trees are lacking. Here in Parque Nacional Tunari (17°19'S 66°08'W) where the plantation is promoted to visitors by a "sendero ecologico" leading the hiker around in this non-native vegetation type.*

6. Bird diversity and traditional land-use in highland forests

by Thor Hjarsen

It is generally recognised that the high-altitude Andean forests contain important resources to local farmer communities. The farmers are actively extracting natural resources from these forests such as timber, food, fodder, and medical resources (for example Hensen 1992; Fjeldså & Kessler 1996). Such “free” resources are important to living standards in the villages, and when the forests are lost, so are of course the resources. Thus, maintenance of the highland forests is linked with socio-economic development. However, it has not previously been assessed systematically how traditional land-use in the forests affect the biological richness there. Results are presented here from a field study on the effects on bird diversity from such human land-use.

Figure 61. Example of burning of a Polylepis *woodland to provide farmland. Such slash-and-burn agriculture is observed in many parts of the Bolivian Andes. The largest* Polylepis *trees often survive the fire but are generally logged by the farmers. Quebrada Mojón (17°29’S 65°25’W).*

Methods

The study was made from December 1995 to April 1996 in village communities near Cochabamba (17°18’S 66°08’W) in north-central Bolivia and in the same study areas as the study areas with native vegetation cover mentioned in Chapter 5. All 32 study areas were classified in relation to human land-use pressure (see below). The classification of study areas was based upon a quantification of anthropogenic land-use activities assumed to be the major factors that effect vegetation and biological richness (see Ellenberg 1983; Fjeldså & Kessler 1996; Hensen 1991; Hensen 1995; Kessler 1995; Kessler & Dreisch 1993; Kok and others 1995; Kress 1994; Lægaard 1992):

- Pasture burning: The High Andean farmers practise yearly burning of grassy areas to provide palatable pasture for sheep and cows. The pasture burning is considered as the main cause for the lack of highland forests regeneration. The woodlands are also burned to clear new agricultural land. Apparently, mature *Polylepis* trees can survive such burning whereas seedlings can not and regeneration is therefore lacking in areas with frequent burning. Evidence of pasture burning were burning marks on trees, freshly burned areas, and lack of seedlings (Fig. 61).

- Livestock grazing: Many grazing areas are overstocked and livestock is able to hinder woodland regeneration by trampling tree seedlings and feeding on leaves. Llamas were observed foraging on low *Polylepis besseri* above Liriuni. Evidence of grazing was presence of livestock, included browsing marks on vegetation, presence of pastures inside woodlands, dung, and hoof-prints.

- Timber production: Timber produced by native trees is extracted by the farmers for household use such as firewood, field fencing material and house construction (Fjeldså & Kessler 1996; Hensen 1991; Kessler & Dreisch 1993). Two types of timber extraction can be identified:
    1. Logging, where whole trunks are taken for house construction or fencing material. Evidence of this activity was clearings, logged trunks and stumps of trees.
    2. Collection of branches. Larger branches were often cut or collected for firewood, but smaller branches with foliage were seen to be collected and brought to farmhouses to feed livestock. Some peasants kept their cow in a small hut near the woodlands and brought fodder to the animal (observed

in Lopez Mendosa, Fig. 62). Evidence of this activity was cut marks on branches or trunks, piles of recently collected branches and sticks, observation of people carrying firewood, etc.

- Other: This category was used for assigning various human-caused effects influencing the habitats such as planted fields, planting of exotic trees inside the native woodland habitat, or human traffic on paths or roads passing through the study area. Such activities often caused erosion and the amount of eroded parts in the study area was also quantified for this category (Fig. 63)

Figure 62. A sign of traditional forest management? In a large Polylepis *woodland above Lopez Mendosa (17°29' 65°24') the farmers were clearly only collecting firewood in a limited area.*

In each land-use category a score between 0 and 5 was given, where 5 indicates a very high pressure from the factor in question. In the category "Other", the dominating factor is identified. A total land-use score was calculated for each area as the sum of all five land-use scores. These values were transformed by dividing all scores with the maximum land-use score of all areas (56). The total land-use scores are thus on a transformed scale where highest score is 1.0. These scores are used for classifying the study areas in three land-use classes.

I. Native woodlands with Low human land-use pressure (total land-use score < 0.50).
II. Native woodlands with medium human land-use pressure (total land-use scores 0.50 < x < 0.70)
III. Native woodlands with high human land-use pressure (total land-use scores > 0.70).

Figure 63. On steeper slopes there is a risk of top soil erosion inside the Eucalyptus *plantation. When live-stock and people enter, the already degraded ground vegetation is disturbed. Risk of water erosion is therefore high. Parque Nacional Tunari (17°19' S 66°08'W).*

The gradient based on the human land-use pressure scores is only applied to natural vegetation habitats and not exotic plantation habitats. All together 10 study areas with a total area of 30 ha were classified as having a Low land-use pressure. Eleven areas with a total area of 33 ha were found to be exposed to a Medium land-use pressure, and finally 10 areas with a total of 33 ha were exposed to a High land-use pressure.

The ornithological census method used in this chapter is identical to the method used in Chapter 5.

Results

How land-use affects bird community structure

The bird community structure in the land-use pressure categories is not affected by human land-use as it appears on Figure 64. The rank-abundance diagrams, which illustrate the relative abundance of each species, are much alike. This visual impression is confirmed by a Kolmogorov–Smirnov's two-sample test that could not significantly distinguish between the relative species abundance of the land-use pressure categories (Table 24), except the medium and low land-use pressure categories. However, the *P* value is very close to the 95% confidence limit and the result may be caused by uncertainties in land-use quantification.

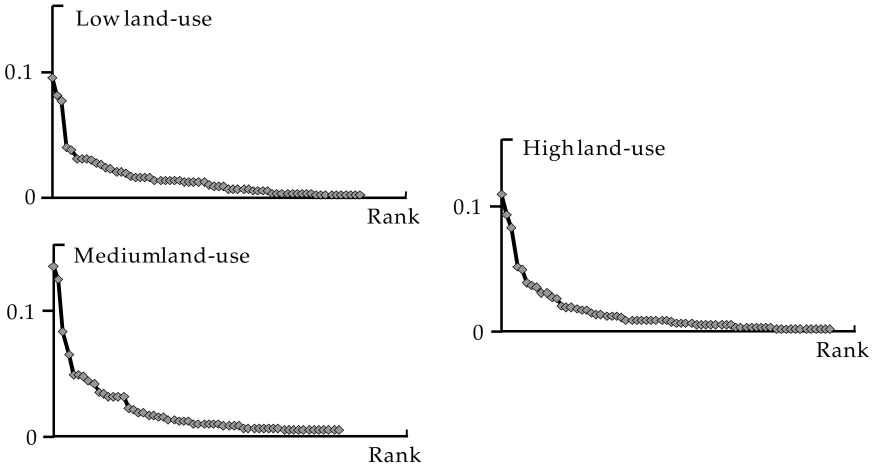


Figure 64. Rank-abundance diagrams showing bird community structure under Low, Medium and High land-use pressure in native woodland habitats of the highlands near Cochabamba.

Table 24. Probabilities for significant difference between the observed bird abundance in all land-use pressure categories

	Low	**Medium**	**High**
Low	–	0.048*	0.137
Medium	–	–	0.326

*Test: Kolmogorov–Smirnov's two-sample test. * = Significant difference (P < 0.05) between habitat classes.*

Bird diversity in relation to human land-use pressure

The richness of the avifauna in this study is expressed by the species richness, the number of observed individuals at a given effort, the rarity-score, the Shannon diversity index, and the α diversity (α) (see methods in chapter 5). Table 25 shows the average of all indices of each habitat class. α diversity is calculated by the log series and is only valid for the whole class as such. Due to restrictions caused by the ordinal scaling of the Shannon index, it is not possible to present averages of this index for each habitat class (Fowler & Cohen 1990).

Table 25. Bird fauna indicators of the land-use pressure classes

Land-use pressure	**Species richness**	**No. of individuals**	**Range size**	**α diversity**
Low	17.8	56.5	1.680	19.0
Medium	15.5	53.1	1.413	15.2
High	20.5	64.3	1.891	18.8

Average values of study areas in each habitat class are shown, except the α diversity index, which is only valid for the whole habitat class.

In Appendix 2 the Shannon indices are given in connection with the study area descriptions. Later, differences in the Shannon indices are used for comparison between study areas in each habitat class separately. An unexpected and important result is that the areas with High land-use pressure also had the highest number of bird species, highest bird density, and even the highest rarity-score. The latter is indicating that these habitats had the

Apparently, very intense traditional land-use posed no threat to the abundance of the endemic bird species distributed in the highlands around Cochabamba.

highest abundance of restricted-range bird species. Apparently, very intense traditional land-use posed no threat to the abundance of the endemic bird species distributed in the highlands around Cochabamba. When we analyse the relative abundance of bird species organised in forage strata guilds, we find no significant difference between the land-use regimes (Fig. 65).

The total number of species recorded in all study areas with native vegetation in each land-use pressure category are: Low land-use pressure habitats – 64 species, Medium land-use pressure habitats – 56 species, and High land-use pressure habitats – 68 species. Table 26 shows occurrence of all species in relation to the land-use pressure inside all study areas.

The species densities listed in Table 26 shows that some specific species apparently are more or less sensitive to human land-use in the native woodland habitats of the highlands around Cochabamba. Most notably is that some of the priority species seem to be unaffected of human activity – they even seem to be attracted by the habitat disturbance imposed on vegetation by man (Fig. 66). Seed eating bird species may generally benefit when, for example, bare soil is exposed after ploughing (these include *Nothoprocta pentlandii*, *Nothura darwinii*, *Saltator aurantiirostris*, *S. rufiventris*, *Catamenia analis*, *Phrygilus atriceps*, *P. unicolor*, *Zonotrichia capensis* and *Poospiza garleppi*). On the other hand, the insect and fruit eating birds generally occur at highest densities in the habitats where human land-use pressure is lowest, these species included: *Ochthoeca sp*., *Turdus chiguanco*, *Myioborus brunniceps*, *Oreomanes fraseri* and *Atlapetes fulviceps*. Other species seem to be dependent on other factors such as vegetation structure (*Scytalopus magellanicus*) or availability of feeding plants (the hummingbirds).

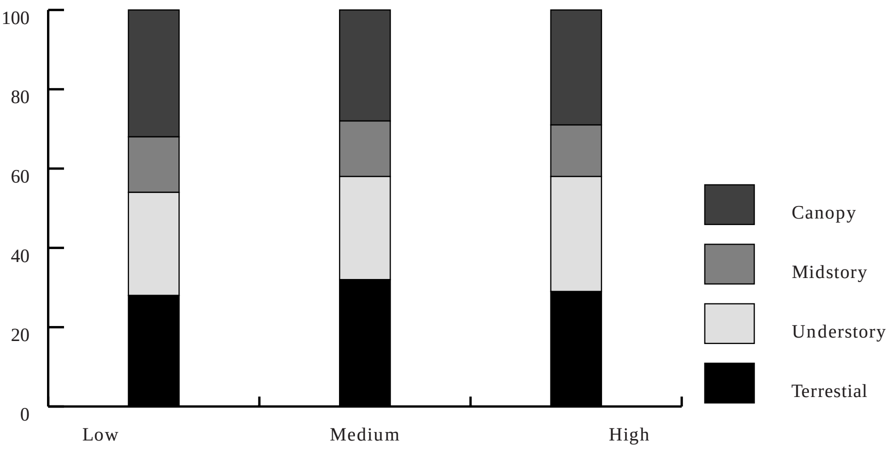


Figure 65. Relative abundance of forage strata guild in the land-use pressure regimes. The figure is based on number of individual birds recorded of species assigned to the different forage guilds. Legend: Low – Low land-use pressure habitats (n=1456), Medium – Medium land-use pressure habitats (n=1377), High – High land-use pressure habitats (n=1,698).

Table 26. Bird densities and land pressure

Bird species	Land use pressure category Low	Medium	High
Nothoprocta pentlandii	30	24	64
Nothura darwinii	0	0	12
Columba fasciata	0	0	30
Columba maculosa	30	12	24
Zenaida auriculata	0	0	9
Metriopelia ceciliae	10	0	15
Metriopelia melanoptera	30	15	18
Bolborhynchus aymara	57	30	64
Bolborhynchus orbygnesius	13	0	0
Colibri coruscans	40	70	55
Patagona gigas	27	12	18

Aglaeactis pamela *	27	48	18
Pterophanes cyanopterus	0	3	6
Sappho sparganura	43	3	12
Metallura tyrianthina	7	55	36
Colaptes rupicola	3	0	3
Colaptes melanochloros	0	12	21
Upucerthia andaecola *	3	0	9
Upucerthia ruficauda	17	0	9
Cinclodes fuscus	3	0	6
Cinclodes atacamensis	0	0	3
Furnarius rufus	0	3	3
Leptasthenura fuliginiceps	33	0	18
Leptasthenura yanacensis *	13	6	33
Synallaxis superciliosa *	3	3	0
Schizoeaca harterti *	7	9	9
Asthenes dorbignyi	60	21	64
Asthenes heterura *	47	9	33
Phacellodomus striaticeps	60	18	82
Melanopareia maximiliani	7	6	6
Scytalopus magellanicus	77	76	42
Ampelion rubrocristatus	40	48	39
Elaenia albiceps	23	3	24
Mecocerculus leucophrys	27	27	18
Serpophaga munda	0	3	0
Stigmatura budytoides	3	0	0
Anairetes parulus	53	48	73
Ochthoeca rufipectoralis	10	0	0
Ochthoeca oenanthoides	13	18	9
Ochthoeca leucophrys	30	48	24
Myiotheretes rufipennis	13	0	9
Knipolegus atterimus	7	3	9
Troglodytes aedon	0	15	3
Mimus dorsalis	7	0	0
Turdus chiguanco	157	136	103
Molothrus badius	50	79	18
Myioborus brunniceps	37	15	6
Oreomanes fraseri *	27	12	18
Diglossa sittoides	23	3	12
Diglossa mystacalis	0	3	0
Diglossa carbonaria *	60	67	58
Thraupis bonariensis	10	12	0
Chlorospingus opthalmicus	20	79	9
Saltator aurantiirostris	73	106	197
Saltator rufiventris *	23	27	76
Catamenia analis	13	6	27
Catamenia inornata	3	3	3
Sicalis olivascens	27	9	12
Phrygilus atriceps	27	3	109
Phrygilus unicolor	23	0	39
Atlapetes fulviceps	17	24	6
Zonotrichia capensis	147	224	230
Poospiza hypochondria	23	33	3
Poospiza erythrophrys	0	6	6
Poospiza garleppi *	7	6	18
Carduelis magellanica	183	206	176

*Extrapolated densities of all bird species (per sq. km) recorded in the land-use pressure categories. Density calculations are based on number of recorded individuals per hectare of habitat. Species marked with an * are identified as priority species by Stattersfield and others (1998) or Ergueta & Morales (1996).*

Figure 66. A mosaic of fields and native vegetation provides very good feeding and roosting areas for certain bird species. In this specific area at San Miguel above Liriuni (17°16'S 66°19'W) the observed concentration of the endemic and threatened Cochabamba Mountain-finch was the highest of all northern study sites.

Similarities between bird communities

Similarities in shared bird species, and habitat classes with equal number of individuals, have been calculated on an objective and mathematical basis by Sørensen similarity measures on both qualitative (C_S) and quantitative data (C_N), by using the calculation methods described by Magurran (1988). The qualitative Sørensen measure looks at the similarity of pairs of sites (that is the habitat classes in this study) in terms of presence and absences of species. The quantitative Sørensen measure takes species abundance into account (Magurran 1988). The results of these calculations are listed in Table 27. Maximum C_N similarity is found between the low and medium land-use pressure areas. Maximum C_S similarity is found between high land-use pressure areas and the two low and medium land-use pressure categories.

Table 27. Sørensen similarity measures of pair-wise sets of land-use pressure classes

	Low	**Medium**	**High**
Low	–	0.71 / 0.98	0.86 / 0.96
Medium	–	–	0.86 / 0.96

In each field the value left of the slash is the qualitative measure based on species similarity (C_S), and right of the slash is the quantitative measure based on similarity in number of individuals (C_N).

Part conclusion and discussion

Overall it has not been possible to identify any major effects from human land-use on the bird fauna associated with native woodlands in the highlands around Cochabamba. Bird community structure, abundance of forage strata guilds, bird diversity, species richness and abundance of species with restricted range-size was in no case affected by land-use. Minor effects were observed on species level, though, where abundance for some species apparently influenced by human land-use. Certain fruit and insect eaters occurred at lower abundance in habitats with high land-use pressure, while some seed-eaters where most abundant in these habitats.

It was of major importance, that several of the priority species occurring in the highland woodlands on the mountain fringes of the Cochabamba basin largely seemed to be unaffected to human land-use. Species dependent on dense vegetation and well-developed understory seemed to prefer habitats with low land-use pressure.

It can therefore be concluded that human land-use does not threaten the endemic avifauna of the area, as long as patches of native trees and bushes are allowed to remain.

It can therefore be concluded that human land-use does not threaten the endemic avifauna of the area, as long as patches of native trees and bushes are allowed to remain. This would be possible in different agroforestry systems, also those presently in use by a few *campesino* communities in the Andean highlands of Bolivia.

7. Rarity, endemism and priorities for local conservation

by Nicholas Moray Williams, Thor Hjarsen, and Poul Nygaard Andersen

The bird fauna may be analysed with respect to local rarity, that is, by identifying the species that are rarely recorded in the study areas. If such species are habitat or food specialists, they may be sensitive to local habitat destruction and can thus be lost from previously known localities if the resources they rely on disappear or are replaced, for example by exotic plantations. Species most sensitive to such local extinctions, will be those with globally restricted distribution. Loss of local populations will affect endemic species proportionally more seriously than widespread species (Fahrig and Merriam 1994). Thus, several authors have emphasised the importance of identifying such species and their distribution, to highlight conservation needs and concentrate efforts (for example Fjeldså 1991b; ICBP 1992; Wege & Long 1995; Caldecott and others 1996; Fjeldså & Kessler 1996). In this chapter we specifically examine species which are or could become conservation dependent.

Rarity on a local scale

"Truly" rare species in this study are 1) those that normally are distributed in the zone covered by this study and 2) those species that normally inhabit high altitude woodlands such as *Polylepis*, but were missing in most of the study sites in both the northern and the southern area. In fact, several species were absent from some localities that apparently had suitable vegetation. Such species may probably be sensitive to local habitat disturbance. The following species are included in the group of locally "missing species": *Columba fasciata*, *Metriopelia ceciliae*, *Bolborhynchus orbygnesius*, *Oreotrochilus adela**, *Synallaxis superciliosa***, *Schizoeaca harterti***, *Ochthoeca rufipectoralis*, *Poospiza erythrophrys* and *P. garleppi**. Two of these species (*) are included in IUCN's red list (Stattersfield and others 1998) and an additional two (**) are included in the national list of endangered species in Bolivia (Ergueta & Morales 1996). Accordingly, these species might be threatened on a global scale, mainly due to their restricted range sizes. The remaining five species are not threatened as such, but could become eliminated locally if the destruction of suitable habitat continues.

Table 28 contains information on the percentage of study areas in which individual species were observed. Five species or 5.6% of all species recorded, occurred in more than 50% of the study areas and are therefore considered as very common in the region covered by the study areas. These are *Colibri coruscans*, *Turdus chiguanco*, *Saltator aurantiirostris*, *Zonotrichia capensis*, and *Carduelis magellanica*. These are all widespread species in most of the Andes (Fjeldså & Krabbe 1990). None of the species belong to any of the threat or habitat specialist categories. Forty-seven species, or 52% of all species recorded, occurred in less than 10% of the study areas. This high number of rarely recorded species is due to naturally low densities (for example, raptors, larger sized passerines, habitat specialists), low detectability (Tinamous), or that study areas were at the margins of the species' ecological or geographical range (for example *Zenaida auriculatus*, *Pterophanes cyanoptera*, *Cinclodes atacamensis*, *Asthenes sclateri*, *Agriornis montana*, *Satrapa icterophrys*, *Mimus dorsalis*, *Oreopsar bolivianus*, *Diglossa mystacelis* and *Sicalis flaveola*). Some species are nocturnal (*Glaucidium bolivianum* and *Caprimulgus longirostris*) and therefore not recorded at the true relative abundance as if an appropriate, comparative field method was used for such species.

Table 28. Bird species in the Cochabamba area (northern study)

Bird species	Percent of study areas (53) where the species were observed
Rhynchotus maculicollis R-r	2
Nothoprocta pentlandii	39
Nothura darwinii	2
Geronaetus melanoleucus	2
Buteo polyosoma	6
Buteo poecilochrous	4
Phalcoboenus megalopterus	2
Falco femoralis	2
Falco sparverius	2
Columba fasciata	6
Columba maculosa	12
Zenaida auriculata	2
Metriopelia ceciliae	6
Metriopelia melanoptera	17
Bolborhynchus aymara	31
Bolborhynchus orbygnesius	2
Glaucidium bolivianum	4
Caprimulgus longirostris	4
Colibri coruscans	59
Oreotrochilus estella	2
Oreotrochilus adela N-t, R-r	2
Patagona gigas	24
Aglaeactis pamela L-c, R-r, P*	14
Pterophanes cyanopterus	4
Sappho sparganura	33
Metallura tyrianthina P*	16
Acestrura mulsant	2
Colaptes rupicola	4
Colaptes melanochloros	12
Upucerthia andaecola R-r	6
Upucerthia ruficauda	6
Cinclodes fuscus	6
Cinclodes atacamensis	2
Furnarius rufus	4
Leptasthenura fuliginiceps	16
Leptasthenura yanacensis N-t, R-r, P*	14
Synallaxis superciliosa P*	4
Schizoeaca harterti L-c, R-r, P*	4
Asthenes dorbignyi R-r, P*	39
Asthenes heterura V, R-r,	20
Asthenes sclateri	2
Phacellodomus striaticeps P*	41
Melanopareia maximiliani	12
Scytalopus magellanicus P*	45
Ampelion rubrocristatus P*	29
Elaenia albiceps	10
Mecocerculus leucophrys	18
Serpophaga munda	2
Stigmatura budytoides	2
Anairetes parulus	43
Ochthoeca rufipectoralis P*	2
Ochthoeca oenanthoides P**	10
Ochthoeca leucophrys P*	26
Myiotheretes rufipennis P**	8
Agriornis montana	2
Muscisaxicola alpina	4
Knipolegus atterimus	12
Satrapa icterophrys	2

Hirundinea ferruginea	2
Myiarchus tuberculifer	2
Notiochelidon murina P*	4
Notiochelidon cyanoleuca	2
Hirundo andaecola	6
Troglodytes aedon	12
Mimus dorsalis R-r	2
Turdus chiguanco	80
Molothrus badius	29
Oreopsar bolivianus L-c, R-r	2
Myioborus brunniceps P*	14
Conirostrum cinereum P*	2
Oreomanes fraseri N-t, P**,	14
Diglossa sittoides P*	12
Diglossa mystacalis	2
Diglossa carbonaria L-c, R-r, <u>P*</u>	35
Thraupis bonariensis	6
Chlorospingus opthalmicus	12
Saltator aurantiirostris	67
Saltator rufiventris V, R-r, P*	49
Catamenia analis	22
Catamenia inornata	8
Sicalis olivascens	12
Sicalis flaveola	4
Phrygilus atriceps P*	29
Phrygilus unicolor P*	16
Atlapetes fulviceps R-r, <u>P*</u>	12
Zonotrichia capensis	78
Poospiza hypochondria	16
Poospiza erythrophrys	2
Poospiza garleppi E, R-r, P*	10
Carduelis magellanica	71

Abbreviations: L-c (Least concern), N-t (Near-threatened), V (Vulnerable), E (Endangered), R-r (Restricted-range species, that is, endemic or near-endemic), P (Associated with* Polylepis *or other woodland habitats of the High Andes), P** (Narrowly associated with* Polylepis*). Where the habitat legend is underlined (<u>P*</u>), the species is associated with* Polylepis *or mixed woodlands according to own field data. The classification of species in threat categories, endemism, and habitat requirements follows Fjeldså (1992, 1993); Fjeldså & Kessler (1996); Ergueta & Morales (1996); Hjarsen (1997) and Stattersfield and others (1998).*

Local or global conservation of high priority bird species

In general, all *Polylepis* specialists may be considered as globally threatened, due to the restricted distribution of their habitat. Protection of local bird populations by conservation of local woodlands in certain areas may therefore be important to global species conservation. Table 29 assess whether local, national or global conservation measures may be important to conservation of the high priority bird species of the Cochabamba basin. Of high importance are the conservation of 6–7 species which globally may become extinct if the natural high altitude woodlands of the Cochabamba basin are not conserved and regenerated.

Of high importance are the conservation of 6–7 species which globally may become extinct if the natural high altitude woodlands of the Cochabamba basin are not conserved and regenerated.

Surveys in southern Cochabamba

We recorded 14 species listed by BirdLife International and IUCN (Collar and others 1994). Seven species are endemic to Bolivia, 11 are restricted range species (Table 30). There is no relation between the number of species in the study areas and the range size rarity score of the areas (Table 31). The two upper montane forest types *Polylepis* and Boliviano–Tucumano forest had the rarest and most threatened species while species richness is low. In general, no correlation was found between species richness and presence of rare species in the study areas. This illustrates the importance for rare species of these very endangered habitat types.

Table 29. Importance of conservation efforts for red-listed bird species

Priority species	Priority criteria: Threatened range	Priority criteria: Restricted	Priority criteria: Woodland dependent	Importance of local conservation: Regional level	Importance of local conservation: National level	Importance of local conservation: Global level
Oreotrochilus adela	X	X	X	X	X	X
Aglaeactispamela	X	X	X	X	X	X
Metallura tyrianthina			X	X		
Upucerthia andaecola		X		X	X	
Leptasthenura yanacensis	X	X	X	X	X	X
Synallaxis superciliosa			X	X		
Schizoeaca harterti	X	X	X	X	X	
Asthenes dorbignyi		X	X	X	(X)	X
Asthenes heteura	X	X	X	X	X	X
Phacellodomus striaticeps			X	X		
Scytalopus magellanicus			(X)	(X)		
Ampelion rubrocristatus			X	X		
Notiochelidon murina			X	X		
Mimus dorsalis		X				
Oreopsar bolivianus	X	X			X	X
Oreomanes fraseri	X	X	X	X	X	
Diglossa carbonaria	X	X	X	X	X	X
Saltator rufiventris	X	X	(X)	X	X	(X)
Phrygilus atriceps			X	X		
Phrygilus unicolor		X	X			
Atlapetes fulviceps		X	X	X	X	
Poospiza Garleppi	X	X	X	X	X	X

The Table shows the importance of conservation efforts in the Cochabamba basin for red-listed bird species. Priority species are species which are threatened and/ or have a restricted distribution range and/or which are dependent on the native, high altitude woodlands of the Cochabamba basin. Importance of local conservation indicates whether local conservation of the priority species distributed in the Cochabamba basin have Regional, National or Global importance.

Table 30. IUCN listed species in southern Cochabamba and northern Potosi

Scientific name	Locality	IUCN status	Endemic to Bolivia	Restricted range	Rarity score
Ara rubrogenys	POL1	Endangered	yes	yes	0.167
Poospiza garleppi	POL1, BTC1	Endangered	yes	yes	0.5
Saltator rufiventris	SDE1	Vulnerable	yes	no	0.091
Aegolius harrisii	SDE6	Near Threatened	no	no	(d)0.013
Upucerthia harterti	POL1	Near Threatened	yes	yes	0.1
Leptasthenura yanacensis	BTC1	Near Threatened	no	no	(d)0.056
Sicalis luteocephala	POL1	Near Threatened	yes	yes	0.143
Oreomanes fraseri	POL1	Near Threatened	no	no	(d)0.023
Scytalopus simonsi		Low Risk, Less Concern	yes	no	0.067
Elaenia strepera	SDE1, SDE2	Low Risk, Less Concern	yes	no	0.044
Lophospingus griseocristatus	SEC1, SDE2, SDE4, SDE5, SDE6	Low Risk, Less Concern	yes	yes	0.05
Poospiza boliviana	SDE4	Low Risk, Less Concern	yes	yes	0.1
Diglossacarbonaria	POL1, SEC1	Low Risk, Less Concern	yes	no	0.111
Oreopsar bolivianus	POL1	Low Risk, Less Concern	yes	yes	0.333

Species are sorted by IUCN status category. (Collar and others 1994; Amoniá 1995; Statersfield and others, 1998). Restricted range = the species occupy less than 50.000 sq. km. Each species was assigned a rarity score equal to the inverse number of 1° Latitude/Longitude grids occupied by the species in South America; species marked with (d) are disjunct over a wide range (Williams 1995; Fjeldså & Rahbek 1997a). See Appendix 2 for details on birds and Appendix 1 for explanations on locality codes.

Most forest species were found in the semi-deciduous forest patches. Most of the species are widespread but one endangered and endemic species, the nomadic *Ara rubrogenys* is dependent on the dry semi-deciduous forest zone in the Valles. *Ara rubrogenys* was recorded several times during fieldwork although not within the actual study areas (Appendix 2). We recorded other restricted range species endemic to the Valles which are more strongly associated with dry scrub for example *Upucerthia harterti*, *Sicalis luteocephala*, *Lophospingus griseocristatus* and *Oreopsar bolivianus*. As we show in chapter 3 scrub species richness is positively associated with overall landscape heterogeneity and it is likely that the forest patches are an important factor in maintaining species diversity at landscape scale.

Box 9. Range size rarity

In order to compare rarity or endemism of observed species, we extracted data from the CTB database of Neotropical bird species distributions (C. Rahbek & J. Fjeldså unpublished database). The data for each species can be reproduced as distribution maps using the Worldmap software (Williams 1995; Fjeldså & Rahbek 1997a). The distribution data are entered in a 1° Lat./Long. grid which close to equator is an area of approximately 111 km x 111 km = 12.321 sq. km. The database is under continuos development, and the range sizes for species observed are extracted February 1997. Each species was assigned a rarity score equal to the inverse number of grids occupied by the species (Williams 1995). In this study range size rarity score for each study area was calculated either as the sum of species rarity scores for each study area as a percentage of the rarity score of all species observed (southern Cochabamba) or by summing the species rarity scores for each individual observation (northern Cochabamba).

Table 31. Sum of range size rarity scores of species present in study areas

	SEC1	SDE1	POL1	SDE2	BTC1	SDE4	SDE5	SDE6
Sum of range-size rarity	0.21	0.24	0.50	0.17	0.37	0.24	0.22	0.26

See Appendix 1 for explanations on locality codes.

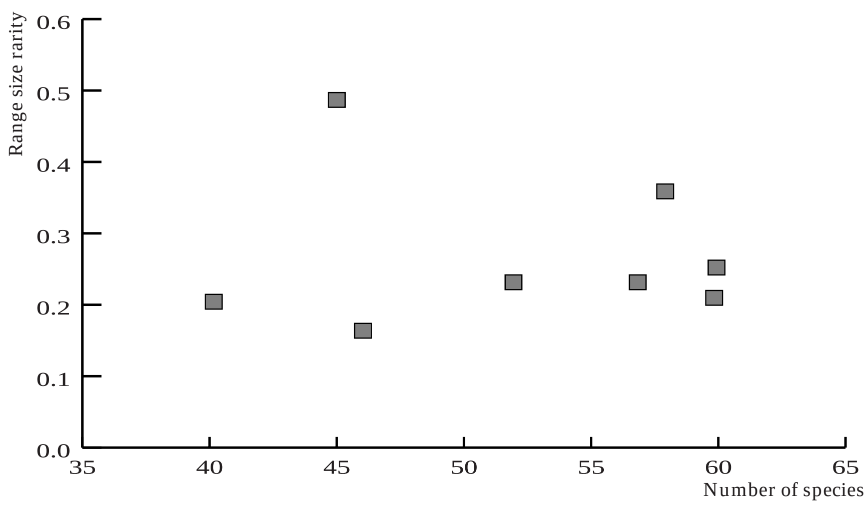


Figure 67. Species richness and summed range size rarity scores per study site. There is no correlation between species richness and presence of rare species in the study areas (Pearson product moment correlation coefficient r = 0.55; n = 8). (source for range size rarity: Rahbek, C. & Fjeldså J. unpublised database).

Surveys in northern Cochabamba

Another method for analysing the abundance of endemic species in different habitat types is to summarise the species specific range-size rarity scores for each individual observation. By assigning the species' range-size rarity score to each individual recorded, a measure for the relative degree of endemism of the bird population is obtained. This was done for the 53 study areas in northern Cochabamba (see Chapter 6).

The rarity-score of each species is the inverse to the number of 1º grids covered by the species distribution area in a WorldMap database. By assigning a rarity-score to each individual observation, all study areas get a total area-specific rarity-score that reflects the degree of endemism of the bird community in the habitat. Thus a study area with several individuals of endemic species will get a higher total rarity-score, than study areas where no such restricted-range species occurred.

The average rarity-scores of the exotic plantation habitat classes are much lower (*Pinus* = 0.26 and *Eucalyptus* = 0.27) than the natural vegetation habitats (range of average from 1.51 to 1.89). As with species richness, the habitat class of high land-use reach maximum average of 1.89. Thus, studied woodland areas with estimated highest human land-use contained the highest concentration of species with restricted ranges. This is a very important result to consider in the process of identifying ecologically sustainable land-use methods in the highland woodlands.

The range of the rarity-scores from all study areas is from 0.0383 to 3.4079. When considering only the top 25% of the rarity-score range (with a summed range size rarity > 2.5655), this identifies the following study areas as areas holding most birds with restricted ranges (land–use class are marked with $^{+}$: low. $^{++}$: medium and $^{+++}$: high):

- *Polylepis* habitat class: Agroforestry system at SM3^{+++}, SM4^{+} and SM5^{+++} near San Miguel (17°16'S 66°19'W). Situated on the road from Quillacollo to Morochata before the pass. Woodland TU5^{+} in Parque Nacional Tunari (17°19'22.6"S 66°07'39.2"W).

- Mixed native vegetation class: KH1^{+++} at Khalani Centro (17°40'S 66°29'W). Situated on the west-south-west facing slope of an unnamed mountain just after km 79 on the Cochabamba–Oruro Road.

When considering the bottom 25% of the rarity-score range (with a summed range size rarity R < 0.8807), the following study areas are poorest for birds with restricted ranges:

- *Eucalyptus* habitat class: CA1, KP4, LI1, MO3, MO5, PO1, PO3, TI2, TU3, TU10.
- *Pinus* habitat class: CA2, CU1, CU2, LI2, TI3, TI4, TU1, TU6, TU7, TU8, TU9.
- *Polylepis* habitat class: CK1^{+}, SM2^{+++}, TU4$^{++.}$
- Mixed native vegetation class: LM1^{++}, PO4$^{++.}$

In total, the upper and lower quartile covers 10 of 32 study areas with native tree vegetation. The remaining study areas are in the intermediate range of rarity-scores (0.8807 < summed range size rarity < 2.5655). Note, that all except one (PO3 with a summed range size rarity = 1.378) of the 22 exotic plantation study areas fall in the lowest quartile of the rarity-score range. Thus the exotic plantations have mainly birds of wide distribution yielding low range size rarity values. Looking at the upper quartile of the summed rarity-scores it appears that three out of the five study areas are classified as high land-use pressure habitats ($^{+++}$). This trend continues into the intermediate range of rarity-scores (0.8807 < summed range size rarity < 2.5655), where the upper five study areas when ranked with decreasing range size rarity are:
KP3^{++}, OR1^{++}, MO1+2ab^{+++}, MO4^{+++}, and LM3^{+}.

Thus high land-use pressure does not pose any threat to the avifauna as long as it contains a mosaic of native trees and bushes. Actually the areas SM3, SM4 and SM5 contained the highest concentrations observed during the fieldwork of *Poospiza garleppi*, the most threatened bird in this study region.

Part conclusion and discussion

Correlation between richness and endemism

The concentration of threatened and restricted range species is high within the Bolivian montane basins.

The concentration of threatened and restricted range species is high within the Bolivian montane basins. The lack of correlation between species richness and occurrence of threatened / restricted range species is not unusual, thus the new established *Area Protegida Madidi* (19,000 sq. km) is estimated to have 1,088 species of which only seven are classed as vulnerable (Remsen & Parker 1995. It is a general pattern in the tropical Andes that neo-endemic and old species with relictual distributions are found together in local assemblages, for example in the Cochabamba basin, while the highest species richness is found in the transition zone between humid lowlands and mountains (Stotz and others 1996; Fjeldså & Rahbek 1997b). Threatened and restricted range species recorded in the study region belong to three habitat types: *Polylepis* woodlands, semi-deciduous forest and dry woodland / scrub.

Probably the most endangered species recorded is *Poospiza garleppi*, which is endemic to the Cochabamba basin and restricted to upper montane *Polylepis* woodlands and humid ravines. *Poospiza garleppi* is under severe threat and efforts to preserve the species needs to be directed at promoting reforestation of mainly *Polylepis* to ease the pressure on few remaining *Polylepis* patches left within its range (Collar and others 1992; Hjarsen 1997). This would simultaneously benefit the other threatened and habitat restricted species found here: *Oreomanes fraseri, Leptasthenura yanacensis, Scytalopus simonsi* and maybe *Saltator rufiventris* although habitat preferences of the latter may be broader than previously assumed (see below).

Most restricted range species recorded in dry semi-deciduous forest are endemic to the Valles but are not considered to be seriously threatened. They seem fairly resistant to habitat change, probably due to the natural variability of the environment and some of the species are quite common in open land. The only endangered species is *Ara rubrogenys*, which tends to forage in flocks mainly along the larger rivers sometimes raiding crops (Collar and others 1992; Pitter & Christiansen 1995). As mentioned this zone is under intensive cultivation and consequently *Ara rubrogenys* has not only lost most of its natural habitat, it is furthermore eating food crop which makes it unpopular among local peasants.

Comments on threat status of some selected species

Although the classification of bird species in threat categories (for example Stattersfield and others 1998) are based on objective criteria actual field data from the Cochabamba basin does not in all cases support current threat category classification:

Aglaeactis pamela is listed as Least-concern by Stattersfield and others (1998). This classification seems inappropriate due to the very limited and disjunct distribution of the species. The bird enters *Polylepis* habitats close to the humid cloud forests (Fjeldså & Krabbe 1990). The logging of humid and tall *Polylepis* woodlands will eliminate the species locally. The species should at least be listed as near threatened in the World list of threatened species.

Oreomanes fraseri is classified as near-threatened by Collar and others (1994) and vulnerable by Ergueta & Morales (1996). The species is sensitive to habitat loss due to its specialised habitat requirements. The species is locally threatened due to loss of *Polylepis* woodlands. Where appropriate habitat were present, we found this bird occurring at unusual high densities. In *Parque*

Nacional Tunari several *Polylepis* woodlands have been replaced by exotics causing this species to become quite rare in certain areas. It is suggested that *Oreomanes fraseri* should be up-graded to vulnerable in the World list of threatened species due to high sensitivity of local habitat disturbances and continuos loss of *Polylepis* woodlands inside the range of this species.

Saltator rufiventris is classified as vulnerable both by Collar and others (1994). Ergueta & Morales (1996) and Stattersfield and others (1998). This classification is based on endemic distribution, rarity, and association to natural high Andean woodlands (Collar and others 1994). It was therefore surprising to encounter *Saltator rufiventris* in as many as 49% of the study areas in the Cochabamba basin and surrounding mountains. The species also appeared to be very adaptable to human disturbances and occurred at high densities in the areas with highest land use pressure. The species was recorded at quite high densities also in exotic plantations confirming a broad habitat selection, or at least opportunistic use of other habitats than the natural woodlands. At one locality, a breeding pair had established a territory in a small stand of *Pinus radiata*. These observations are in accordance with earlier observations by S. Maijer who argues that the species should at least be moved to a lower threat category or maybe removed totally from the World list of threatened species (S. Maijer pers. comm.). *Saltator rufiventris* was apparently a common bird in the zone covered by the fieldwork and we will partly support the view of S. Maijer proposing the species downlisted to the Near-threatened or maybe even the Least-concern category. It did not seem more vulnerable than all other species dependent on natural woodlands in Cochabamba but has been found to be very rare further south in the Valles (Fjeldså & Maijer 1996).

8. Conclusions

The following parameters were found to be of importance for the maintenance of rich landscape diversity in the southern and northern montane Cochabamba region (Table 32).

Table 32. Essential parameters for conservation of bird diversity

Landscape parameter	**Significance for species diversity**	
	Northern Cochabamba (*Polylepis*)	Southern Cochabamba (semi-deciduous forest)
Forest structural diversity	Positive relationship	Positive relationship
Tree species richness	Rare bird species favoured higher tree species richness	Not investigated
Heterogeneity of matrix	Not investigated	Not significant
Connectedness of forest patches	Not investigated	Significant

Factors found to affect forest biodiversity in the northern and the southern Cochabamba.

- Our study demonstrates that feasibility of land use mapping of difficult terrain with Landsat TM images.

- The remaining native semi-deciduous and *Polylepis* woodlands are very fragmented and disturbed by human land use practices. In southern Cochabamba native forest cover has been reduced to ca 9% of the mapped area (ca. 90 x 90 km). Much of the remaining forest is heavily grazed by free ranging livestock.

- Despite the present fragmentation and disturbance of native dry semi-deciduous and *Polylepis* forest in both regions there still remains several endemic and restricted range bird species which are globally threatened. These species are primarily found in native forest patches and the higest densities were found in patches with high structural diversity and where patches were not far apart. Plantations of introduced tree species can not substitute the biological richness of the native forest ecosystems.

- The fact that the forest patch areas nearest the largest forested area or where smaller patches are not far apart had the most species, suggests that connectivity of forest patches is important for maintenance of forest birds.

- To maintain forest bird species it is vital that the remaining native forest cover is protected and that land use and reforestation practices in the region are altered. Future management plans should provide for the maintenance and establishment of a network of native forest patches in order to facilitate the dispersal of species into suitable forest habitat.

- If a network of forest patches is maintained in the south it is possible to maintain a high beta-diversity of forest species. This implies that if the present land-use practices was changed to better manage the remaining forest patches it would be possible to maintain a rich landscape. However, it is important that the forest patches are disturbed less by cattle than what is presently found.

- Based on visual satellite interpretation we conclude that the most important region for endangered species is the northern Cochabamba where several larger patches of *Polylepis* remain.

Dedication of the local villages and wise management of land seems to be the keys to attaining higher degrees of conservation and long-term sustaining of natural resources. Such objectives may be reached by implementing various projects, which may provide a basis for development and introduction of new land-use methods or more likely reintroduction and modification of ancient methods. To ensure viability of such activities knowledge of local socio-economic mechanisms and cultural traditions are vital.

Project planning and implementation should be a multi-level and multi-sectorial effort-integrating participant from different levels of society and different professionals. Unfortunately, this is often forgotten, and most projects focus on one object alone. Real world development projects dealing with natural resource management are still often dominated by simple timber production goals where the establishment of exotic plantations seems to be the principal activity. Such projects seem to ignore the natural resources.

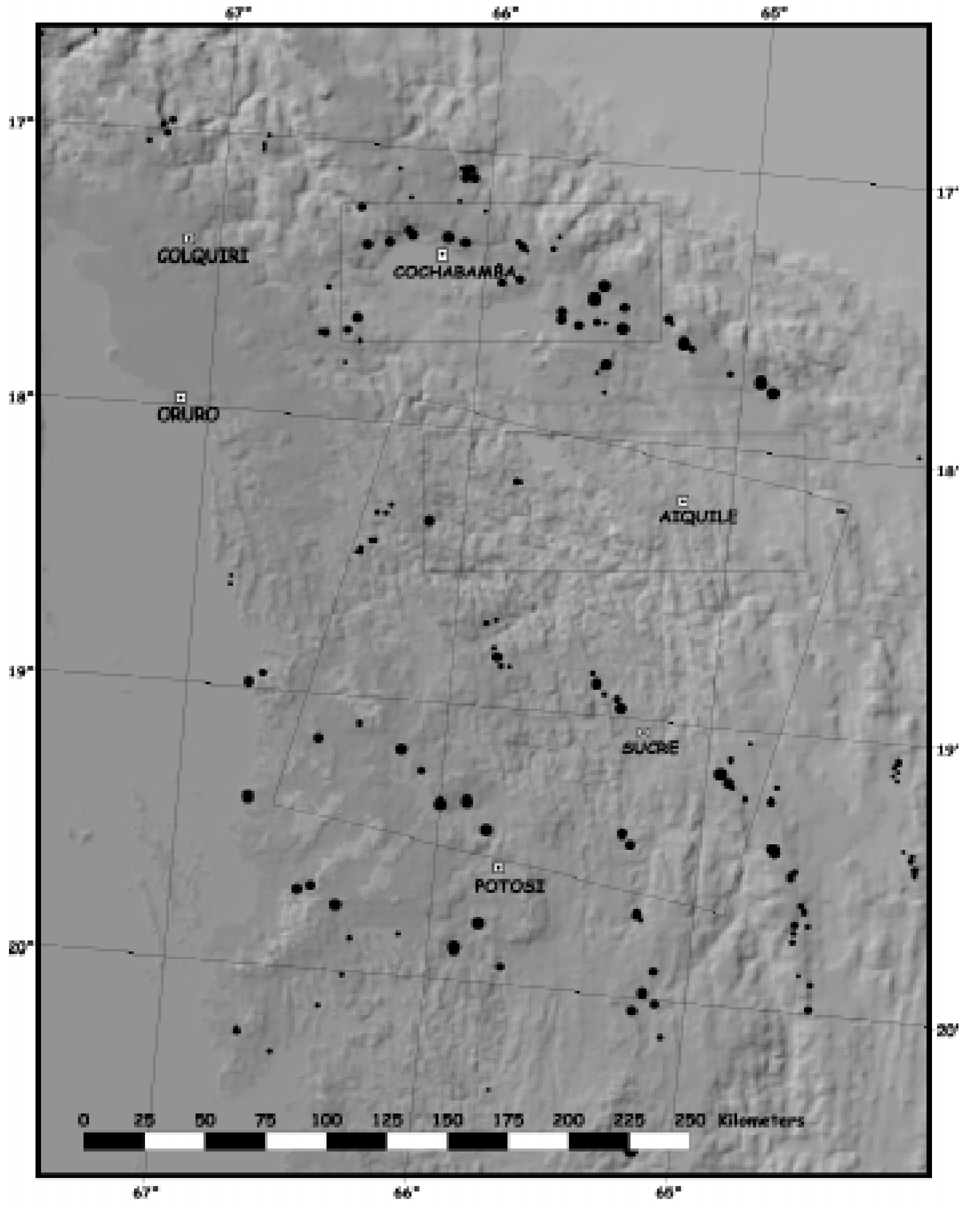


Figure 68. Map of known Polylepis *localities in the study region. The black dots show known locations of* Polylepis *identified by Fjeldså & Kessler (1996). These highlands with* Polylepis *should, together with the relatively large semi-decidious forested area east of Aiquile (see Fig. 2), be included in a future conservation strategy for the region. The frames on the map show the location of the study areas in this report.*

Appendix 1. Description of study sites

by Thor Hjarsen, Nicholas Moray Williams and Poul Nygaard Andersen

For all localities visited in this study, brief descriptions of the habitats are given below. For an overview of the location of the study sites please see maps on pages: 14, 17 and 18. The descriptions include geographical and topographical information about coordinates and altitude, and for the northern sites aspect and inclination. Each site is also described by a brief characterisation of the vegetation structure. Furthermore, in the northern sites, observations were made on hydrological conditions, and human land-use pressure (land-use category is stated for all natural vegetation habitats). Ecological imbalances or threats are also stated, some on a subjective background. For the northern sites , the vegetation heterogeneity index (V_H), and the Point-Centered Quarter method density index(PCQM density index) for each study is listed (see page 40 for calculations). The avifauna is likewise described with the most important species stated. Various parts of the information presented below already appears in several tables in the main text of this report. Please refer to these for detailed explanations on calculation methods, definitions, etc.

Northern study sites

CA1, La Candelaria

Eucalyptus plantation (17°15’34.7”S 65°56’04.5”W), April 7, 1996. Altitude: 3,300 m, aspect: 76°, inclination: 40°. V_H: 0.072. Located in the ravines behind *Casa Evangelica Candelaria* and belongs to this church. The area was a mature (average DBH: 24.4 cm) plantation with *Eucalyptus globulus* (PCQM density index: 1.0) with 25–30 m high trees on steep slopes. The area was quite humid (index: 3) due to influence from *yungas*. The ravine contains a stream with permanent water supply from Parque Nacional de Tunari further to the west. The ground vegetation was almost pure grass (*Calamagrostis tarmensis, Festuca dolichophylla*) with a few bushes (*Baccharis pentlandii, B. subalata* and *Satureja boliviana*). The general plant species richness was medium to low (index: 3) and low thickness of organic matter and leaf litter. An important path in the area was used by villagers to reach fields and pastures above. Cows were seen grazing in parts of the plantation. No apparent erosion problems. The area did not contain any notable bird diversity (5 species, 10 individuals), and the *Carduelis magellanica* observed (6 individuals) used the tree tops as resting and singing posts. Four to five *Cathartes aura* were spending the nights in the plantation outside the study area.

CA2, La Candelaria

Pinus plantation (17°16’27.2”S 65°55’54.7”W), April 7, 1996. Altitude: 3,510 m, aspect: 56°, inclination: 45°. V_H : 0.041. Located in the ravine behind *Casa Evangelica Candelaria* and belonging to this church, CA2 is inside a larger area of densely (PCQM density index: 0.373) planted *Pinus radiata*, 12–18 m high trees (average DBH 33.3 cm). The area was quite humid (index: 3) due to high climatic influence from *yungas* zone. The ravine contains a stream with permanent water supply from *Parque Nacional de Tunari* further to the west. Some trees have been logged over time, but no major human activity seems to take place. Ground vegetation was almost lacking due to shadowing from the pines but in a few plots *Polylepis racemosa* var. *lanata* grew. These *Polylepis* had probably survived the afforestation with exotics but were under stress due to competition for light and covering by needles dropped by the pines. Exactly where the *Polylepis* occurred, a lush vegetation was found with bushes (*Ophryosporus* sp.), herbs (*Campyloneuron amphostenon, Adiantum thalictroides, Hydrocotyle* sp., and *Ageratina azangaroensis*) and mosses (unidentified). Because of the general lack of light the grass coverage was very low (3%). The general plant richness was low (index: 2). Thickness of organic matter and leaf litter high (both 3 cm) due to deposition of pine needles. The bird fauna was dominated by seed-eaters using the trees as singing posts (*Phrygius unicolor*) or resting (*Carduelis magellanica*). One *Diglossa sittoides* passed through the plantation while feeding on the branches of the *Polylepis* trees present. The bird community in this area had the lowest Shannon index of all *Pinus* areas: 1.27.

CA3, La Candelaria

Polylepis woodland (17°16’33.3”S 65°56’08.3”W), April 8, 1996. Altitude: 3,600 m, aspect: 68°, inclination: 25°. V_H : 0.344. Medium land-use class. Located in the ravine a few kilometres behind *Casa Evangelica Candelaria* and belongs to this church. A larger area (8–10 ha) of 8–10 m high *Polylepis racemosa* var. *lanata* (average DBH 32.7 cm). The area was very humid (index: 4) due to high climatic influence from the *yungas* zone, and the natural vegetation cover was in a good state. The ravine contained a stream with permanent water supply from *Parque Nacional Tunari* further to the west. Ground vegetation inside the woodland was in a very good state due to large rocks and many low branches making human entrance inside the forest difficult, but considerable logging, grazing and agricultural activities took place along the borders. This biotope was maybe the largest *Polylepis* woodland in the region, but under considerable pressure due to establishment of fields. General plant species richness was high (index: 4) and vegetation structure complex. *Escallonia myrtilloides* var. *patens* and several important species of bushes (*Berberis commutata, Baccharis pentlandii, Gynoxys* sp. and *Baccharis subalata*) and herbs (*Blechnum penna marina, Polystichum* sp., *Polypodium megalolepis, Senecio* sp., and *Gallium corymbosum*) occurred. Many minor and larger rocks were completely covered by mosses and lichens (total moss cover 10%). Lianas (*Mutisia mandoniana*) covered 2% but grasses (*Calamagrostis tarmesis, Festuca dolichophylla* and *Nassella inconspicua*) only 3% of the area. The bird fauna was quite diverse with 13 species (35 individuals), with *Agleactis pamela* (2 individuals) as the most notable due to its vulnerability. Typical forest birds recorded were *Ampelion rubrocristata, Lepthastenura yanacensis, Diglossa carbonaria* and *Bolborhynchus* sp.

CK1, Cerro Kehuiñal

Polylepis woodland (17°33'28.7"S 65°42'48.4"W), April 12, 1996. Altitude: 3,360 m, aspect: 352°, inclination: 20°. V_H : 0.689. Low land-use class. Located on the road between *Araní* and *Vacas*. The closest village just south-east of the road was Est. Kehuiñal according to topographical maps (IGM map sheet 6441 II, 1:50,000). CK1 is inside a larger area (75 ha) of low (1–1.2 m) continuous, but highly degraded vegetation of *Polylepis tomentella* ssp. *nana*. The tree is endemic to this single location and is as such vulnerable. WCMC listed the subspecies as Critically Endangered in April, 1997 (Jenkins in litt.). Land-use pressure was considered moderate to high (index: 24), due to grazing (Fernandez 1996). The forest only receives water from precipitation, which is considered to be the most limiting factor. Ground vegetation was limited and dominated by grasses (*Muhlenbergia peruviana, Festuca dolichophylla, Aristida adscensionis* and *Elyonurus tripsacoides*), and many rocks and boulders. Some more vegetation (*Dodonea viscosa, Baccharis dracunculifolia* and *Berberis rariflora*) occurred in a local depression and along the road. This border vegetation was probably very important for sustaining the surprisingly diverse bird fauna of this locality (15 species, 36 individuals, Shannon diversity index: 2.51). None of the bird species present were *Polylepis* specialists, and very few will probably occur since the vegetation was very degraded.

CU1–CU3, Cerro Cuchillani

(17°18'S 66°09'W**)**. The south-facing slope of this mountain are facing towards Cochabamba. Can be located from Cochabamba town by some red and white radar installations on the slopes. The place is reachable by road starting off at the parks main entrance, climbing to the upper transverse road going west and then downwards. The area is affected in lower parts by humans (gardens and fields). Higher up, some natural vegetation is still left, however, large parts have been afforestated with *Eucalyptus globulus* and *Pinus radiata*. A signboard at a large, newly established *Pinus* plantation say: "*Proyecto Forestal Cuchillani Phase II. Asociación Boliviana de Iniciativas para el Desarollo ABID. CORDECO IC COTESU*". We do not know what phase I contained, and if anymore phases are to be expected. The planted areas are included in the *Parque Nacional Tunari*, and it is unclear who will benefit from this plantation besides of the agencies involved.

CU1, Cerro Cuchillani

Pinus plantation (17°18'44.2"S 66°09'37.1"W), April 13, 1996. Altitude: 3,100 m, aspect: 210°, inclination: 10°. V_H : 0.089. This plantation of *Pinus radiata* was about 6 ha with young 5–7 m high trees (average DBH: 7.2 cm). The general plant species richness was low, however, some *Polylepis besseri* and *Baccharis obtusifolia* occurred very close to, and inside, the study area. Land-use pressure was considered moderate to high (index: 24), with some domestic grazing inside the area and fields close by. The plantation only receives water from precipitation. Ground vegetation was dominated by grasses (20% coverage: *Calamagrostis antoniana, Muhlenbergia peruviana* and *Briza subaristata*). Some mosses (5%) and lichens (7%) were found. The bird fauna was quite diverse (11 species, 24 individuals, Shannon diversity index: 2.22), probably due to a nearby "corridor" of *Polylepis*. Species such as *Sappho sparganura, Anairetes parulus* and *Poospiza hypochondria* were recorded, but no priority species were present. In the pines, *Carduelis magellanica* was the most prominent species.

CU2, Cerro Cuchillani

Pinus plantation (17°19'17.4"S 66°08'59.7"W), April 13, 1996. Altitude: 3,450 m, aspect: 222°, inclination: 8°. V_H : 0.839. This plantation of *Pinus radiata* was about 6 ha with young 6.5 m high trees (average DBH: 11.8 cm) planted quite densely (PCQM density index: 0.213). The general plant species richness was low and ground vegetation almost lacking. *Polylepis besseri, Baccharis obtusifolia* and *B. dracunculifolia* occur very close to the study area. Land-use pressure was considered moderate to high (index: 24), with some domestic grazing inside the area and fields close by. The plantation only receives water from precipitation (humidity index: 2). Ground vegetation was dominated by grasses (20% coverage), and the occurrence of mosses and lichens were limited (5 and 7%). The bird fauna was not as diverse (6 species, 6 individuals) as CU1 and was dominated by wide-spread seed-eaters (*Carduelis megallanica* and *Zonotrichia capensis*).

CU3, Cerro Cuchillani

Polylepis woodland (17°14'50.0"S 66°05'52.2"W), April 13, 1996. Altitude: 3,670 m, aspect: 196°, inclination: 20°. V_H : 0.418. Low land-use class. Area with good natural vegetation (general plant species richness index: 3) dominated by *Polylepis besseri* ssp. *subtusalbida* (30% coverage, 2.5–3 m high) with other native trees and bushes (*Alnus acuminata* (15%, 6 m), *Gynoxys glabriuscula, Baccharis dracunculifolia, Satureja boliviana, Baccharis polycephala* and *Ribes brachybotrys*). Herb and grass layer was also well developed (33% total coverage). The whole area was surrounded by a large plantation of *Pinus radiata* and a road was going through. Humidity was medium to high (index: 3) due to a small stream. Needle litter layer was thick (3 cm). The bird fauna was relatively diverse (11 species , 12 individuals), with several high priority species occurred: *Asthenes heteura, Leptasthenura yanacensis, Oreomanes fraseri* and *Saltator rufiventris*. The area was thus important as an "island" of natural vegetation in a "sea" of monotonous plantation and probably served as a dispersal corridor for the habitat specialists.

KH1–KH3, Khalani Centro (17°40'S 66°29'W):
Situated on the west-south-west facing slope of an unnamed mountain just after km 79 on the Cochabamba–Oruro Road. A steep dirt road, starting close to where the oil pipeline crosses the road takes one down to the valley bottom with Rio Palca (IGM map sheet SE 19–8, 1:250,000). The whole mountain slope was covered by *Polylepis besseri*. However, this woodland was under severe human pressure and regeneration was generally lacking (see below). Some agricultural fields below the woodland near the river, but most agricultural areas were concentrated on the other side of the valley. The woodland was apparently the only major wood resource for the peasants in the area. Precisely this slope has potential for a reforestation and land-management program since the woodland was the only major *Polylepis* area in the region, holds several of the priority species, and was serving as communal timber resource area.
Note: The widespread *Polylepis* woodlands on the eastern slope of the nearby Cerro Kheñwa Sandora (Fjeldså's coord.: 17°42'S 66°33'W) reported 10 years ago by Fjeldså (1987), was later identified as an EBA ("Cerro Cheñua Sandra" [*BO20*] in Wege and Long (1995), coord. stated: 17°39'S 66°29'W), with *Saltator rufiventris* and *Poospiza garleppi*. As also stated later by Fjeldså and Kessler (1996), this woodland has apparently been lost today: We could not locate any continuous woodlands on slopes or mountains at the given coordinates. Local peasants could not provide any further information on such woodlands either.

KH1, Khalani Centro
Mixed native vegetation (17°40'19.8"S 66°29'40.2"W), February 18, 1996. Altitude: 3,720 m, aspect: 180°, inclination: 34°. V_H : 0.301. High land-use class. This open woodland of *Polylepis besseri* ssp. *subtusalbida* (20% coverage) was dominated by quite large trees (2.5 m high, average DBH: 20.5 cm). The trees were growing far apart (PCQM density index: 0.089), with only very few *Polylepis* seedlings in between, indicating low regeneration due to domestic grazing and probably early pasture burnings. Humidity was sustained by a nearby large river (Rio Palca) and precipitation. The area had bushes (20%: *Baccharis dracunculifolia, B. obtusifolia, Berberis rariflora, Saturaja boliviana* and *Gynoxys glabriuscula*), herbs (25%), *Puya herzogii* (3%) and grasses (30%). Located close to fields. The bird fauna was very diverse (24 species , 72 individuals) with several priority species: *Asthenes heteura*, *Saltator rufiventris*, *Leptasthenura*'s, and game birds (*Columba maculosa, Metriopelia ceciliae, Nothoprocta pentlandii*). The high diversity was mainly due to border effect between different habitats (*Polylepis*, bush areas, potato fields) and occurrence of open-land species (such as *Hirundo andecola, Upucerthia andaecola, Cinclodes atacamensis, Prygilus atriceps* and *P. unicolor*).

KH2, Khalani Centro
Polylepis woodland (17°40'21.6"S 66°29'27.1"W), February 18, 1996. Altitude: 3,720 m, aspect: 270°, inclination: 20°. V_H : 0.551. Low land-use class. This area of open *Polylepis besseri* ssp. *subtusalbida* was dominated by quite large trees (2.5 m high, average DBH: 24.6 cm). The trees grew far apart (20% coverage, PCQM density index: 0,049), with only very few *Polylepis* seedlings as in KH1. Bushes (28%), herbs (20%) and pasture dominated (30%). No notable epiphytes were present. Humidity was sustained only by precipitation. The bird fauna was diverse (21 species, 61 individuals), with both forest and open-land species, similar to KH1, though *Asthenes heteura* was not recorded. This was probably due to almost complete lack of bushy vegetation with suitable nesting sites. Several tyrranids were present (*Ochthoeca leucophrys, Ochthoeca oenanthoides, Polioxolmis rufipennis* and *Muscisaxicola alpina*).

KH3, Khalani Centro
Polylepis woodland (17°40'14.5"S 66°29'40.1"W), February 19, 1996. Altitude: 3,810 m, aspect: 247°, inclination: 37°. V_H : 0.551. High land-use class. This area of *Polylepis besseri* ssp. *subtusalbida* was dominated by quite large (2.5 m high, average DBH: 25.3 cm) trees. The trees grew far apart (PCQM density index: 0.074), with only very few *Polylepis* seedlings as in KH1 and KH2. General plant species richness was low (index: 2), and so was humidity (index: 2). As in KH2, *Baccharis* and *Gynoxys* were the most important species of the bush vegetation. The bird fauna was however quite diverse (16 species, 56 individuals, Shannon index: 2.75), with both forest and open-land species. None of the endangered priority species were observed, but will probably also occur due to habitat similarity with KH2. Several important game species were recorded: *Nothoprocta pentlandii, Nothura darwini* and *Columba maculosa.*

KP1–KP4, Kehuiña Pampa (17°29'S 65°24'W)
From about km 100 to km 150 on the old Cochabamba–Santa Cruz Road in the Rio Coari Valley, the south-facing slopes hold several good and quite large patches of *Polylepis. Polylepis racemosa* occurs in the high parts and *Polylepis tomentella* in the low parts near the road. The area was generally quite humid due to afternoon fogs drifting from the nearby *yungas* zone (on the same road 40–50 km after the southern turnoff towards Torotoro, the habitats suddenly becomes much drier, but this whole zone also has large *Polylepis* woodlands certainly worth exploring). The vegetation community is highly influenced by the *yungas* (Fernandez T. 1996). Kehuiña Pampa village is situated just below Cerro Tokho Tokho Pampa (IGM map sheet 6541 IV, 1:50,000). Visitors are recommended to make immediately contact with the *dirigente*. Local peasants were quite sensitive due to recent conflict over border-etablishment of *Parque Nacional Carrasco.* The ravines we visited contained large and quite undisturbed patches of natural forests. All priority bird species were recorded in this region. Forest habitat conservation and regeneration, and introduction of sustainable land-management are highly needed

in this region. Local peasants apparently already had high perception of forest management and agroforestry techniques: We saw examples of area-restricted communal firewood extraction in the *Polylepis* forest, and forest cover was only partly cleared on fields, thus creating favourable micro-climatic conditions for crops. PROFOR has a tree nursery in the area (*Rancho Zapata*), and undertakes plantation activity, unfortunately almost exclusively with exotic species (as an example, the tree nursery held in 1996 / 97 these amounts of trees: 138,000 *Pinus* spp., 45,000 *Eucalyptus* spp. and only 1,500 *Polylepis sp.* (Anonymous 1996b). Several of the exotic plantations were established inside or very close to *Polylepis* woodlands with deleterious effects on native vegetation.

KP1, Kehuiña Pampa

Mixed native vegetation (17°29'59.9"S 65°24'17.2"W), January 13–15, 1996. Altitude: 3,180 m, aspect: 190°, inclination: 10°. V_H: 0.869. Low land-use class. This open woodland was used by local farmers. In the study area were several potato fields, many tracks went through and grazing was observed. The vegetation was dominated by native species, mainly bushy trees or bushes to a heigth of 2 – 3 m (*Polylepis racemosa* ssp. *lanata).* Important plant species were: *Azara salicifolia, Citharexylum punctatum*, *Vallea stipularis, Baccharis dracunculifolia, B. nitida, B. pentlandii, Berberis commutata* and *Gynoxys glabriuscula*. The humidity was medium to high (index: 3), average DBH very low (3.7 cm), and the distribution of bushy and tree vegetation was patchy. The bird fauna was diverse (19 species, 86 individuals), containing several seed-eaters, probably as a result of the agricultural activity near the area: *Phrygilus atricceps, Carduelis magellanica, Catamenia analis* and *Zonothricia capensis.* A family of *Falco femoralis* was hunting in the area. Also several furnarids and tyrannids occurred. This diversity was mainly due to border effect between different habitats (*Polylepis,* bush areas, potato fields), and furthermore occurred several open-land species (*such as Hirundo andecola, Upucerthia andaecola, Cinclodes atacamensis, Prygilus atriceps, P. unicolor*). One *Poospiza garleppi* (juv. sub-ad.) was observed just outside the study area in a similar habitat.

KP2, Kehuiña Pampa

Polylepis woodland (17°29'45.1"S 65°24'27.6"W), January 14, 1996. Altitude: 3,350 m, aspect: 185°, inclination: 12°. V_H : 0.669. Low land-use class. This area was also intensely used by the peasants for wood logging and domestic grazing. The vegetation was quite fragmented, with small patches and corridors of more dense vegetation admixed open short pastures. Some trees were quite large (6 – 8 m high, average DBH: 19.8 cm). *Polylepis racemosa* ssp. *lanata* dominated with some *Citharexylum punctatum* and *Vallea stipularis.* Important bushes were: *Baccharis dracunculifolia, B. nitida, Berberis commutata, Gynoxys glabriuscula* and *Brachyotum microdon*. A quite high percentage of the plants was in flower (8%). The humidity was medium-high (index: 3), and the area close to a large stream. 17 bird species with 59 individuals were observed (Shannon diversity index: 2.67). Two important Trochilidea occurred: *Agleactis pamela* and *Metallura tyrianthina*. Other forest species were: *Ampelion rubrocristata, Diglossa carbonaria, Synallaxis superciliosa,* and *Anairetes parulus.* Occurrence of *Polylepis* specialist (*Polioxolmis rufipennis* and *Poospiza garleppi*) in adjacent and similar habitat, indicated the ornithological significance of the study area.

KP3, Kehuiña Pampa

Mixed native vegetation (17°30'03.6"S 65°24'27.6"W), January 15–16, 1996. Altitude: 3,210 m, aspect: 196°, inclination: 26°. V_H : 0.258. Medium land-use class. An area with some native mixed vegetation, highly affected by agriculture, tracks and exotic plantation of mature *Eucalyptus globulus*. The study area was surrounded by fields and houses with gardens and pastures. A small patch of *Pinus* sp. was also inside in the study area. The area was a mosaic with both natural and exotic vegetation, and areas subjected to human land-use. Of native trees was only *Polylepis tomentalla* present. Due to the height and low density of the *Eucalyptus*-trees, a quite lush vegetation of bushes occurred: *Baccharis pentlandii, B. draunculifolia, Berberis paucidentata, Schinus andinus* and *Berberis commutata.* The herb layer was also well-developed, and so was thickness of leaf litter (3 cm), and organic matter (3 cm). A high degree of border effect and ß diversity resulted in high bird fauna diversity (Shannon index: 2.25), but low equability (0.79) (For comparison, the bird fauna in the *Polylepis* study area in this locality (KP2), was much more diverse and had higher equability: Shannon index: 2.53 and equability: 0.89). Due to proximity of fields, houses, gardens and road a large amount of widespread and opportunistic bird species occurred: *Bolborhynchus aymara, Patagona gigas, Molothrus badius, Furnarius rufus Troglodytes aeodon, Saltator aurantiirostris, Carduelis magellanica, Catamenia analis and Zonotrichia capensis.* However, also habitat specialists were recorded: *Metallura tyrianthina* and *Diglossa carbonaria*. In total, 140 individuals were recorded, thus, the highest recorded bird density during the field work.

KP4, Kehuiña Pampa

Eucalyptus plantation (17°29'57.4"S 65°24'28.2"W), January 15–16, 1996. Altitude: 3,240 m, aspect: 180°, inclination: 22°. V_H : 0.123. Plantation of *Eucalyptus globulus* (10–15 m high, average DBH 9.0 cm), densely planted (PCQM density index: 0.704) inside a degraded woodland with some larger *Polylepis tomentella* (3 m high). The area was dry (humidity index: 2), rocky and currently with medium to highly affected by unregulated sheep grazing and collection of firewood, besides of the exotic plantation (land-use pressure index: 32). The vegetation had low diversity with a few *Baccharis polycephala, B. dracunculifolia, Satureja boliviana* and *Berberis paucidentata.* 20% herb and 20% grass cover made up the ground vegetation. Most dominant grass was *Stipa ichu*. General plant species richness was low (index: 1). The bird fauna was poor (7 species, 15 individuals), with mostly widespread species: *Turdus chiguanco, Asthenes dorbignyi, Carduelis magellanica,* and *Zonotrichia capensis.* Furthermore, a few *Diglossa carbonaria* was observed. With proper management (mainly exclusion of grazing livestock), the *Polylepis* could probably rapidly regenerate.

LI1–LI3, Liriuni (Quillacollo) (17°17'S 66°17'W)

This area is a well known bird collection locality, and bird watching site. The thermal baths attract many tourists. Due to earlier observations of *Saltator rufiventris* and *Poospiza garleppi* in the area, it was identified as an EBA (***BO18*** in Wege and Long 1995). The area is densely populated with many houses, gardens and fields but still some substantial *Polylepis* forests are left, in particular, on the slopes north of and above *Liriuni* village. Some very large plantations have earlier been established (with *Eucalyptus globulus*), but recently also *Pinus radiata* has been planted extensively. A new road going up from the baths have been constructed in connection with an Italian donated water tunnel project (the Misicuni–Corani Tunnel), which aims to supply the Cochabamba Basin with water from Rio Miziquni. The local peasants appeared to be tired of visitors and birdwatchers - local permission was very hard to get!

LI1, Liriuni

Eucalyptus plantation (17°18'01.6"S 66°17'45.1"W), February 23, 1996. Altitude: 3,050 m, aspect: 196°, inclination: 20°. V_H : 0.021. Plantation of very high (35–40 m, average DBH 15.9 cm) *Eucalyptus globulus* covering 6–8 ha. The area is very interesting as a demonstration of the effects on ground vegetation and topsoils from a mature *Eucalyptus* plantation: Ground vegetation was lacking below the trees, though, a lot of sunlight was penetrating the canopy (PCQM density index: 0.175). The reason is both human traffic and probably allelopathy (see main text of the report). Because of a general lack of ground vegetation most of the top soil was lost by water erosion. Humidity was low (index: 2), and vegetation structure not very complex (3 strata). The bush layer (1.2 m high) covered about 7% of the study area, and also the coverage of herbs (5%) and grasses (5%) were low. Due to proximity of *Polylepis*, agricultural fields, and gardens, the avifauna was quite diverse (12 species, 30 individuals).

LI2, Liriuni

Pinus plantation (17°17'19.9"S 66°17'24.6"W), February 23, 1996. Altitude: 3,150 m, aspect: 294°, inclination: 11°. V_H : 0.136. Plantation of young *Pinus radiata* (4–12 m, average DBH: 2.5 cm) covering 10 ha of pasture land. At the border along the road, some *Eucalyptus globulus* were planted. No natural woody vegetation left. No apparent human activities inside the plantation – the grasses were tall. No wood logging recorded. Leaf litter layer was thin (0.5 cm), and no layer of organic matter present. Five % of the area was covered by bushes (*Salvia* sp. and *Baccharis dracunculifolia*), and about 35% covered by herbs (*Eringium paniculatum, Richardia coldenoides and Stevia chamaedrys* among others*)* and grasses (*Festuca sublimis, Nasella inconspicua* and *Elyonorus tripsacoides*). General plant species richness was low (index: 1). The birds were widespread and common species (*Asthenes dorbignyi, Molothrus badius, Saltator aurantiirostris, Carduelis magelannica* and *Zonothrichia capensis*), with some open-land species (*Knipolegus aterrimus* and *Catamenia analis*). As in other *Pinus* plantations, *Colibri coruscans* (2 individuals), which used the trees as singing posts, were observed.

LI3a + LI3b, Liriuni

Mixed native vegetation (17°17'01.0"S 66°17'03.9"W), February 24 & April 5, 1996. Altitude: 3,330 m, aspect: 258°, inclination: 35°. V_H : 0.555. High land-use class. This study area was visited twice to check replication of the bird census method in use, however, only one vegetation survey was made. The study area was situated in a small, but steeply sloped ravine, below the road, which caused some erosion. Several crop fields were located inside the area, and wood logging occurred. Tourists also walked along the tracks in the area (and were shooting birds with slingshots!). General human disturbance was high. Humidity was medium to high (index: 3), and general habitat composition quite complex due to a mosaic of fields, and areas with both disturbed and reasonably undisturbed vegetation (plant species richness index: 3). There was a small stream at the bottom of the ravine with dense vegetation (outside study area). *Polylepis besseri* and *Escallonia* sp. were 2–4 m high and covered ca 40%, but grew far apart (PSQM index: 0.097). Little regeneration took place (average DBH: 17.8 cm). In spite of high disturbance, the avifauna was diverse (a / b: 25 / 23 species, 59 / 77 individuals – Shannon index: 3.01 / 2.88). This was due to the highly fragmented vegetation mosaic providing several "micro-habitats". However, this illustrates that even at high degrees of human disturbance, native vegetation systems can support a substantial bird fauna. Most important bird species were: *Falco sparverius, Colibri coruscans Asthenes dorbignyi, Asthenes heteura, Polioxolmis rufipennis, Diglossa carbonari, Anairetes parulus,* and *Saltator rufiventris.*

LM1–LM3, Lopez Mendosa (17°30'S 65°22'W)

Lopez Mendosa is situated north of the old Cochabamba–Santa Cruz Road at km 120. The small village is below Cerro Santa Barbara just west of Rio Lopez Mendosa (IGM map sheet 6541 III, 1:50,000). The area was accessible by car via a small dirt road (though, becoming quite slippery at the top-end!). The south-west facing slopes had large humid *Polylepis* woodlands, and was generally influenced by the *yungas* zone. Peasants in the area was quite suspicious to visitors, because of recent conflicts on the establishment of *Parque Nacional Carrasco*. Great care with obtaining local working permits from the *sindicatos* must be employed (we initially failed wich caused a "diplomatic" crisis!). The whole area towards Quebrada Mojon (MO1–MO5) will be suitable for sustainable management and reforestation programs if local acceptance and participation can be acquired. In one area (LM2), the botanical survey was done twice (LM2a and LM2b) to check degree of replication. Due to records of *Saltator rufiventris* and *Poospiza garleppi* the area aspires to become a "Neotropical key-area" according to the criterias used by Wege and Long (1995).

LM1, Lopez Mendosa

Mixed native vegetation (17°30'34.2"S 65°22'48.3"W), January 3–4, 1996. Altitude: 3,240 m, aspect: 66°, inclination: 44°. V_H : 0.405. Medium land-use class. Steep area with 3–4 m high *Polylepis racemosa* ssp. *lanata*. The area had low tree regeneration (average DBH: 17.8 cm), with quite large distance between tree individuals (PCQM density index: 0.220). The lower part of the study area included some more mixed vegetation with *Azara salicifolia, Citharexylum punctatum, Baccharis nitida* and *B. draunculifolia*. Other important plant species was *Berberis commutata, B. paucidentata* and *Brachyotum microdon*. Quite high land-use pressure was observed due to intense logging. The bird fauna was diverse (Shannon index: 2.4, but not many restricted-range species were recorded (Rarity score: 0.56). Though, several native forest species occurred: *Metallura tyrianthina, Anairetes parulus, Ampelion rubrocristata, Chlorospingus ophtalmicus, Ochthoeca leucophrys* and *Diglossa mystacelis*. Near the study area, in similar habitat, 2 *Asthenes heteura* were recorded.

LM2a & LM2b, Lopez Mendosa

Mixed native vegetation (17°30'34.9"S 65°22'41.1"W), January 5–6, 1996. Altitude: 3,340 m, aspect: 192°, inclination: 12°. V_H : 0.422. Medium land-use class. Area with 8 m high *Polylepis* ssp. *racemosa lanata*, admixed *Citharexylum punctatum* and *Hesperomeles lanuginosa*. The area is quite interesting, since it apparently was reserved as communal timber extraction area by the peasants. The *Polylepis* grew on a plane area and was quite degraded in certain plots due to such logging, however, the vegetation was generally in good condition. On distance, this area appeared lighter due to transparency of underlying rocks (see ***Figure 1.7***). Some grazing took place. The bird fauna was diverse (16 species, 50 individuals, Shannon index: 2.51), with some restricted-range species (Rarity score: 1.78), and several forest species occurred: *Rhynchotus maculicollis, Metallura tyrianthina, Aglaeactis pamela, Ampelion rubrocristata, Chlorospingus ophtalmicus, Ochthoeca leucophrys* and *Diglossa mystacelis*. Two nocturnals were also recorded: *Glaucidium bolivianum* and *Caprimulgus longirostris*.

LM3, Lopez Mendosa

Polylepis woodland (17°29'59.8"S 65°24'10.2"W), January 7, 1996. Altitude: 3,650 m, aspect: 160°, inclination: 31°. V_H : 0.602. Low land-use class. A humid area with *Polylepis racemosa* ssp. *lanata*. Some of the emergents were very high: 19–20 m, and a single individual even reached c 25 m, and had a DBH near 210 cm!! Average DBH was 22.2 cm. The study area was of generally tall forest with very well-developed undergrowth. Several tracks were passing to fields and pastures above, but no major signs of logging was visible. The general canopy was about 3–4 m high and dominated by *Oreopanax rusbyi* and *Hesperometes lanuginosa*. *Vallea stipularis, Citharexylum punctatum* and *Azara salicifolia* dominated the understory. Furthermore, several species of bushes (*Berberis paucidentata, Baccharis nitida, Satureja boliviana* and *Brachyotum microdon*), and herbs were recorded. Worth noting, was the high coverage of mosses (5%), lianas (8%) and lichens (3%), but low grass coverage (5%). A stream passed the area and substantial amounts of water leached from the banks. Large ferns occurred along the stream. Thickness of leaf litter and organic layer was high; 3 and 5 cm, respectively. Diversity of the avifauna was high (Shannon index: 2.26), and many of the records were of restricted-range species (Rarity score: 2.00), although not many species in total were recorded (11 species, 40 individuals). Most important was: *Agleactis pamela* (7 individuals), *Ampelion rubrocristata, Ochthoeca rufipectoralis, Columba maculosa* and *Diglossa carbonaria*.

MO1–MO4, Quebrada Mojón(17°29'S 65°25'W)

February 7–8, 1996. Quebrada Mojon is a well know collection and birding site at km 100 on the old Cochabamba–Santa Cruz Road. Due to records of *Saltator rufiventris* and *Poospiza garleppi* the area was identified as a key-area ("*Quebrada Majon*", 17°24'S 65°23', BO19) by Wege and Long (1995). At the highest altitudes (> 3,600 m), substantial woodlands with *Polylepis* remain. Some unfortunate afforestations with *Eucalyptus globulus* inside native vegetation was observed, but no allelopathic effects yet visible. The peasant community was very friendly and curious, maybe because we succeeded in obtaining permit from the *dirigente* 3–4 weeks earlier, when he and a large part of the community did some communal channel digging nearby. Fransisco Sagót from *Asociacion Armonia* / BirdLife Bolivia, Santa Cruz, participated on this trip. Fransisco Sagót did some mistnetting and made a complete bird list of the area.

MO1+2, Quebrada Mojón

Polylepis woodland (17°29'27.4"S 65°25'09.8"W), February 7–8, 1996. Altitude: 3,450 m, aspect: 217°, inclination: 19°. V_H : a: 0.261 / b: 0.675. Medium land-use class. Two areas were pooled due to small plot sizes. The ornithological survey covered both biotopes, while the botanical work was done twice – also to check bias in the botanical method. The area had a dense vegetation of *Polylepis racemosa* ssp. *lanata*, admixed with *Vallea stipularis* and *Hesperomeles lanuginosa* (in flower). Other plant species recorded: *Baccharis pentlandii, B. dracuncunifolia, Satureja boliviana, Scinus microphyllus* and *Brachyotum microdon*. Eight per cent of the area was covered by the lianas, of which *Sarcostemma caupanulatum* and *Passiflora mollisima* were identified. The latter was in flower. Grasses covered 12% with *Stipu ichu, Bromus* sp. and *Calamagrostris* sp. as dominating species. The avifauna was very interesting with 61 individual recordings in 18 species. Shannon diversity was high: 2.69, and so was the Rarity score: 2.26. Most notable was the high density of the hummingbirds *Metallura tyrianthina* and *Agleactis pamela.* Otherwise, the area contained several forest species such as: *Ampelion rubrocristata, Anairetes parulus, Diglossa carbonaria, Schizoeaca harterti, Atlapetes fulviceps, Saltator rufiventris* and *Poospiza erythropus.* Several interesting species were recorded from the same biotope but outside the study area: *Rynchotus maculicollis, Glaucidium boliviana, Turdus fuscater* and *T. nigriceps.*

MO3, Quebrada Mojón
Eucalyptus plantation (17°29'38.8"S 65°25'07.6"W), February 8, 1996. Altitude: 3,240 m, aspect: 270°, inclination: 21°. V_H : 0.616. This plantation of 12–15 m high *Eucalyptus globulus* was established inside a large area of a larger moderately degraded *Polylepis* woodland, although the surrounding land areas provided several alternative sites! Inside the plantation, 8–9 m high *Polylepis racemosa* ssp. *lanata* occurred (16% of the trees recorded by PCQM was *Polylepis* and 84% *Eucalyptus*), together with several other species of native vegetation: *Baccharis* sp., *Berberis* sp., *Brachyotum microdon, Puya tunariensis.* Twenty per cent of the area was covered with grass. Leaf litter thickness was 0.5 cm with no accumulation of organic matter. Only 5 species of bird occurred (11 individuals); all common species: *Nothoprocta pentlandii, Turdus chiguanco, Saltator aurantiirostris* and *Zonotrichia capensis.* Also 2 *Ampelion rubrocristata* were recorded, and in the surrounding *Polylepis,* several *Saltator rufiventris* was recorded. The presence of the latter two species was probably due to the native vegetation present.

MO4, Quebrada Mojón
Polylepis woodland (17°29'02.3"S 65°25'09.8"W), February 8–9, 1996. Altitude: 3,600 m, aspect: 180°, inclination: 19°. V_H : 0.675. High land-use class. This area was the upper limit of the largest continuous *Polylepis* woodland in the ravine. The study area was shaped as a "finger" of forest along a small stream with green short pasture on both sides. The trees were quite large and the undergrowth well developed. A small path followed the stream inside this "forest finger". *Polylepis racemosa* ssp. *lanata* covered 20% of the study area. The trees were about 8 m high, and in between grew about 3 m high *Vallea stipularis* and *Hesperomeles lanuginosa* (both in flower). The bush and herb layer was well developed with *Baccharis pentlandii* and *Brachyotum microdon* flowering. Grasses covered about 5%. Avifauna was strikingly rich in spite of altitude (Shannon index: 2.85, equability: 0.97): 69 individuals of 20 species were recorded. Most notable were: *Agleactis pamela, Metallura tyrianthina, Colibri coruscans, Diglossa carbonaria, Saltator rufiventris,* and *Oreomanes fraseri.* Near the study area, in similar vegetation, and in the adjacent puna habitat, these additional species was recorded: *Nothura darwini, Vultur gryphus* (5 individuals), *Buteo poecilochrorus,* and *Anthus bogotensis.* Furthermore, an unidentified species of rodent (Muridae), slowly climbed across a boot!

MO5, Quebrada Mojón
Eucalyptus plantation (17°30'23.8"S 65°25'12.6"W), February 9, 1996. Altitude: 3,320 m, aspect: 28°, inclination: 23°. V_H : 0.052. A plantation of 12 m high *Eucalyptus globulus* in degraded mixed native forest, surrounded by natural forest vegetation with *Polylepis.* General plant species richness was low (index: 1), with some *Baccharis dracunculifolia, Satureja boliviana,* and various herbs. A large portion of the area (40%) was covered by grasses. The avifauna was dominated by common and widespread species (Rarity score: 0.05), such as *Molothrus badius, Zonotrichia capensis,* and *Carduelis magellanica.*

OR1–OR2, Oropeza (Incallajta) (17°36'S 65°31'W)
April 11–13, 1996. This area, 10 km west–south–west of the Incallajta ruins, had quite large areas of *Polylepis besseri* on south-facing slopes in the valley of Rio Pocona Mayu (IGM map sheets 6541 II and III, scale 1:50,000). Along the river and in the river bed, was several large stands of *Alnus acuminata.* A road in good state enters from Vacas. Towards Pocona the road was blocked according to local peasants. This area may be relevant for projects aiming for reforestation and regeneration of native forests, however risk of erosion yet not very high. Because of recordings of *Oreotrochilus adela, Saltator rufiventris* and *Poospiza garleppi,* the area should be included in BirdLife's "Neotropical key area" system.

OR1, Oropeza (Incallajta)
Mixed native vegetation (17°36'00.5"S 65°31'52.3"W), April 11–12, 1996. Altitude: 3,400 m, aspect: 120°, inclination: 8°. V_H : 0.633. Medium land-use class. This study area was situated in the forested riverbed, including lowest part of the banks. The area had good vegetation of *Alnus acuminata* and bushes. The surrounding slopes had low *Polylepis besseri,* potato fields and pastures. Inside the woodland some *Alnus* had recently been cut, apparently for construction timber. Besides of the 7–8 m high *Alnus,* the woody vegetation of *Citharexylum punctatum, Baccharis dracunculifolia, B. nitida,* and *Satureja boliviana.* Some herbs, but no grasses, were present. The leaf litter layer was thin (2 cm), and general plant species richness estimated to be medium to low (index: 2). The trees covered 50% of the study area, and 4 plant strata were counted. The avifauna was very diverse (Shannon index: 2.94) with several restricted range species (Rarity score: 2.40), in total 24 species and 68 individuals, of which some were: *Colibri coruscans, Patagona gigas, Asthenes dorbignyi, Synallaxis azarea, Myioborus brunniceps, Diglossa carbonaria, Atlapetes fulviceps* and *Poospiza garleppi.* In similar adjacent biotope two *Saltator rufiventris* were recorded.

OR2, Oropeza (Incallajta)
Polylepis woodland (17°36'38.7"S 65°29'59.2"W), April 12–13, 1996. Altitude: 3,450 m, aspect: 70°, inclination: 28°. V_H : 0.507. High land-use class. A quite arid, rocky and degraded area with 2–3 m high *Polylepis besseri* covering 25% of the study area. It was more of a bushland. A road and several tracks went through, and sheep were grazing in the area. The vegetation was not very species rich (index: 2), with *Baccharis dracunculifolia* as only other woody species. Grasses covered 25% of the area. In spite of the very degraded vegetation, the area had a high avifauna diversity (Shannon index: 2.77), and several very interesting species were recorded: *Oreotrochilus adela, Asthenes sclateri, Asthenes heteura, Muscisaxicola alpina, Knipolegus aterrimus, Agriornis montana*, and *Saltator rufiventris.*

PO1, Quebrada Potreros
Eucalyptus plantation (17°18'40.9"S 66°18'53.1"W), February 22, 1996. Altitude: 2,850 m, aspect: 160°, inclination: 5°. V_H : 0.006. Located in the ravine behind a major scout camp just 2–3 km west of the *Quillacollo–Liriuni* Road. A popular picnic spot with some large and mature *Eucalyptus globulus* plantations in the lowest parts. The *Eucalyptus* covered 80% of the study area and reached 30 m height. No bushes occurred in the study area, which only had 13% herb cover and 5% grass cover, thus, general plant species richness was low (index: 1). A total of 7 species were recorded (including *Nothoprocta pentlandii, Metriopelia melanoptera, Turdus chiguanco* and *Colibri coruscans*). In the surrounding bush vegetation two *Saltator rufiventris* occurred.

PO2, Quebrada Potreros
Mixed native vegetation (17°18'42.7"S 66°18'40.1"W), February 22–23, 1996. Altitude: ,3150 m, aspect: 160°, inclination: 8°. V_H : 0.219. Low land-use class. A plane area with low, degraded vegetation (max. height: 1.2 m), with various bushes (such as *Baccharis dracunculifolia, Schinus myrtifolius, Salvia* sp., *Piper* sp.) and herbs. No *Polylepis* present. The plant species richness was considered medium to high (index: 3) in spite of the lack of forest cover. The area was under heavy grazing from cattle. Picnic, camping and game hunting took also place in the area. A large stream passed nearby where the vegetation was higher (2–3 m). In spite of the degraded vegetation, the avifauna was very diverse (Shannon index: 2.95), with some influx of lowland species (25 species, 70 individuals): *Nothoprocta pentlandii, Turdus chiguanco, Colibri coruscans, Sappho sparganura, Thraupis bonariensis, Elaenia albiceps, Diglossa sittoides, Stigmatura budytoides, Atlapetes fulviceps, Satrapa icterophrys, Myiarchus tuberculifer*, and *Saltator rufiventris*.

PO3, Quebrada Potreros
Eucalyptus plantation (17°18'22.8"S 66°18'54.4"W), February 22–23, 1996. Altitude: 3,180 m, aspect: 112°, inclination: 12°. V_H : 0.043. Low land-use class. Plantation of *Eucalyptus globulus* (25 m high; average DBH: 16.6 cm) established on a slope. On nearby slopes occurred some *Polylepis besseri*. Inside the plantation, erosion was apparently beginning due to the general lack of ground vegetation, and trampling from human foot traffic. The bushy vegetation was similar to PO1. Not many bird species were recorded (6 species, 10 individuals): *Oreopsar bolivianus, Turdus chiguanco, Sappho sparganura*, and *Zonotrichia capensis.*

PO4, Quebrada Potreros
Mixed native vegetation (17°18'22.8"S 66°18'54.4"W), March 2, 1996. Altitude: 3,120 m, aspect: 180°, inclination: 6°. V_H : 0.293. Medium land-use class. An area very similar to PO2 with no trees but low vegetation of bushes (*Salvia* sp., *Baccharis dracunculifolia* and *Scinus microphyllus*), herbs (*Commelina elliptica, Eryngium* and *Viguiera*) and grasses (*Stipa micronata, S. ichu* and *Calamagrostis*). General plant species richness was low (index: 2), and so was the humidity (index: 2). This area was heavily affected by grazing. However, the avifauna was quite species rich (15 species, 42 individuals), with high Shannon diversity: 2.39. Important birds: *Colaptes melanochlorus, Colibri coruscans, Diglossa sittoides, Anairetes parulus, Saltator rufiventris.*

SM1–SM5, San Miguel (17°16'S 66°19'W)
Situated on the road from Quillacollo to Morochata before the pass. The village is located just above the river-crossing (However, SM4 and SM5 are to the left of the road, 200 m before the river). The inhabitants of this small village were very friendly and acquainted with bird watchers. The area seems to be the best area near Cochabamba to find *Poospiza garleppi*. In total, recorded 8–10 individuals were recorded in the area! The school teacher kindly provided lodging in the class room due to heavy rain at arrival. A considerable areas of *Polylepis besseri* ssp. *subtusalbida* is left – probably 20–30 ha. in total, and the peasants seem to integrate the native vegetation with crop fields. The grassy hillside above the village was forested with *Polylepis* some 5–6 years ago (Maijer pers. comm.). Some unfortunate afforestation with *Eucalyptus globulus* has taken place inside *Polylepis* woodlands just above the village. This area is a relevant location for integrated, sustainable land-management programs. The locality is included in the Neotropical key-area BO18 covering the slopes from Liriuni to Cerro Tunrari (Wege & Long 1996).

SM1, San Miguel
Polylepis woodland (17°16'28.6"S 66°19'52.6"W), March 4–5, 1996. Altitude: 3,800 m, aspect: 164°, inclination: 20°. V_H : 0.784. High land-use pressure. This area had agricultural fields (30% of whole area), admixed with hedges and small groups of *Polylepis besseri* ssp. *subtusalbida* and especially *Baccharis* and *Berberis.* The area was situated on the south–west facing slope between Rio San Jasinto and Rio Falsuri just south–east of the village (IGM map sheet no. 6342 III, scale 1:50,000). Human land-use pressure was high, with fields, grazing areas, gardens, and foot traffic. However, some high (7 m) *Polylepis besseri* was present (25% cover), together with *Citharexylum punctatum* (5% cover), a variety of bushes (*Baccharis dracinculifolia, B. pentlandii* and *Berberis*

commutata), herbs, and epiphytes (5 % mosses, 5% lichens and 4 % lianas (*Bomarea crocca*). *Puya herzogii* covered 5 %. Grasses covered 30% of the area. Five plant strata were recognised and humidity was high (index: 4). The avifauna was very interesting with several high priority species (18 species, 70 individuals): *Pterophanes cyanopterus, Colibri coruscans, Scytalopus magellanicus simonsi, Lepthastenura fuliginiceps, Ampelion rubrocristata, Diglossa carbonaria* and *Saltator rufiventris.* We also assume that *Poospiza garleppi* occur in this study area since quite many birds of the species were recorded in the area.

SM2, San Miguel

Polylepis woodland (17°16'11.5"S 66°19'42.4"W), March 4, 1996. Altitude: 3,750 m, aspect: 150°, inclination: 30°. V_H : 1.200. High land-use class. A quite degraded woodland of *Polylepis besseri* ssp. *subtusalbida* just above the village with some plantation of *Eucalyptus globulus* established inside and nearby. No fields inside the area. According to the peasants the plantation was established 7 years ago. If this is correct, the soil must be unsuitable for *Eucalyptus* growth, because the trees were just c 3 m high. Other vegetation admixed was: *Citharexylum punctatum*, a very few and small *Pinus* sp., 10% bush cover (*Satureja boliviana, Gynoxys, Baccharis pentlandii*), and 30% grass cover (*Calamagrostris* sp.). The diversity of the avifauna was high (Shannon index: 2.37), with 13 species and 33 individuals. The Rarity score was low (0.52) and most birds recorded were open-land species. Among other species, one *Saltator rufiventris*, one *Oreomanes fraseri*, and one *Ampelion cristatus* were recorded.

SM3, San Miguel

Polylepis woodland (17°16'11.7"S 66°19'23.9"W), March 3–4, 1996. Altitude: 3,850 m, aspect: 144°, inclination: 12°. V_H : 0.422. High land-use class. An area heavily affected by humans with several agricultural fields, admixed well-grown and dense hedges and "miniature" woodlands with native species: *Polylepis besseri* ssp. *subtusalbida, Citharexylum punctatum, Baccharis pentlandii, Gynoxys, Satureja boliviana* and *Berberis commutata.* The general plant species richness was medium–high (index: 3), and humidity likewise (index: 3). The area hosted several important bird species (25 species, 91 individuals), thus, a very high Rarity score (3.24): *Leptasthenura fuliginiceps, Diglossa carbonaria, Atlapetes fulviceps, Oreomanes fraseri, Ampelion rubrocristatus, Saltator rufiventris* and *Poospiza garleppi* (4 individuals). This area demonstrates very well, that all high priority bird species may also occur in areas heavily affected by humans. Here, just some fragments of undisturbed native vegetation are left. The vegetation mosaic of crop fields and hedges with native vegetation, provide multiple feeding niches to the birds.

SM4, San Miguel

Polylepis woodland (17°16'53.4"S 66°20'20.0"W), April 20–21, 1996. Altitude: 3,450 m, aspect: 170°, inclination: 10°. V_H : 0.364. Low land-use class. Area with some agricultural fields, and a part of the forest cover had very recently been cleared to provide space for more crops. Cattle were grazing in the woodland, but still large parts of the area was in good state. Plant species richness was medium to low (index: 2), and so was humidity (index: 2). *Polylepis besseri* ssp. *subtusalbida* covered 35 % and was 1.5 –4.5 m high. Other plant species recorded: *Baccharis dracunculifolia, B. polycephala, Salvia sp.* and *Schinus microphylla.* Twenty per cent of the area was covered by herbs, and 10% by grasses (*Stipa ichu, Festuca* sp. and *Nasella* sp.). The diversity of the avifauna was high (Shannon index: 2.98) with 26 species recorded - highest species number of all areas. Both forest and open-land species were recorded. Most notable was: *Colibri coruscans, Oreotrochilus estella, Sappho sparganura, Patagona gigas, Asthenes heteura, A. dorbignyi, Anairetes parulus, Leptasthenura fuliginiceps, Diglossa carbonaria, D. sittoides, Myioborus brunniceps, Saltator rufiventris* and *Poospiza garleppi.* Above the study area 2 *Vultur gryphus* was circling (not included in the list).

SM5, San Miguel

Polylepis woodland (17°16'22.4"S 66°19'51.6"W), April 21–22, 1996. Altitude: 3,630 m, aspect: 234°, inclination: 10°. V_H : 0.529. High land-use class. Located just adjacent to SM4 and thus a similar biotope. Some additional important plant species were recorded: *Berberis rariflora* and *Escallonia* sp. The avifauna was also similar (25 species, Shannon index: 3.08) with, for example *Colibri coruscans, Asthenes dorbignyi, A. heteura, Diglossa carbonaria, Ampelion rubrocristata, Ochthoeca leucophrys, Saltator rufiventris,* and *Poospiza garleppi.*

TI1–TI5, Tiquipaya (Cerro Cruzani) (17°18'S 66°13'W)

Located north of the suburb Tiquipaya, Cerro Cruzani and Cerro Rankapampa (IGM map sheet 6342 II, scale 1:50,000) holds some substantial woodlands of *Polylepis besseri* ssp. *subtusalbida* (in total 25–30 hectares). The natural woodlands were generally under severe pressure from pasture burning, grazing and exotic plantations with *Eucalyptus globulus* and *Pinus radiata.* Little regeneration of *Polylepis* was observed, and most woodlands were open with large mature trees. We do not know whether this area is included in *Parque Nacional Tunari*, and then formally protected (but in reality endangered, if the park extend afforestation to this area!).

TI1, Tiquipaya (Cerro Cruzani)

Polylepis woodland (17°18'07.7"S 66°13'13.6"W), March 18, 1996. Altitude: 3,550 m, aspect: 200°, inclination: 5°. V_H : 0.416. Medium land-use class. An area with open (PCQM density index: 0.179) stand of *Polylepis besseri* ssp. *subtusalbida,* in average 9 m high. Land-use pressure was significant with pasture burning and grazing. The area was quite dry (index: 2), dominated by grasses (30% coverage). General plant species richness was medium to low (index: 2) with: *Baccharis dracunculifolia, Berberis rariflora, Agathis* sp., *Gynoxys* sp. as other woody vegetation. Some bromeliads occurred on dry rocky parts *(Puya herzogii, P. tunariensis* and *Eryngium* sp.). The avifauna held 16 species represented by 41 individuals, giving a high

Shannon index of 2.37. Of interest were: *Buteo polyosoma, Asthenes heteura, Scytalopus magellanicus, Anairetes parulus, Leptasthenura yanacensis,* and *Oreomanes fraseri.*

TI2, Tiquipaya (Cerro Cruzani)
Eucalyptus plantation (17°18’15.9”S 66°12’53.2”W), March 22, 1996. Altitude: 3,300 m, aspect: 170°, inclination: 10°. V_H : 0.178. Plantation with 6 m high (average DBH: 9.8 cm) *Eucalyptus globulus* established on former grassland. Grazing, trambling, and human foot traffic was not under control thus creating severe top soil erosion in the plantation, and on the slopes facing toward the road. Trees were planted quite far apart (PCQM density index: 0.106), ground vegetation was dominated by grasses (20%) with no regeneration of bushes or herbs. The avifauna (7 species, 15 individuals) had only widespread species (Rarity score: 0.09): *Saltator aurantiirostris, Zonotrichia capensis, Carduelis magellanica*, etc. Another clear example of the ecological implications created by badly managed *Eucalyptus* plantations.

TI3, Tiquipaya (Cerro Cruzani)
Pinus plantation (17°18’07.8”S 66°12’52.2”W), March 22, 1996. Altitude: 3,320 m, aspect: 154°, inclination: 27°. V_H : 0.436. An area with dense plantation (PCQM density index: 0.358) of 6 m high *Pinus radiata* (average DBH: 17.0 cm), inside a former woodland of *Polylepis besseri* ssp. *subtusalbida*, of which a few trees still were alive (3% coverage of live *Polylepis* trees). The ground vegetation was degraded, with very little bushes (5% coverage), herbs (10%), and grasses (10%). The avifauna was common and widespread species (Rarity score: 0.19) as in TI2, except for one *Saltator rufiventris*.

TI4, Tiquipaya (Cerro Cruzani)
Pinus plantation (17°18’07,8”S 66°12’52,2”W), March 22, 1996. Altitude: 3,320 m, aspect: 158°, inclination: 20°. V_H: 0.184. An area adjacent and very similar to TI3 with dense plantation (PCQM density index: 0.366) of 5 m high *Pinus radiata* (average DBH: 13.2 cm), established inside a former woodland of *Polylepis besseri* ssp. *subtusalbida*. The ground vegetation was underdeveloped, with very little bushes (9% coverage), herbs (15%),and grasses (5%). The avifauna was of common, widespread (Rarity score: 0.08) species with influx from open-land fauna: *Sicalis flaveola, Zonotrichia capensis,* and *Carduelis magellanica*. No priority species were recorded.

TI5, Tiquipaya (Cerro Cruzani), Mixed native vegetation (17°16’50.2”S 66°12’59.9”W), April 2, 1996. Altitude: 3,240 m, aspect: 168°, inclination: 15°. V_H : 1.235. Low land-use class. Ravines situated just behind TI3 and TI4, with dense mixed vegetation and a small stream. On the western slope a large *Pinus* plantation (with TI3 and TI4), and on the eastern slope a pasture and an *Eucalyptus* plantation. Some wood logging and human foot traffic due to path running through the study area. Humidity high (index: 4). The tree covered 60% (average DBH: 13.2 cm) with *Alnus acuminata* (10 m high), *Myrica pubescens* (8 m), and *Valea stipularis* (6 m). The avifauna (19 species, 46 individuals) was mainly dominated by species with preference for humid forest habitats, but also a few open-land species: *Colibri coruscans, Sappho sparganura, Scytalopus magellanicus, Turdus chiguanco, Atlapetes fulviceps, Chlorospingis ophtalmicus, Ampelion rubrocristatus, Saltator rufiventris* (3 individuals), and *Carduelis magellanicus.*

TU1–TU10, Parque Nacional Tunari (17°19’S 66°08’W): *Parque Nacional Tunari* is a legally protected national park, where human settlement, agriculture and pasture burning is prohibited (Crespo 1989). However, the park is not included in the SNAP (*Systema Nacional de Areas Protegidas*) by the Bolivian Government. The national park is apparently used for commercial timber production by local authorities (CORDECO, Prefectura de Cochabamba and the park management). What the economic earnings are used for is unknown. Earlier, GTZ supported this activity economically, but today the Swiss Agency for Development and Cooperation (SDC / COSUDE) is funding the park. Most areas below 3,700 m on the slopes facing towards south, have been afforestated with exotics – unfortunately also inside the native forest habitats. *Polylepis* only survives in some ravines, and at higher altitudes probably unsuitable for planting exotics. If cash-generating crop production is unavoidable in the park, agricultural systems with establishment of inter-field hedges of native trees, would be a much more ecologically sustainable solution, and from a socio-economical viewpoint, poor and landless peasants would benefit from such labour intensive activities. According to recent newspaper articles (Los Tiempos 1996a), major concern of the authorities is to enforce the borders of the national park. Instead activities should be directed into proper management of the natural resources already inside the park.

Crespo (1989) investigated the impact of the exotic plantations on native vegetation in *Parque Nacional Tunari*, and found that the plantations had a low number of native plant species (see also main text). This information, and other locally available information resources, have surprisingly not yet been consulted by the park management or donor agency. However, the park is a popular picnic site and obviously offers some very good opportunities for environmental education of the *Cochabambinos*. Unfortunately, all information activities are directed at the exotic trees with tracks and signboards in the plantation areas; the ecological paths take the visitor through *Eucalyptus* plantations, a forest habitat native to the Austral-asian region. One signboard guiding to a *“bosque nativo”* which was a small eroded ravine with a few *Polylepis* clinging to the steep slopes was noted. By using such information strategies the park management completely fails to educate the Bolivian public on aspects of High Andean ecology. Instead visitors gets the impression, that planted forests are superior to native forests.

A complete re-evaluation of the management and information strategy in *Parque Nacional Tunari* is therefore highly recommended and needed.

TU1, Parque Nacional Tunari, km 5
Pinus plantation (17°19'46.5"S 66°08'13.6"W), January 26–27, 1996. Altitude: 3,450 m, aspect: 220°, inclination: 15°. V_H : 0.021. An area with high (25–30 m, average DBH: 29 cm) *Pinus radiata* and very little undergrowth. Dead trees of *Polylepis besseri* ssp. *subtusalbida* observed inside the plantation. A small track leads to a ravine nearby with some *Polylepis.* Major disturbance was from tourists and cars. No bushy vegetation was present and only very little herbs and grasses (*Stipa ichu*) – general plant species richness was low (index: 2). Humus layer was thick (2 cm) due to deposition of spruce needles, and humidity was medium to high (index: 3). The avifauna was poor in species (9 species, 17 individuals), however a few pairs of *Scytalopus magellanicus* were nesting in large piles of dead pine branches left from tree logging. Furthermore, two *Atlapetes fulviceps* were feeding at the transition zone toward *Polylepis* habitat, and two *Columba fasciata* were resting in the pine tree tops.

TU2, Parque Nacional Tunari, km 8
Mixed native vegetation (17°20'03.3"S 66°08'14.5"W), January 30, 1996. Altitude: 3,320 m, aspect: 210°, inclination: 18°. V_H : 0.042. Medium land-use class. The study area is situated in the ravine between TU1 and TU3, and had a complex flora with a few high (25–30 m) *Pinus radiata*, several 2–3 m high *Polylepis besseri* ssp. *subtusalbida*, some pastures, and a clearing with high grasses and low bushes. Some large bushes were in flower and repeatedly visited by hummingbirds. Grazing occurred at the pasture and tourists used the tracks passing through. The avifauna was the most diverse of all areas (Shannon index: 4.16). Some of the species recorded were: *Colibri coruscans, Sappho sparganura, Asthenes dorbignyi, Diglossa carbonaria, Ampelion rubrocristatus, Saltator rufiventris, Poospiza hypochondria.*

TU3, Parque Nacional Tunari, km 8
Eucalyptus plantation (17°19'46.5"S 66°08'13.6"W), January 30, 1996. Altitude: 3,460 m, aspect: 210°, inclination: 10°. V_H : 0.03. Situated just east of TU2, this large plantation of *Eucalyptus globulus* has been established on former grassland formerly with an open woodland of *Polylepis besseri* ssp. *subtusalbida.* The ground vegetation was dominated by grasses (*Stipa ichu, Festuca* sp. , *Calmagrostris* sp.), and plant species richness was low (index: 1). Avifauna was poor (4 species, 10 individuals), with the lowest Rarity score of all areas (0.043).

TU4, Parque Nacional Tunari, km 11
Polylepis woodland (17°19'34.3"S 66°08'07.7"W), January 31, 1996. Altitude: 3,480 m, aspect: 271°, inclination: 16°. V_H : 0.421. Medium land-use class. A small area with open woodland of 2.5–3 m high *Polylepis besseri* ssp. *subtusalbida* and some bushes (*Baccharis polycephala, B. dracunculifolia, Lupinus altimontanus*), herbs, and grasses (*Stipa ichu, Calamagrostris* sp.). The main road was passing through this area, and some grazing took place. The avifauna was diverse (Shannon index: 3.79), and contained important species: *Melanoptera maximiliani, Saltator rufiventris*, and *Oreomanes fraseri*. One *Poospiza garleppi* was recorded in similar habitat just outside the limits of the study area.

TU5, Parque Nacional Tunari
Polylepis woodland (17°19'22.6"S 66°07'39.2"W), January 31–February 1, 1996. Altitude: 3,630 m, aspect: 214°, inclination: 15°. V_H: 0.784. Low land-use class. Small ravine with open *Polylepis besseri* ssp. *subtusalbida*, various bushes (*Baccharis polycephala, B. dracunculifolia* and *Lupinus altimontanus*), and a generally well developed herb and grass layer. Epiphytes covered substantial parts (mosses: 10%, lichens: 10%). Grazing took place in the area, and probably also some grass burning and wood logging, thus, regeneration of *Polylepis* was almost completely lacking. The surrounding steep slopes had large plantations of *Pinus radiata.* The avifauna was important with highest Rarity score recorded for all study areas: 3.41, and all high priority species of the Cochabamba area present: *Asthenes heteura* (9 individuals! – a family), *A. dorbignyi, Leptasthenura yanacensis, Oreomanes fraseri* (5 individuals), and *Saltator rufiventris.* Furtermore, several open-land species were recorded: *Cinclodes fuscus, Catamenia inornata,* and *Carduelis magellanica.* This study area illustrates well, that even moderately degraded native vegetation hosts a substantially diverse avifauna.

TU6, Parque Nacional Tunari
Pinus plantation (17°20'03,3"S 66°08'14,5"W), January 31–February 1, 1996. Altitude: 3,500 m, aspect: 208°, inclination: 12°. V_H : 0,097. Plantation of mature (15–20 m high, average DBH: 20.8 cm) *Pinus radiata* adjacent to TU5. A few dead and dying *Polylepis besseri* ssp. *subtusalbida* inside the plantation which had very thin ground vegetation due to lack of light. Several mushrooms encountered. In the few clearings some bushes grew (*Satureja boliviana, Baccharis dracunculifolia*). The avifauna hosted one pair of territory claiming *Saltator rufiventris* and a few more species: *Turdus chiguanco, Scytalopus magellanicus, Catamenia inornata,* and *Anairetes parulus.*

TU7, Parque Nacional de Tunari
Pinus plantation (17°20'03.3"S 66°08'14.5"W), March 28, 1996. Altitude: 3,600 m, aspect: 160°, inclination: 10°. V_H : 0.334. Plantation of mature (25 m high, average DBH: 19,8 cm) *Pinus radiata* with very little forest floor vegetation, due to shading from dense pine canopy. A few dying and dead *Polylepis besseri* ssp. *subtusalbida* were present (7.5% of the trees according to the PCQM measurements). Five per cent of the study area was covered with bushes (*Buddleja* sp., *Gynoxys* sp. and *Baccharis dracunculifolia*), and 28% with grasses. The avifauna was poor (4 species, 8 individuals), with two *Saltator rufiventris* which probably nested in one of the pines.

TU8, Parque Nacional Tunari
Pinus plantation (17°19’08.4”S 66°07’39.2”W), March 29, 1996. Altitude: 3640 m, aspect: 180°, inclination: 30°. V_H : 0.160. Plantation of 15 m high *Pinus radiata* (average DBH: 19.9) with a few *Polylepis besseri* ssp. *subtusalbida* (2.5% of the trees encountered in PCQM), and *Baccharis*. Adjacent a small ravine with native vegetation, serving as a natural habitat corridor inside a large area of *Pinus* plantation. Inside the study area only other woody plants were *Gynoxys* sp. Seven species of birds was recorded (12 individuals), with *Asthenes heteura* as most important species. The one *A. heteura* recorded was feeding in the pines close to the natural habitat corridor. Other recorded birds: *Scytalopus magellanicus*, *Phacellodomus striaticeps*, *Anairetes parulus*, *Saltator rufiventris* (1 individual), and *Carduelis magellanica*.

TU9, Parque Nacional Tunari
Pinus plantation (17°18’32.5”S 66°09’42.3”W), March 30, 1996. Altitude: 3,620 m, aspect: 20°, inclination: 33°. V_H : 0.018. Plantation of 10–12 m high *Pinus radiata* mixed with some native species: *Polylepis besseri* ssp. *subtusalbida* and *Berberis* sp. *Eucalyptus globulus* was planted at the border of the study area. The ground vegetation was poor with 10% coverage of herbs and 10% coverage of grasses. The avifauna (6 species, 10 individuals) was of mainly widespread and common species (Rarity score: 0.12): *Saltator aurantiirostris*, *Turdus chiguanco*, *Zonotrichia capensis*, and *Carduelis magellanica*.

TU10, Parque Nacional Tunari
Eucalyptus plantation (17°18’02.5”S 66°09’20.6”W), April 13, 1996. Altitude: 3,620 m, aspect: 192°, inclination: 15°. V_H : 0.052. Plantation of *Eucalyptus globulus* (15 m high, average DBH: 11.0 cm) with very little undergrowth but grasses (35% cover). *Gynoxys* and *Baccharis dracunculifolia* covered 5%, and general plant species richness was low (index: 1). Nearest occurrence of native forest vegetation was some 150–200 m away in a small ravine. Avifauna was the poorest of all localities with only 2 species recorded!: *Sappho sparganura* and *Carduelis magellanica*.

Southern study sites

POL 1, Acasio
Polylepis woodlands (18° 05´ 25"S 66° 08´ 39"W), April 5–April 12, 1995. Altitude 3,500 m. *Polylepis* woodlands on slope below Sacacca–Acasio road and in two narrow ravines above the road. Streams in the ravines. Younger trees covered with *Tillandsia*. The area is surrounded by scattered scrub and fields and is very eroded. Trees were being cut down for charcoal production, and clearings had been made in the woods for fields. Some evidence of coppice. Trees up to 8 m. Listed as locality DK–95, 1 in Fjeldså & Kessler (1996).

BTC1, Lajamayu
Bolivian Tucuman forest, (18° 21´ 30"S 65° 18´ 30"W), May 10 – May 16, 1995. Altitude 2,750 m. Quebrada Lajamayu just E of Estancia Khewiñal. Ravines with strips of dense humid montane forest typical of the Bolivian Tucuman formation. Dominated by *Polylepis*, *Podocarpus parlatorei* and *Myrcianthes callicoma*. Main ravine running north–south with stream in bottom. West facing slope dry with scrubs and scattered fire damaged *Polylepis* trees, intersected by small wooded ravines running into the main ravine. Estancia Khewiñal is a dry cultivated plateau approached by very bad roads via Laguna Jatun. Some slopes covered mainly by *Alnus acuminata* east of the actual study area. Listed as locality DK–95, 3 in Fjeldså & Kessler (1996).

SDE1, Mojon Punta
Semi-deciduous forest, (18° 14´ 24"S 65° 17´ 41"W), April 30–May 4, 1995. Altitude 2,500 m. In Cerro Mojon Punta. Forest in three ravines running north below the road between Estancia Novillero and Molinero. Trees up to 15 m. Elements of dry intermontane, semi-deciduous montane and humid forest. A few single standing *Polylepis* trees on the slopes. Many epiphytes and cacti on trees. Stream running in main ravine. Hilltops and upper slopes dominated by *Dodonea viscosa* scrub. Many cattle trails on the slopes.

SDE2, Thipa Khasa
Semi-deciduous forest (18° 18´ 15´´S 65° 15´ 19"W), May 5–May 8, 1995. Altitude 2,300 m. Cerro Thipa Khasa. One hours walk west from the crossing of Río Pappelon along the road to Estancia Novillero. Wooded slope facing east down towards Rio Papellon. Dry semi deciduous forest dominated by *Tipuana tipu* with trees up to 15 m. Some bushes typical of semi-deciduous humid forest in bottom of ravines. Much secondary shrubs cover on the more level upper slope. We could see more extensive forested slopes south further down river but were unable to access these areas. In the valley bottom along the river and on part of the slopes there was cultivation of maize. Many cattle trails on the slopes.

SDE3, Pajchamayu
Semi-deciduous forest, (18° 22´ 52"S 65° 17´ 18"W), May 15, 1995. Altitude 2,000 m. Quebrada Pajchamayu Slopes with dry semi-deciduous forest in valley bottom by a river. Approached by foot from BTC1 Lajamayu along path that drops nearly 1,000 m over 2 km. Strips of *Tipuana tipu* forest nearly continuos with Lajamayu grading into drier forest of *Schinopsis*, *Dodonea viscosa*, *Tecoma* and columnar cacti. Trees up to 18 m. Some epiphytes at the very bottom of ravines. Fields on the upper slopes and along the river.

SDE4, Pirhua Pirhua
Semi-deciduous forest, (18° 19´ 38"S 65° 00´ 10"W), May 19–May 23, 1995. Altitude 2,450 m. Five narrow ravines approached from below 1 km west of Estancia Pirhua Pirhua. Mixed semi-deciduous Myrtaceae/ *Tipuana tipu* forest with trees up to 12 m in bottom of

ravines. East facing slopes very much drier than those facing west due to exposure to morning sun. Dense undergrowth. *Dodonea viscosa* and *Baccharis* scrub cover on upper slopes and surrounding level areas. Cattle trails on the slopes. Surrounding lands very eroded but the forest seemed to continue on the other side of the ridges.

SDE5, Kiñi Pampa
Semi-deciduous forest (18° 18´ 58"S 64° 57´ 54"W), May 23–May 25, 1995. Altitude 2,200 m. Quebrada Kiñi Pampa four hours walk northeast of Estancia Pirhua Pirhua. Extensive dry forest in terrain of rolling hills. Humid undergrowth in bottom of ravines many with running water. *Tipuana tipu, Schinopsis haenkeana, Acacia, Tecoma,* and some Myrtaceae. Trees up to 15 m. Cover of *Dodonea viscosa* scrub on upper slopes and hill tops. Cattle trails on the slopes. The study area is part of the largest area with forest cover surveyed. Unfortunately, we were told by local people to leave the area after less than 36 hours.

SDE6, Puca Yacu
Semi-deciduous forest, (18° 20´ 03"S 64° 45´ 07"W), May 27–June 1, 1995. Altitude 2,350. Semi-deciduous forest in ravines below the road between Pasorapa and Estancia Jugadero. *Schinopsis, Acacia,* and *Alnus acuminata* along streams in bottom of ravines. Some Epiphytes (*Tillandsia* and cacti*)* on trees. East facing slopes were very much drier than the opposite sides due to exposure by morning sun.

SDE7, Buena Vista Loma
Semi-deciduous forest, (18° 21' 42''S 64° 46' 27''W), June 1, 1995. Altitude 2,300 m. Dry and semi-humid forest in ravines below the road to Estancia Jugadero. Trees up to 10 m mainly *Schinopsis* and *Acacia. Alnus acuminata* along streams in bottom of the ravines. Many epiphytes (*Tillandsia* and cacti) on trees.

SEC1, Tomata
Arid second growth scub. (18° 21´ 09"S 65° 51´ 48"W), March 31–April 4, 1995. Altitude 2,200 m. North facing lower slope by Rio San Pedro in nothern Potosi dpt. Very disturbed. Scattered bushes and trees. Many cut and burned trunks. Only few trees up to 7 m. Some small ravines with streams and dense bush cover. Strip of lush vegetation along the riverbanks not surveyed.

SCR1, Dodonea 1,
Second growth scub, (18° 19' 15''S 65° 00' 11''W), May 2, 1995. Altitude 2,300 m. Hilltop and east facing slope by Río Pappelon with ground cover of *Dodonea viscosa*, low cover of herbs and grasses.

SCR 2, Dodonea 2
Second growth scub, (18° 20' 08''S 64° 45' 08''), May 29, 1995. Altitude 2,450 m. Flat slopes facing southeast above the road between Pasorapa and Peña Colorado. Ground cover of *Dodonea viscosa.*

GRS1, Jugadero
Grassland, (18° 22' 09''S 64° 47' 18''W), May 31, 1995. Altitude 2,600 m. Grass covered slopes and hilltops near Estancia Jugadero with single standing scrub (*Baccharis).* Ground cover dominated by low grasses and herbs.

Appendix 2. Avifauna

by Thor Hjarsen, Nicholas Moray Williams and Poul Nygaard Andersen

This list covers, in taxonomic order, all bird species recorded during the fieldwork . We have also included Spanish, Quechua, and / or Aymara names in brackets, after the English name, whenever possible. These local names follow Armonía (1995), and / or Fjeldså & Kessler (1996).

After the species names, information on threat status according to IUCN's recent categories (IUCN 1994) according to and Stattersfield and others (in press). Then, follows the Rarity-score specific for each species, and a listing of the study areas with the area code, where the species was recorded. The localities are organised in accordance with the tree habitat class (EUC, PIN, POL, and MIX). Furthermore, the recorded density of the species in each of these classes is stated (number of individuals per sq. km). General notes are made on the species' distribution and habitat preference, based on Fjeldså & Krabbe (1990), Wege & Long (1995), Fjeldså & Kessler (1996). Furthermore, we comment on the apparent effects of the various tree habitats, and human land-use, that is the vulnerability of each species to human activities such as logging, agriculture, plantation forestry, etc. Some of the recorded species are new to the *Polylepis* avifauna, compared to the recently published *Polylepis* bird list in Fjeldså & Kessler (1996). Such species inhabit *Polylepis* in part of their range, but are also occurring in other forest or shrub habitats (Fjeldså 1992). We have marked these species with an asterisk (*).

At last, we have listed additional bird species that were recorded outside the study areas but in adjacent habitats, during trekking or driving. The comments following these additional species are only very brief.

Legend: The study areas where each species has been recorded are stated by the code (see Appendix 1 for details of each area), which have been sorted in each of four habitat classes used: POL: *Polylepis* woodlands, MIX: Mixed native forest vegetation, EUC: *Eucalyptus* plantations, and PIN: *Pinus* plantations.

Bird species recorded in study sites

Tinamidae – Tinamous

Rhynchotus maculicollis, Huayco Tinamou (Huayco).
Rarity score: 0.035. MIX (5 individuals / sq. km): LM2a+b. This species was formerly the highland-form of *R. rufescens*, until recently proposed to lift the highland-form to species rank, due to distinct song patterns (Maijer 1996). Very little is known on the ecology and status of this highland species. It was heard and tape recorded twice during the field work, in both cases at an open and moderately degraded *Polylepis* habitat, admixed with dense shrubbery. It was also heard calling near KP2.

Nothoprocta pentlandii, Andean Tinamou (Perdiz Serrana, Kullu, Kiula).
Rarity score: 0.011. POL (39 individuals / sq. km): CA3, KH2, KH3, MO1+2, MO4, SM1, SM3, SM4, SM5, TU4. MIX (44 individuals / sq. km): KH1, KP1, LI3a, PO2, PO4. EUC (20 individuals / sq. km): KP4, LI1, MO3, PO1, PO3. PIN (3 individuals / sq. km): LI2. Occurs along the Andes on slopes mainly in shrubsteppe and rather open woodlands. The species was mainly recorded by calls. Apparently, this important game bird avoids *Pinus* plantations probably because of lack of herb and grass cover which provides shelter and feeding grounds.
Southern study region: POL1

Nothura darwinii, Darwin's Tinamou (Perdiz de la Puna).
Rarity score: 0.009. POL (7 individuals / sq. km): KH3. Occurs in semi-arid habitats, grasslands and shrubbery of the Bolivian and Argentinean valleys, across the Altiplano to central Peru. The species were recorded (by calls) at several locations, all with open degraded *Polylepis* forest habitat, and in grassland.

Accipitridae – Hawks

Geronaetus melanoleucos, Black–chested Buzzard Eagle (Aguilucho Grande, Águila Mora).
Rarity score: 0.002. MIX (3 individuals / sq. km): LI3a. Widespread in South America up to the Andean puna zone. Occurs in rugged terrain with puna grassland and woodlands, including *Polylepis*. One bird was recorded hovering above an area with fields, pastures and degraded *Polylepis besseri*. Mature exotic plantations will probably be unsuitable as feeding areas, since this bird spots prey on ground level by sight.
Southern study region: SEC1, BTC1, SDE4.

Buteo polyosoma, Red–backed Hawk (Aguilucho de Loma Roja, Paca, Anca).
Rarity score: 0.003. POL (5 individuals / sq. km): CA3, TI1. MIX (3 individuals / sq. km): KH1. Widespread along the Andes up to the puna zone in areas with shrubbery, and thus also *Polylepis* woodlands. Recordings are to few to conclude anything on effects of plantations, but these will probably not hold sufficient with prey. Neither will the raptors enter dense *Pinus* plantations.

Buteo poecilochrous, Puna Hawk (Aguilucho de la Puna).
Rarity score: 0.014. POL (4 individuals / sq. km): CK1, SM3. Widespread in the puna zone from Bolivia north to the páramos of Colombia. Sometimes in stands of *Puya raimondii* and *Polylepis*. Exotic plantations provides probably not sufficient with prey to be

attractive for this large raptor.
Southern study region: POL1, BTC1.

Falconidae – Falcons

Phalcoboenus megalopterus, Mountain Caracara (Caracara Cordillerana, Chinalinda, María, Alkamari).
Rarity score: 0.009. MIX (5 individuals / sq. km): TI5. Common and distributed along the Andes mainly in the puna zone. Prefers open-land habitat where the birds often walk on pastures and roads searching for invertebrates and carcasses. Only recorded once, which is too rare to make generalisations on habitat preferences. It is assumed that the exotic plantations does not provide many feeding possibilities.
Southern study region: POL1, BTC1.

Falco femoralis, Aplomado Falcon (Halcón Plomizo, Mamani, Mamanilla)
Rarity score: 0.001. MIX (8 individuals / sq. km): KP1. Common and widely distributed in savannahs and highlands of South America sometimes around *Polylepis* woodlands. One family party (2 ad., 1 juv.) was recorded, hunting in an area of mixed forest woodland with some *Polylepis* and fields. The area was a preferred hunting location during 3 days and had high density of passerines.
Southern study region: POL1.

Falco sparverius, American Kestrel (Halconcito Común, Q'illi–Q'illi).
Rarity score: 0.001. MIX (5 individuals / sq. km): LI3a. Widespread throughout the Americas in open habitats with scattered trees and shrubbery including *Polylepis* woodlands. The species was recorded in one study area, and repeatedly at other localities in natural habitats of grasslands with shrubbery and woodlands.
Southern study region: SDE1.

Crasidae – Guans

Penelope obscura, Dusky–legged Guan (Pava de Monte Común).
Rarity score: 0.008. Southern study region: SDE4, SDE5, SDE6.

Columbidae – Doves and Pigeons

Columba fasciata, Band–tailed Pigeon (Paloma Nuca Blanca).
Rarity score: 0.006. MIX (26 individuals / sq. km): LI3a, LI3b. PIN (9 individuals / sq. km): TU1. Widespread in the Andean region from Venezuela to northern Argentina on wooded hill slopes, semi-arid cloud forests and secondary forest. One recording was done in a *Pinus* plantation in *Parque Nacional Tunari* of birds sleeping in tree tops of 25–30 m. high pines. Native forest habitats probably holds more feeding possibilities than exotic plantations. Important game bird for peasants.
Southern study region: SDE1.

Columba maculosa, Spot-winged Pigeon (Paloma Manchada).
Rarity score: 0.003. POL (18 individuals / sq. km): KH2, KH3, LM3. MIX (26 individuals / sq. km): KH1, LM1, LM2a+b. Widespread in lowlands and highlands of southern South America, mainly in humid to semi-arid woodlands and shrub. This species was only recorded in native forest habitats, and only in study areas with relatively undisturbed humid vegetation.
Southern study region: POL1, BTC1.

Zenaida auriculata, Eared Dove (Torcaza).
Rarity score: 0.001. MIX (21 individuals / sq. km): LI3a. Common and widespread in most of South America except the Amazonian rain forests. Occurs in semi-arid open-lands and savannahs near human settlements. The record was probably a straggler from the *Cochabamba* urban areas a few kilometres away, thus, the calculated density is arbitrary. Southern study region: SEC1, BTC1, SDE4.

Columbina picui, Picui Ground-dove (Chaicita, Torcacita).
Rarity score: 0.002. Southern study region: SEC1, SDE1, SDE6.

Columbina talpacoti, Ruddy Ground-dove. (Torcacita Común).
Rarity score: 0.001. Southern study region: SEC1.

Metriopelia ceciliae, Bare-faced Ground-Dove (Tortolida Moteada, Palomita, Cururuta).
Rarity score: 0.013. MIX (21 individuals / sq. km): KH1, LI3a, PO2. Widespread in the Bolivian and Peruvian Andes in shrubbery, woodlands and stands of cacti and puyas. The species was recorded in native forest habitats, and birds were often observed feeding on adjacent crop fields. Southern study region: POL1.

Metriopelia melanoptera, Black-winged Ground-Dove (Tortolita de Ala Negra, Palomita Cordillerana).
Rarity score: 0.007. POL (26 individuals / sq. km): CU3, OR2, SM4, SM5, TU4. MIX (13 individuals / sq. km): LI3b, OR1. EUC (3 individuals / sq. km): PO1. Widespread and common in the Andes in shrubbery and woodlands, and often observed feeding on pastures or agricultural areas. It is hunted by peasants. Small flocks were often recorded on fields inside *Polylepis* woodlands. The *Eucalyptus* habitat (PO1), was a quite small area located close to natural shrub vegetation. Southern study region: POL1.

Leptotila megalura, Large-tailed Dove Yerutí Yungueña).
Rarity score: 0.029. Southern study region: SEC1, SDE1, SDE2, SDE4, SDE5, SDE6.

Psittacidae – Parrots

Ara rubrogenys, Red-fronted Macaw (Paraba Frente Roja, Loro Burro, K' aka Loro). Endangered.
Rarity score: 0.167. Southern study region: SDE3. **Endemic** to Bolivia. Endangered because of persecution and habitat destruction. Nearly exclusively found in the Río Grande and northern Río Pilcomayu river valleys. Predominantly associated with dry semi-deciduous or deciduous subtropical woodland at 1,100–2,500 m (Collar and others 1992; Pitter & Christiansen 1995). Breeds semi-colonially in cliffs (Christiansen & Pitter 1994). Feeds in trees, bushes or on the ground for seeds, fruits and pods depending on seasonal availability during the year. In the dry season survives on fruits in semi-deciduous vegetation along rivers, but since these areas have now largely been modified, shows a preference for grown crops and is persecuted as a pest in maize- and peanut crops (Collar and others 1992; Pitter & Christiansen 1995). Own observations: Observed along Rio Chico in Department of Chuquisaca between Puente Arce and Chuqui Chuqui. On the 23 march 1995 between daybreak and 8.30am, 64 individuals were counted flying south in small groups along Río Chico at Ponte Chuqui Chuqui. During a five-hour stay at the bottom of Quebrada Pajcha Mayu (SDE3), seven km north of Rio Grande two individuals were observed together. In both areas, it is regarded as locally common (Pitter & Christiansen 1995).

Aratinga acuticaudata, Blue-crowned Conure. (Calancate Común).
Rarity score: 0.004. Southern study region: SDE5, SDE6.

Aratinga mitrata, Mitred Conure. (Calancate Cara Roja).
Rarity score: 0.036. Southern study region: SDE1, BTC1, SDE4, SDE5, SDE6.

Myiopsitta monachus, Monk Parakeet (Cotorra).
Rarity score: 0.004. Southern study region: SEC1.

Bolborhynchus aymara, Grey-hooded Parakeet (Perico de Capucho Gris, Catita Serrana Grande).
Rarity score: 0.022. POL (25 individuals / sq. km): KH2, OR2, SM1, SM3, SM4, SM5, TI1, MIX (87 individuals / sq. km): KH1, KP1, KP3, LI3a, LI3b, OR1, PO2, TI5, PIN (3 individuals / sq. km): CU2. Widespread in Valles and basins of the Andes in pre-puna zone in habitats with herbs, bushes and trees; often also *Polylepis*. The species feed on seeding grass, herbs and bushes. Apparently, the exotic plantations do not contain feeding plants attractive for this small parrot. Southern study region: SEC1, SDE1, POL1, SDE6.

Bolborhynchus orbygnesius, Andean Parakeet (Perico Andino).
Rarity score: 0.026. POL (7 individuals / sq. km): TU5. Rather locally distribution in the Andes of Bolivia and Peru, on shrubby slopes and mesothermic woodlands sometimes with *Polylepis*. Apparently, fond of areas with *Podocarpus*. The species was only recorded once in a study area, but often seen flying above. No birds was observed settling in exotic plantations.

Forpus xanthopterygius, Blue-winged Parrotlet (Periquita, Catita Enana).
Rarity score: 0.0025. Southern study region: POL1.

Brotogeris versicolurus, Canary-winged Parakeet. (Mariquita, Catita Chirirí).
Rarity score: 0.004. Southern study region: SDE6.

Cuculidae – Cuckoos

Piaya cayana, Squirrel Cuckoo (Cocinero, Piscua, Picuá, Tingazú).
Rarity score: 0.001. Southern study region: SDE5, SDE6.

Tytonidae – Barn Owls

Tyto alba, Barn Owl (Lechuza, Lechuza de Campanario).
Rarity score: 0.001. Southern study region: SDE1, SDE4, SDE5, SDE6.

Strigidae – Typical Owls

Otus choliba, Tropical Screech-owl (Sumurucucú, Alilicucu Común)
Rarity score: 0.001. Southern study region: SDE5, SDE6.

Glaucidium bolivianum, Pygmy-Owl.
Rarity score: 0.028. MIX (3 individuals / sq. km): LM2a, LM2b. Recently acquired species rank after split from *G. jardinii*. The species is confined to Bolivia and occurs in most of the forest habitats of the upper Andes, including *Polylepis*. This species was only observed once in a study area, and twice outside the study areas (fragmented habitats of *Polylepis besseri* near MO1+2 and TU5). All observations were made in native forest habitat. No complete surveys was done for nocturnal species in this study, thus, densities are biased. It is likely, that the owl also may inhabit mature *Pinus* plantations, since the trees provide good shelter. Southern study region: SDE6.

Aegolis harrisii, Buff-fronted Owl (Leucochita canelus). Low Risk, less concern.
Rarity score: 0.013. Southern study region: SDE6. Disjunct range at 2,000–3,900 m in dry regions mainly in ravines with dense *Polylepis*, *Alnus* or *Podocarpus* trees. Breeds in tree holes. One individual taped and seen at SDE6 in ravine with *Alnus* cover.

Caprimulgidae – Nightjars

Caprimulgus longirostris, Band-winged Nightjar (Chotacabras cerrano, Atajacaminos Ñañarca).
Rarity score: 0.003. MIX (3 individuals / sq. km): LM2a, LM2b. Widespread in the Andes and in the lowlands of southern South America, from semi-arid or humid forests to bushy ravines in the puna zone. One individual was recorded in an open, quite degraded

Polylepis woodland, where the bird was repeatedly flushed from the ground. No complete search was done for nocturnal species in this study, thus, it is not a useful density assessment. Southern study region: SDE1.

Trochilidae – Hummingbirds

Colibri coruscans, Sparkling Violetear (Colibri Oreja-violeta, Picaflor Cara Azul, Lulinchu).
Rarity score: 0.007. POL (44 individuals / sq. km): CK1, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TI1, TU4. MIX (90 individuals / sq. km): KP3, LI3a, LI3b, LM1, OR1, PO2, PO4, TI5, TU2. EUC (43 individuals / sq. km): LI1, PO1, PO3, TI2, TU3. PIN (58 individuals / sq. km): CU1, CU2, LI2, TI3, TI4, TU1. Common in the valleys in most of the Andes in woodlands, shrubbery, often near villages and flowering *Eucalyptus*. This species was recorded in a broad range of habitats, including plantations, where it often was observed singing from treetops. Birds were seen feeding on the large flowers of *Eucalyptus*. A widespread species that seems to occur with high densities also in exotic plantations. Southern study region: SEC1, SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Chlorostilbon aureoventris, Glittering-bellied Emerald. (Picaflor Común).
Rarity score: 0.002. Southern study region: SDE1, SDE2, SDE4, SDE5, SDE6.

Amazilia chionogaster, White-bellied Hummingbird. (Picaflor Vientre Blanco).
Rarity score: 0.01. Southern study region: SEC1, SDE1, SDE2, SDE4.

Oreotrochilus estella, Andean Hillstar (Picaflor-andino de Vientre Rayado, Picaflor Puneño, Luli).
Rarity score: 0.02. POL (2 individuals / sq. km): SM4. Widespread in the Andean puna zone in areas with *Puya raimondii* and *Polylepis* and associated feeding plants. The species was only recorded from one *Polylepis* locality, but observed in other areas, with either mixed native woodlands (often shrubbery in flower), or *Polylepis*. It will probably not occur in exotic plantations due to lack of suitable feeding plants such as *Brachyotum microdon*.

Oreotrochilus adela, Wedge-tailed Hillstar (Picaflor-andino de Cola Marginada). Near-threatened.
Rarity score: 0.083. POL (2 individuals / sq. km): OR2. Endemic to the Valles of Bolivia where it occurs in semi arid to temporarily humid shrubby habitats often in rocky areas. Arid *Polylepis* woodlands may often be suitable habitats, thus, the study area, where this species was recorded, was an arid heavily degraded *Polylepis* woodland. The surrounding slopes all had similar habitats and may probably house more birds of this species. The species has earlier been recorded nearby, at Vacas and at the *Incallajta* ruins (Fjeldså and Kessler 1996).

Patagona gigas, Giant Hummingbird (Picaflor Gigante, Lorenzo, Loro).
Rarity score: 0.008. POL (19 individuals / sq. km): CK1, KH3, SM1, SM3, SM4, SM5. MIX (21 individuals / sq. km): KP3, OR1, PO2, PO4, TI5. PIN (3 individuals / sq. km): CU1. Widely distributed in the arid and semi arid parts of the Andes where the bird often associates with shrubbery and woodlands incl. *Polylepis*. Feeds on various bushes and several species of *Puya*. Was never recorded in *Eucalyptus* plantations, and will probably not enter mature stands of *Pinus*, because the species prefer more open vegetation. Furthermore, the plantations apparently lacked suitable feeding plants. Southern study region: POL1, BTC1.

*Aglaeactis pamela**, Black-hooded Sunbeam (Raya-de-Sol Negra). Vulnerable.
Rarity score: 0.143. POL (26 individuals / sq. km): CA3, KP2, LM3, MO1+2, MO4. MIX (15 individuals / sq. km): LM2a, LM2b. This beautiful hummingbird is endemic to the Eastern Bolivian Andes in Cordillera Real from near La Paz to Cochabamba. The species prefers upper cloud forest habitats, and humid woodlands admixed with *Polylepis*. The bird was recorded in reasonable undisturbed woodlands with dense shrubbery, often with tall *Polylepis racemosa* ssp. *lanata* in the mountainous region north-east and east of Cochabamba close to the yungas. The birds seemed to accept some grazing, logging and small fields, but were lacking if the woodlands became too open, or replaced by exotic plantations.

Pterophanes cyanopterus, Great Sapphirewing (Picaflor Azul Grande).
Rarity score: 0.020. POL (4 individuals / sq. km): SM1, MIX (3 individuals / sq. km): KP3. In upper cloud forests along the Andes but enters also humid shrubbery and *Polylepis* woodlands. In both areas, where the species was recorded quite extensive agriculture took place, however substantial amounts of natural vegetation were present between field areas. The species was never recorded in exotic plantations. In addition, recorded in mixed vegetation near Quebrada Mojon and Misicuni (17°06’04.5”S 66°19’28.9”W 3,750 m).

Sappho sparganura, Red-tailed Comet (Colibri de Cola Larga Roja, Picaflor Cometa).
Rarity score: 0.015. POL (21 individuals / sq. km): CK1, CU3, KH2, SM3, SM4, SM5, TU5. MIX (28 individuals / sq. km): KP1, LI3a, LI3b, PO2, TI5, TU2. EUC (17 individuals / sq. km): CA1, PO3, TU10. PIN (3 individuals / sq. km): TU1. Widespread in Bolivia and Argentina in valleys and basins of the Andes. Occurs in semi arid and more humid shrubbery and woodlands. It was recorded in a wide variety of habitats including *Eucalyptus*, where it often was seen feeding on the large flowers. However, the *Eucalyptus* may probably not provide sufficient with nesting sites. The species were most abundant in mixed native

vegetation habitats. Southern study region: SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

*Metallura tyrianthina**, Tyrian Metaltail (Colibri Purpureo).
Rarity score: 0.014. POL (23 individuals / sq. km): KP2, MO1+2, MO4. MIX (15 individuals / sq. km): KP3, LM1, ML2a, LM2b. EUC (3 individuals / sq. km): MO5. Occurs all along the Andes south to Bolivia. Inhabits humid forests and tree line shrubberies. High densities were only recorded in natural vegetation habitats. Occurred also in quite degraded *Polylepis* habitats, if feeding was possible on "hummingbird flowers", such as *Brachyotum microdon*. The observation from *Eucalyptus* was in an area surrounded by *Polylepis* vegetation.

Acestrura mulsant, White-bellied Woodstar.
Rarity score: 0.018. EUC (3 individuals / sq. km): LI1. Disjunctly distributed along the Andes where it inhabits semi-humid forests and shrubs. Was recorded once in a mature and reasonably open stand of *Eucalyptus* just above the thermal baths in Liriuni. Probably a straggler from the plains of the Cochabamba Basin below. It is not possible to conclude on habitat preferences from one observation.

Bucconidae – Puffbirds

Nystalus maculatus, Spot-backed Puffbird.
Rarity score: 0.003. Southern study region: SEC1.

Picidae – Woodpeckers

Colaptes rupicola, Andean Flicker (Carpintero Andino, Pito, Yaca-Yaca).
Rarity score: 0.011. POL (4 individuals / sq. km): KH2, KH3. Widespread and common in the Andean puna zone from southern Ecuador to northern Argentina. Breeds in shrubbery habitats, also with *Polylepis* or *Puya raimondii*. Recorded from open woodlands with *Polylepis* in this study. More often, it was recorded in the grasslands on the adjacent slopes near *Polylepis* woodlands. An open-land species, that will not enter more dense stands of either natives or exotics. Southern study region: POL1, BTC1.

Colaptes melanochloros, Green-barred Flicker (Carpintero Real Verde / Común).
Rarity score: 0.002. POL (5 individuals / sq. km): SM3, TI1. MIX (13 individuals / sq. km): LI3b, PO4. EUC (7 individuals / sq. km): TI2, TU3. Occurs in sub-Andean zones of Argentina and Bolivia, but enters valleys and basins in Bolivia where it occurs in woodlands with *Alnus* and *Polylepis*. Observed in various types of native shrubbery and woodlands, and also in *Eucalyptus*. Still, abundance was highest in the mixed native vegetation habitats. Southern study region: SEC1, POL1, BTC1, SDE4.

Campephilus leucopogon, Creamed-backed Woodpecker. (Carpintero Lomo Blanco)
Rarity score: 0.008. Southern study region: SDE5, SDE6.

Campephilus melanoleucos, Crimson-crested Woodpecker. (Carpintero Garganta Negra).
Rarity score: 0.001. Southern study region: SDE2, SDE5.

Dendrocolaptidae – Woodcreepers

Sittasomus griseicapillus, Olivaceous Woodcreeper. (Tarefero).
Rarity score: 0.001. Southern study region: SDE5, SDE6.

Lepidocolaptes angustirostris, Narrow-billed Woodcreeper (Chinchero Chico).
Rarity score: 0.002. Southern study region: SEC1, SDE2, SDE4, SDE5, SDE6.

Furnariidae – Ovenbirds

Upucerthia andaecola, Rock Earthcreeper (Bandurrita de las Piedras, Bandurrita Cola Castaña).
Rarity score: 0.036. POL (4 individuals / sq. km): CK1, OR2. MIX (5 individuals / sq. km): KH1. In arid to semi-arid puna zone of northern Argentina and Valles of Bolivia where it occurs in open shrubbery and woodlands. The bird was only recorded in native vegetation habitats. It will probably not enter mature or dense plantations. Southern study region: POL1, BTC1.

Upucerthia ruficauda, Straight-billed Earthcreeper (Bandurrita (de) Pico Recto).
Rarity score: 0.013. POL (11 individuals / sq. km): KH2, KH3, KP2. Widespread and common in arid zones of several Andean countries north to Peru. Occurs on rocky slopes with shrubbery, *Puya* and open *Polylepis*. This species, preferring open-lands, was never recorded from exotic plantations.

Upucerthia harterti, Bolivian Earthcreeper. Near threatened.
Rarity score: 0.100. Southern study region: SDE6. **Endemic** to Bolivia at 1,400-3,000 m in arid montane scrub and edges of deciduous woodlands. Poorly known (Fjeldså & Krabbe 1990). Forages in low trees and shrubs, often on the ground (Ridgely & Tudor 1994). Recorded as common locally in arid scrub just south of Rio Grande in Chuquisaca Department (Krabbe and others 1996). One individual seen 30 may 1995 at Puca Yacu and one taped 1 June 1995 at Buena Vista Loma both in arid scrub.

Cinclodes fuscus, Bar-winged Cinclodes (Churrete Común, Kachiranka, Kacha).
Rarity score: 0.004. POL (4 individuals / sq. km): KH3, TU5. MIX (3 individuals / sq. km): KH1. Common in Andean puna and páramo zones often near streams or bogs with some shrubbery or trees providing shelter, including *Polylepis*. This semi-open land species was only recorded in native vegetation habitats. The bird feed on invertebrates on the ground, and exotic plantations may

probably not offer sufficient with food, or shelter possibilities. Southern study region: POL1, BTC1, SDE5.

Cinclodes atacamensis, White-winged Cinclodes (Churrete Castaño, Remolinera Castaño).
Rarity score: 0.011. MIX (3 individuals / sq. km): KH1. Widespread in the Andean puna zone and more narrowly attached to streams than *C. fuscus*. It was recorded in one open stand of mixed native vegetation which was close to a large stream. Never observed in exotic plantations. The bird is primarily an open-land species which occurs near permanent streams.

Furnarius rufus, Rufous Hornero (Hornero, Tiluchi, Ayumbicay).
Rarity score: 0.002. POL (2 individuals / sq. km): SM3. MIX (3 individuals / sq. km): KP3. Widespread and common in the south-eastern lowlands of South America. Occurs locally in Andean valleys and basins up to 3500 m, mostly close to human settlements. The bird was recorded in natural vegetation, but due to the wide distribution in many different habitats, it will probably also occur in exotic plantations if these provide sufficient feeding possibilities. Plantations near gardens and fields may thus be inhabited. Southern study region: SEC1, SDE2.

Leptasthenura fuliginiceps, Brown-capped Tit-Spinetail (Tijeral de Capucho Marrón, Coludito Canela).
Rarity score: 0.022. POL (18 individuals / sq. km): CU3, SM1, SM2, SM3, SM4. MIX (15 individuals / sq. km): KP1, TI5. PIN (3 individuals / sq. km): TI4. Distributed in the pampas and Andean region of Bolivia and north–western Argentina in arid and semi-arid shrubbery and woodlands. The species was mainly recorded in native woodland habitats with *Polylepis*, *Baccharis* and *Gynoxys*. The *Pinus* recording (TI4), was in an area with "corridors" of *Polylepis* admixed. *Pinus* will to some extend provide the bird with sufficient shelter and insects. *Eucalyptus* may be too open, and with to low food availability. Southern study region: POL1, BTC1.

Leptasthenura yanacensis, Tawny Tit-Spinetail (Tijeral Rufo). Near-threatened.
Rarity score: 0.059. POL (26 individuals / sq. km): CA3, CU3, KH2, KH3, TI1, TU5. MIX (5 individuals / sq. km): KH1. Disjunct occurrence from Bolivia to southern Peru, mainly in *Polylepis*, but in the south also in more mixed shrubbery. In the Cochabamba area this species is apparently totally dependent on *Polylepis* woodlands. Was never recorded in exotic plantations, thus, destruction of *Polylepis*, or replacement with exotics, may be threats to the species in the Cochabamba area. The species was also recorded at several other localities with native vegetation. Southern study region: POL1. One individual seen 9 April 1995 foraging in ravine with *Polylepis* at POL1.

*Synallaxis superciliosa**, Azara's Spinetail (Genérico, Checui).
Rarity score: 0.011. POL (2 individuals / sq. km): KP2. MIX (3 individuals / sq. km): OR1. The species is widely distributed along the Andean mountain chain and quite common in arid and semi-arid shrubbery and woodlands. The ssp. *superciliosa* is confined to Bolivia and northern Argentina. This shy species was only recorded in dense shrubbery of natural vegetation. The bird will probably only occur in exotic plantations if dense bush vegetation is present. Southern study region: SDE1, SDE2, BTC1, SDE4, SDE5, SDE6.

*Schizoeaca harterti**, Black-throated Thistletail. Least concern.
Rarity score: 0.200. POL (9 individuals / sq. km): LM3, MO1+2. Endemic to the Cochabamba *yungas*. Fairly common in humid forests and shrubbery including *Polylepis*. The bird was recorded in dense undergrowth of humid and reasonably undisturbed *Polylepis racemosa* forests. The localities were confined to the humid slopes near the *yungas*. Clearly, exotic plantations will not provide sufficiently with dense undergrowth to sustain this quite secretive species.

Cranioleuca pyrrhophia, Stripe-crowned Spinetail (Curutié Blanco).
Rarity score: 0.005. Southern study region: SEC1, SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Asthenes dorbignyi, Creamy-breasted Canastero (Canastero Castaño, Canastero Rojizo)
Rarity score: 0.036. POL (54 individuals / sq. km): CK1, KH2, KH3, KP2, MO4, OR2, SM1, SM4, SM5, TI1, TU5. MIX (59 individuals / sq. km): KH1, KP1, KP3, LI3a, LI3b, OR1, TU2. EUC (7 individuals / sq. km): KP4. PIN (3 individuals / sq. km): LI2. This species is taxonomic complex and several subspecies could be valid species. The ssp. *dorbignyi* in Bolivia and northern Argentina inhabits the pre-puna zone with open cacti stands, shrubbery, and woodlands with *Polylepis* admixed. The bird was found in a variety of habitats from dense shrubbery to very open *Polylepis* woodlands. This common and widespread bird was surprisingly rare in exotic plantations. The birds often occurred near houses and fields, if native shrub was present. Southern study region: SDE1, POL1, BTC1, SDE4, SDE5, SDE6.

*Asthenes heterura**, Maquis Canastero (Canastero de Iquico). Vulnerable.
Rarity score: 0.250. POL (33 individuals / sq. km): CU3, OR2, SM4, SM5, TI1, TU5. MIX (23 individuals / sq. km): KH1, LI3b, OR1. PIN (3 individuals / sq. km): TU8. Endemic to the Bolivian Valles and locally distributed in dense scrub and *Polylepis* woodlands. Observations were almost exclusively from native vegetation habitats, where the bird was often seen feeding in *Polylepis*. The *Pinus* habitat recording (TU8), was made in a plantation surrounded by and admixed with *Polylepis besseri*. Survival of local populations of this species will depend on the presence of native woodlands and shrubbery. Exotic plantations, replacing the native high Andean woodlands may thus be a direct threat. The species occurred also in areas with quite high human disturbances. In addition, the species was also recorded

in an area adjacent to LM1, and in the Misicuni region (17°06'04.5"S 66°19'28.9"W).

Asthenes sclateri, Puna Canastero.
Rarity score: 0.024. POL (2 individuals / sq. km): OR2. Distributed in the Andean puna zone from Laguna Titicaca to northern Argentina where it inhabits open bunch grasslands and open *Polylepis* woodlands. The bird was recorded in one study area with open *Polylepis* woodland, however it was mainly observed in puna vegetation above 3,500 m.

Phacellodomus striaticeps, Streak-fronted Thornbird (Esperino Andino, Esperino de Frente Rayada).
Rarity score: 0.033. POL (75 individuals / sq. km): CA3, CU3, KH3, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TI1, TU5. MIX (23 individuals / sq. km): KP1, LI3a, LI3b, OR1, PO2. PIN (24 individuals / sq. km): CU1, CU2, TI3, TU8. Common in Bolivia and northern Argentina up to pre-puna zone. Inhabits semi-arid and temporarily humid thornscrub, and woodlands with *Polylepis*. This widespread species was found in a broad variety of habitats, also near houses and fields, and in *Pinus* plantations. These plantations often had *Polylepis*, *Baccharis* or *Gynoxus* admixed, or were at least close to native shrubbery or woodlands. The species was never recorded in *Eucalyptus* plantations.

Phacellodomus striaticollis, Freckle-breasted Thornbird.
Rarity score: 0.011. Southern study region: SDE6.

Formicariidae – Antbirds

Thamnophilus caerulescens, Variable Antshrike (Choca Común).
Rarity score: 0.002. Southern study region: SDE4, SDE5, SDE6.

Thamnophilus ruficapillus, Rufous-capped Antshrike (Choca Corona Rojiza).
Rarity score: 0.006. Southern study region: SDE1, SDE2, SDE4, SDE5, SDE6.

Rhinocryptidae – Tapaculos

Melanopareia maximiliani, Olive-crowned Crescent-chest (Gallito de Collar).
Rarity score: 0.039. POL (4 individuals / sq. km): SM4, TU4. MIX (10 individuals / sq. km): LI3a, LI3b, PO2, PO4. Occurs in yungas and lowlands in south-eastern Bolivia into northern Argentina, but enters locally the valleys and basins of the Andes. Inhabits in the Andes semi-arid shrubbery and woodlands including *Polylepis*. This insectivore species was recorded in native vegetation habitats and never in exotic plantations. One reason could be insufficient food resources, and lack of ground cover for this secretive species. Southern study region: SDE2, BTC1.

Scytalopus magellanicus, "Andean Tapaculo" complex [White-browed Tapaculo].
Rarity score: 0.067. POL (60 individuals / sq. km): CA3, CU3, KH2, KP2, LM3, MO1+2, MO4, SM1, SM5, TI1, TU5. MIX (46 individuals / sq. km): LM1, KP1, LM2a, LM2b, OR1, TI5. PIN (36 individuals / sq. km): CA2, TU1, TU6, TU7, TU8, TU9. Widespread in the Andes and Brazilian highlands. Taxonomic complex genus under revision. The birds inhabit dense undergrowth, where they quietly move around very mouse-like. Often recorded by the characteristic song vocalisation with loud series of "tycks", repeated now and then from dense undergrowth. This species was never recorded in *Eucalyptus* plantations, probably because of lack of dense undergrowth. The *Pinus* plantations in *Parque Nacional Tunari* are production stands with some coppice at borders and in recent clearings. There was often also piles of dead branches and logs on forest floor. In such "micro-habitats" the tapaculos were recorded. The birds were probably relatively easier to detect in the *Pinus* plantations, than in the natural woodlands with denser understory. Thus the high density recorded in *Pinus* is maybe a sample bias. The species is closely associated with dense undergrowth, and is therefore suitable as "indicator species" for evaluation of biological richness and complexity in study areas. Southern study region: POL1. Two individuals seen at POL1 in undergrowth of *Polylepis* woodland

Cotingidae – Cotingas

*Ampelion rubrocristatus**, Red-crested Cotinga (Cotinga de Cresta Roja).
Rarity score: 0.015. POL (42 individuals / sq. km): CA3, KP2, LM3, MO1+2, MO4, SM1, SM2, SM3, SM5. MIX (21 individuals / sq. km): LM1, LM2a, LM2b, TI5, TU2. EUC (7 individuals / sq. km): MO3. Distributed along the Andes in humid and semi-humid forests and woodlands, including humid *Polylepis* woodlands. Generally this species was found in quite dense habitats with *Polylepis* and *Alnus*, mainly in sheltered ravines. In Quebrada Mojon, the species was abundant and two birds were recorded in a young and open *Eucalyptus* plantation surrounded by native woodland. The exotics will normally not provide nesting sites, but may be used as singing posts to mark territories, because the birds favoured to be perched in tree tops.

Tyrannidae – Tyrant Flycatchers

Camptostoma obsoletum, Southern Beardless Tyrannulet (Piojito Silbón).
Rarity score: 0.001. Southern study region: SDE4.

Suiriri suiriri, Suiriri Flycatcher.
Rarity score: 0.002. Southern study region: BTC1, SDE6.

Elaenia albiceps, White-crested Elaenia (Fiofío Silbón).
Rarity score: 0.004. POL (2 individuals / sq. km): MO1+2. MIX (44 individuals / sq. km): KP1, LI3a, LI3b, PO2. Widespread in most of South America in a variety of

shrubbery and forest habitats, including Andean forests. Feeds on insects and berries. Never recorded from exotic plantations, probably due to lack of food items. Recorded in relatively high densities in mixed native vegetation habitats. Southern study region: SEC1, SDE1, BTC1, SDE5, SDE6.

Elaenia strepera, Slaty Elaenia, (Fiofío Plomizo). Low Risk, less concern.
Rarity score: 0.043. Southern study region: SDE1, SDE2. At 1,500 - 2,300 m The breeding range is restricted to a small area of the Andes in northwestern Argentina and southern Bolivia (Tarija, Chuquisaca, probably also Santa Cruz departments) (Marantz & Remsen 1991). Found in bushes and trees along streams in wooded valleys as well as forest borders (Ridgely & Tudor 1994). Searches for insects from bushes, or hover-gleans for berries (Fjeldså & Krabbe 1990).

Mecocerculus leucophrys, White-throated Tyrannulet (Piojito Gargantilla, Tiranillo de Garganta Blanca).
Rarity score: 0.007. POL (21 individuals / sq. km): KP2, LM3, MO1+2, MO4. MIX (18 individuals / sq. km): LM1, LM2a, LM2b, OR1, TI5. Common and widespread in Andean humid forests - also in higher parts, where it enters *Polylepis* and *Alnus* habitats. The species was never recorded in exotic plantations, probably due to insufficient amounts of insects, on which it feeds. Newly fledged nestlings were observed in an area with agricultural fields and *Polylepis racemosa* ssp. *lanata* admixed (Quebrada Mojon). Southern study region: SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Serpophaga munda, White-bellied Tyrannulet (Piojito Vientre Blanco).
Rarity score: 0.017. MIX (3 individuals / sq. km): LM1. In semi-arid and arid regions from western Bolivia to central Argentina in shrubbery and forests. It was once recorded in a locality with fields, grazing pastures and also substantial amounts of native vegetation admixed, such as *Citharexylum* and *Baccharis*.

Stigmatura budytoides, Greater Wagtail-Tyrant (Calandrita).
Rarity score: 0.006. MIX (3 individuals / sq. km): PO2. Widespread in lowlands of South America in thorny woodlands. Occurs in the Andean valleys and basins in arid and semi-arid habitats. It was recorded from a locality with generally large influx of lowland avifauna due to closeness with the Cochabamba Basin. The habitat had mixed semi-humid vegetation with no *Polylepis* or exotics present. Southern study region: SEC1, SDE1, SDE2, SDE4, SDE5, SDE6.

Anairetes flavirostris, Yellow-billed Tit-tyrant (Cachudito Pico Amarillo).
Rarity score: 0.005. Southern study region: SDE1, SDE2, BTC1, SDE4.

Anairetes parulus, Tufted Tit-Tyrant (Cachudito de Copeta, Cachudito Pico Negro).
Rarity score: 0.004. POL (63 individuals / sq. km): CK1, CU3, KH2, KP2, MO1+2, MO4, OR2, SM1, SM4, SM5, TI1. MIX (46 individuals / sq. km): KP1, LI3a, LI3b, LM1, OR1, PO4, TU2. PIN (15 individuals / sq. km): CU1, TU6, TU8, TU9. Common and widespread in most of the Andes in semi-humid habitats of bushland or woodlands including *Polylepis*. Dense, small-leafed trees and bushes are preferred. It was recorded in a variety of habitats including *Polylepis* stands in areas heavily used by the peasants. The species also occurred in *Pinus* plantations, and in a single *Eucalyptus* plantation. All these plantations had either some *Polylepis* admixed, or *Polylepis* occurring at close range, however, the species was never recorded in pure stands of *Eucalyptus*, and only in low abundance in *Pinus*. Southern study region: POL1, BTC1.
Hemitriccus margaritaceiventer, Pearly-vented Tody-tyrant (Mosqueta Ojo Dorado).
Rarity score: 0.002. Southern study region: SDE6.

Ochthoeca rufipectoralis, Rufous-breasted Chat-Tyrant (Pitajo de Pecho Rufo).
Rarity score: 0.013. POL (2 individuals / sq. km): LM3. Generally distributed in the Andes in humid and semi-humid montane forests. It was once recorded in a study area of *Polylepis* habitat, but furthermore observed at other localities, where *Polylepis* dominated the vegetation. Never recorded in exotic plantations.

Contopus fumigatus, Greater Pewee (Burlisto Copetón). Rarity score: 0.007. Southern study region: SDE1, SDE2, SDE5.

Ochthoeca oenanthoides, D'Orbignyis Chat-Tyrant (Pitajo de d'Orbignyi Pitajo de Canela).
Rarity score: 0.012. POL (9 individuals / sq. km): KH2, SM5. MIX (13 individuals / sq. km): KH1, LM2a, LM2b. Quite common in High Andean woodlands in the puna zone mainly in *Polylepis* habitats. The species was only recorded in habitats of native vegetation, often also in areas with quite high logging pressures. Never recorded in exotic plantations, probably due to lack of sufficient food items. Southern study region: POL1.

Ochthoeca leucophrys, White-browed Chat-Tyrant (Pitajo de Seja Blanca, Pitajo Gris).
Rarity score: 0.013. POL (18 individuals / sq. km): KH2, MO1+2, MO4, SM5, TU5. MIX (51 individuals / sq. km): KP1, KP3, LI3a, LM1, LM2a, LM2b, OR1. PIN (3 individuals / sq. km): TI4. Widespread in the Andes in drylands with shrubbery, and woodlands including *Polylepis*. Recorded at several localities, mainly in habitats with open vegetation, some pastures or bunchgrasses, and with understory of bushes and herbs. Such areas probably provide sufficient with insects. Only recorded once in an exotic plantation of young *Pinus radiata*, with some *Polylepis besseri* admixed. Southern study region: SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Polioxolmis rufipennis, Rufous-webbed Bush-Tyrant (Tiránido de Membrana Rufa).

Rarity score: 0.019. POL (7 individuals / sq. km): KH2, KP2. MIX (8 individuals / sq. km): KH1, LI3b. Locally in highlands of Peru and Bolivia in *Polylepis* woodlands. This species was only recorded in native vegetation habitats with *Polylepis* admixed. The areas were often fragmented woodlands with small pastures. Such fragmented vegetation supports the feeding habits of this bird: It often glides from branches to the ground to pick up insects. Exotic plantation "ecosystems" will probably not provide this quite large insectivore sufficient prey.

Agriornis montana, Black-billed Shrike-Tyrant (Arriero de Pico Negro).
Rarity score: 0.005. POL (4 individuals / sq. km): OR2. Mainly a bird of the open puna zone throughout the Andes, but often seen close to *Polylepis* woodlands. It was once recorded in a study area of open, bushy *Polylepis besseri*. Other observations were from similar habitats.

Muscisaxicola alpina, Plain-capped Ground-Tyrant (Dormilona Cenicienta, Tayankallo).
Rarity score: 0.016. POL (4 individuals / sq. km): KH2, OR2. Widespread and generally common in puna and páramo zone from Colombia to Bolivia on grasslands and sometimes in association with *Polylepis*. It was recorded twice in open *Polylepis* woodlands, of which one (KH2) was with mature trees with low regeneration due to grass burning. The other study area (OR2), had low trees due to cutting for firewood and domestic grazing. Continuos plantations of exotic tree species will exclude this species.

Muscisaxicola maculirostris, Spot-billed Ground-tyrant (Dormilona Chica).
Rarity score: 0.005. Southern study region: SDE4.

Muscisaxicola rufivertex, Rufous-capped Ground-tyrant (Dormilona Gris).
Rarity score: 0.009. Southern study region: BTC1.

Knipolegus atterimus, White-winged Black-Tyrant (Viudita Común)
Rarity score: 0.006. POL (4 individuals / sq. km): OR2. MIX (10 individuals / sq. km): LI3a, OR1, PO2. PIN (9 individuals / sq. km): CU1, LI2. Disjunctly distributed in southern Peru and Bolivia, and into Argentinean pampas zone in arid and semi-arid bushlands and shrubs. The species was found in a few areas with open vegetation of bushes and trees admixed bunchgrasses. The recordings made in *Pinus* were from areas with young trees maximum 7 - 8 m high admixed some native bush species and bunchgrass. A species of fragmented bush - and woodlands that will not occur in denser plantations of either *Eucalyptus* or *Pinus*. Southern study region: SEC1, SDE1, SDE2, BTC1, SDE4, SDE5, SDE6.

Satrapa icterophrys, Yellow-browed Tyrant (Suirirí Amarillo).
Rarity score: 0.002. MIX (5 individuals / sq. km): PO2. Widespread in most of South American lowlands where the species occur in a broad variety of bush and forest vegetation habitats. Two individuals were recorded in Potreros in a habitat of low, degraded vegetation with bushes, herbs and grasses. Southern study region: SDE1.

Hirundinea ferruginea, Cliff Flycatcher (Birro Común).
Rarity score: 0.002. MIX (3 individuals / sq. km): OR1. Widespread in savannahs south of Amazon and in the Guyana highlands. Also enters the valleys and basins of Bolivia where it occurs in Andean semi-arid woodlands often in association with rocks and boulders. The species was recorded in one study area, and several additional birds were seen in habitats with patchy *Polylepis* near steep, rocky slopes. The species was never observed in exotic plantations (a breeding pair was nesting near Sjoerd Maijer's house in Calle Zegarra, central Cochabamba). Southern study region: SEC1, SDE1, SDE2, BTC1, SDE4, SDE5.

Myiarchus tuberculifer, Dusky-capped Flycatcher (Burlisto Corona Negra)
Rarity score: 0.001. MIX (3 individuals / sq. km): PO2. Mainly distributed in northern South American lowlands and Andean valleys to northernmost Argentina. Occurs in both dry and humid forest types including gardens. One bird was recorded at Quebrada Potreros in a habitat of low, degraded vegetation of bushes, herbs and grasses. Southern study region: SDE1, POL1, SDE2, SDE5.

Xenopsaris albinucha, White-naped Xenopsaris (Tijerilla).
Rarity score: 0.003. Southern study region: SDE4, SDE6.

Pachyramphus validus, Crested Becard (Anambé Grande).
Rarity score: 0.002. Southern study region: SDE2.

Phytotomidae - Plantcutters

Phytotoma rutila, White-tipped Plantcutter (Cortarramas).
Rarity score: 0.007. Southern study region: SEC1.

Hirundinidae - Swallows and Martins

Notiochelidon murina, Brown-bellied Swallow (Golondrina de Vientre Castaño).
Rarity score: 0.013. POL (14 individuals / sq. km): KP2, MO4. Widespread near humid montane shrubbery and *Polylepis* woodlands throughout the tropical parts of the Andes.The birds were recorded in two study areas inside quite large stretches of *Polylepis*. In addition, it was observed in other areas near larger *Polylepis* woodlands. The air above the native forests apparently holds sufficient with insects to attract the swallow. The species was never observed foraging

above plantations.

Notiochelidon cyanoleuca, Blue-and-White Swallow (Siluri). Rarity score: 0.001. MIX (18 individuals / sq. km): TU2. Occurs in most of South America in almost all types of habitats including urban areas. A flock was recorded feeding in an open area of a mixed vegetation with a few large pines. Southern study region: SEC1, SDE1, SDE4.

Hirundo andecola, Andean Swallow (Golondrina Andina). Rarity score: 0.019. POL (23 individuals / sq. km): KH3, TU5. MIX (5 individuals / sq. km): KH1. Widespread in the Andean puna of Peru and Bolivia where it also occurs in association with open *Polylepis* woodlands. Like *Notiochelidon murina* only native woodland habitats provide sufficient with flying insects to attract swallows. Was never recorded in association with exotic plantations.

Corvidae - Crows, Jays and allies

Cyanocorax chrysops, Plush-crested Jay (Suso, Urraca Común).
Rarity score: 0.003. Southern study region: SDE5, SDE6.

Troglodytidae - Wrens

Troglodytes aedon, House Wren (Chichuriro, Ratona Común, Cucarachero Común)
Rarity score: 0.001. POL (2 individuals / sq. km): TU4. MIX (15 individuals / sq. km): KP3, LI3b, TU2. PIN (9 individuals / sq. km): TI4, TU1. Widespread and common (“supertramp”) in South America in lowlands and montane areas. In the Andes often in *Polylepis* habitats up to 4,500 m. The species was recorded from rather few localities probably due to its secret behaviour. It moves around in dense vegetation near the ground, where it searches for insects. The bird often reveals itself by the characteristic high pitched song, or snarling alarm calls. Southern study region: SEC1, SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Mimidae - Mockingbirds

Mimus dorsalis, Brown-backed Mockingbird (Calandria Castaña).
Rarity score: 0.04. POL (4 individuals / sq. km): CK1. Near-endemic (restricted range) in Andean basins of Bolivia and northern Argentina, and a few isolated populations in extreme north-western Bolivia and adjacent Chile. Inhabits arid open-lands with shrubs and woodlands admixed. In the Cochabamba area the species is often associated with *Scinus molle* and in some places also *Polylepis*. Birds were recorded in the degraded habitat of the critically endangered *Polylepis tomentella* ssp. *nana* south-east of Arani. Below Liriuni in agricultural lands with *Scinus*, many individuals were counted. It may very likely also enter open *Eucalyptus* and young *Pinus* plantations, since such habitats do not differ much in humidity and plant diversity from the arid shrub-lands. Southern study region: BTC1.

Turdidae - Thrushes

Turdus chiguanco, Chiguanco Thrush (Zorzal Chiguanco, Chiguanco).
Rarity score: 0.006. POL (118 individuals / sq. km): CA3, CK1, CU3, KH2, KH3, KP2, LM3, MO1+2, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TU4, TU5. MIX (133 individuals / sq. km): KH1, KP1, KP3, LI3a, LM1, LM2a, LM2b, OR1, PO2, PO4, TI5, TU2. EUC (57 individuals / sq. km): CA1, LI1, MO3, PO1, PO3, TI2, TU3. PIN (33 individuals / sq. km): CU1, TU1, TU6, TU7, TU9. Widespread in puna and páramo habitats in the Andes. Occurs in woodlands and shrublands, including *Polylepis*. One of the most abundant species in this study with 147 records. Still the species occurred with highest densities in the natural vegetation classes compared to the exotic plantations. The exotic plantations, thus, displaced even this common species. Southern study region: SEC1, SDE1, POL1, SDE2, BTC1.

Polioptilinae - Gnatcatchers

Polioptila dumicola, Masked Gnatcatcher (Tacuarita Azul).
Rarity score: 0.003. Southern study region: SEC1, SDE2, SDE4, SDE5, SDE6.

Vireonidae - Vireos and allies

Cyclarhis gujanensis, Rufous-browed Peppershrike (Juan Chiviro).
At 3,500 m in semi-humid *Alnus* woodland in Quebrada Falsuri (17°19’05.5”S 66°19’09.2”W) located just west of Liriuni. Southern study region: SDE1, POL1, SDE4, SDE5.

Vireo olivaceus, Red-eyed Vireo (Chiví Común).
Rarity score: 0,004. Southern study region: SDE1, SDE2, SDE5.

Icteridae - Icterids

Molothrus badius, Bay-winged Cowbird (Tordo Músico).
Rarity score: 0.003. POL (9 individuals / sq. km): SM1, SM2, SM3, SM4. MIX (103 individuals / sq. km): KP1, KP3, LI3b, OR1, PO2, TI5. EUC (33 individuals / sq. km): CA1, LI1, MO5. PIN (12 individuals / sq. km): LI2, PO1. Widespread in semi-arid bush and woodland habitats in Bolivia and Argentina. Often in urban areas or villages near fields and pastures. This bird is not a *Polylepis* specialist, and does therefore not occur in high densities in this habitat. Instead, habitats with mixed native vegetation influenced by humans (like Quebrada Potreros) often had high abundance of this species, and apparently the birds also inhabited exotic plantations at quite high densities. Southern study region: SEC1, POL1, SDE2.

Oreopsar bolivianus, Bolivian Blackbird. Least concern. Rarity score: 0.333. EUC (13 individuals / sq. km): PO3. Endemic to the Cochabamba Basin, where it occurs mainly in dry habitats at 2,400-3,200 with sparse ground cover, cacti, and scattered trees. Requires cliffs for nesting. Often seen in flocks. Forages in groups of usually three to eight, on the ground for insects and arthropods, gleans insects from leaves and branches of small shrubs (especially *Dodonea*) (Fjeldså & Krabbe 1990). A flock was recorded roosting in the tree tops of a small *Eucalyptus* plantation near a steep cliff. The plantation did probably not provide special opportunities, other than resting posts near nesting area. Southern study region: SEC1. Group of six at SEC1 and three in Quebrada Bella Vista along Rio Chico.

Parulidae - Wood-warblers

Myioborus brunniceps, Brown-capped Whitestart. (Candelita de Capucho Marrón, Arañero Corona Rojiza).
Rarity score: 0.018. POL (18 individuals / sq. km): CU3, SM4, SM5. MIX (21 individuals / sq. km): OR1, PO2, PO4, TI5. A relatively common bird in semi-evergreen forests of Bolivia and Argentina. Occurs even in very small thickets of bushes and trees, including *Polylepis*, *Gynoxys* and *Baccharis*. It was never recorded in exotic plantations. Southern study region: SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Parula pitiayumi, Tropical Parula (Pitiayumí).
Rarity score: 0.001. Southern study region: SDE5, SDE6.

Coerebidae - Honeycreepers

Conirostrum cinereum, Cinereous Conebill (Mielerito Cinerero).
Rarity score: 0.013. POL (4 individuals / sq. km): SM3. Widespread in the higher Andes from Ecuador to Bolivia and on the entire pacific slope in Peru. Inhabits both humid and arid shrub-lands and woodlands in its range. Often in *Polylepis*. The species was only recorded once inside the study areas, but it was also observed at several other *Polylepis* habitats (in Quebrada Mojon and Kehuiña Pampa).

Oreomanes fraseri, Giant Conebill (Párajo de Quenales). Near-threatened.
Rarity score: 0.023. POL (32 individuals / sq. km): CU3, MO4, SM2, SM3, TI1, TU4, TU5. This disjunctly distributed, and locally relatively common bird, is closely associated with *Polylepis* habitats where it forages for insects and spiders by flaking bark on trunks and branches. Seems to be very sedentary, remaining in high altitude *Polylepis* patches even under extreme weather conditions (Fjeldså 1991). The disjunct distribution is an reflection to loss of suitable habitats in the Andes. Two to four birds were often seen together, and feeding as they moved slowly around on *Polylepis* branches. The birds seemed to move around a lot and probably required at least many fragmented areas of *Polylepis*. The species was never recorded in exotic plantations - and only once shortly in a *Berberis*. Also observed near TU5 and in the Misicuni region (17°06'04.5"S 66°19'28.9"W). Southern study region: POL1. Observed regularly at POL1 (2-3 individuals together) in *Polylepis* patches and surrounding second growth scrub. Seen on all observation days.

Diglossa sittoides, Rusty Flowerpiercer (Diglossa Rojiza, Payador).
Rarity score: 0.010. POL (12 individuals / sq. km): SM4, SM5. MIX (15 individuals / sq. km): LI3b, PO2, PO4. PIN (0.03 individuals / ha): CA2. Locally distributed in Andean basins from Venezuela to north-western Argentina in open country with scattered trees and bushes in semi-arid to humid regions. Often associated with *Polylepis* and diverse shrubs. The bird was only recorded in native vegetation habitats. The record from CA2 was a bird foraging in *Polylepis* trees inside a dense *Pinus* plantation. Southern study region: SEC1, SDE1, SDE2, BTC1, SDE4, SDE6.

Diglossa mystacalis, Moustached Flowerpiercer.
Rarity score: 0.035. MIX (3 individuals / sq. km): LM1. Disjunctly distributed in humid tree line habitats of Peruvian and Bolivian Andes. It was recorded once in an area with dense, semi-humid to humid vegetation with *Baccharis* and a few *Polylepis*.

*Diglossa carbonaria**, Gray-bellied Flowerpiercer, Carbonated Flowerpiercer (Diglossa Carbonosa). Vulnerable
Rarity score: 0.111. POL (56 individuals / sq. km): CA3, KP2, LM3, MO1+2, MO4, SM1, SM3, SM4, SM5. MIX (72 individuals / sq. km): KP1, KP3, LI3a, LM2a, LM2b, OR1, PO2, TU2. EUC (7 individuals / sq. km): KP4. Endemic to Bolivian humid and semi-humid woodlands and forests with *Polylepis*. The highest densities of the species was recorded in native mixed vegetation, thus, this habitat probably provide most feeding possibilities. Also observed feeding at the flowers of *Eucalyptus*, but the plantation habitat is probably unsuitable for nesting due to general lack of dense vegetation with hides. Southern study region: POL1, BTC1. Recorded in woody ravines.

Thraupidae - Tanagers

Thraupis bonariensis, Blue-and-Yellow Tanager (Azulejo Azul y Amarillo, Naranjero).
Rarity score: 0.004. MIX (15 individuals / sq. km) OR1, PO2, PO4. Widespread in the Andean basins in Peru, Bolivia and north-western Argentina and in adjacent lowlands. In semi-arid shrub including *Polylepis*. The species was recorded in very mixed vegetation, and in *Alnus* woodlands. Never observed in exotic plantations. Southern study region: SEC1, SDE1, SDE2, BTC1, SDE4, SDE5, SDE6.

Chlorospingus ophthalmicus, Common Bush-Tanager (Frutero Yungueño).
Rarity score: 0.011. POL (12 individuals / sq. km): LM3, MO1+2. MIX (38 individuals / sq. km): LM1, LM2a, LM2b, TI5. Distributed along the Andes from Venezuela to northern Argentina where it inhabits

humid forests and second growth. Recorded at highest densities in areas with mixed native vegetation where it moved through the vegetation in small groups often together with *Atlapetes fulviceps.* Never observed in exotic plantations. Southern study region: BTC1, SDE5.

Thlypopsis ruficeps, Rust-and-yellow Tanager (Tangará Alisero).
Rarity score: 0.026. Southern study region: SDE1, SDE2, SDE4, SDE5.
Piranga flava, Hepatic Tanager (Fueguero Común).
Rarity score: 0.002. Southern study region: SEC1, SDE1, SDE2, SDE4, SDE5, SDE6.

Pipraeidea melanonota, Fawn-breasted Tanager (Saíra de Antifaz).
Rarity score: 0.004. Southern study region: SDE4, SDE5, SDE6.

Euphonia musica, Blue-hooded Euphonia.
Rarity score: 0.003. Southern study region: SDE1, SDE5.

Fringillidae - Finches

Saltator aurantiirostris, Golden-billed Saltator (Pepitero de Pico Dorado, Pepitero de Collar).
Rarity score: 0.018. POL (118 individuals / sq. km): CA3, CK1, KH2, KP2, MO1+2, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TI1, TI4, TU4. MIX (159 individuals / sq. km): KH1, KP1, KP3, LI3a, LI3b, LM1, OR1, PO2, PO4, TU2. EUC (50 individuals / sq. km): KP4, LI1, MO3, PO1, TI2. PIN (27 individuals / sq. km): CU1, CU2, LI2, TU9. Widespread in the Andean basins and valleys and in adjacent lowlands in a broad range of habitats, including urban areas. The bird was recorded 153 times in 34 study areas, which makes this species the third most common in this study. It occurred also in exotic plantations, but at densities 50-75% below native vegetation habitats. Southern study region: SEC1, SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Saltator rufiventris, Rufous-bellied Saltator (Pepitero de Vientre Rufo, Pepitero Colorado). Vulnerable.
Rarity score: 0.091. POL (44 individuals / sq. km): CU3, KH2, MO1+2, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TU4, TU5. MIX (51 individuals / sq. km): KH1, KP3, LI3b, PO2, PO4, TI5, TU2. EUC (7 individuals / sq. km): LI1. PIN (21 individuals / sq. km): CU1, TI3, TU6, TU7, TU8. Near-endemic with restricted range in the Bolivian Valles into extreme northern Argentina. Inhabits montane forests and woodlands with preferably dense *Alnus* and *Polylepis*. Have apparently specialised food requirement towards fruits of mistletoes (Collar and others 1992) and thus dependent on natural vegetation habitats where such epiphytes occur. Can maybe nest in dense and mature *Pinus* plantations: A territory claiming pair fighting with a neighbouring pair was recorded at the border between a *Pinus* plantation and a *Polylepis* woodland. Also observed near our Khallani camp site (17°40'31.9"S 66°29'34.9"W), north of Misicuni (17°06'04.5"S 66°19'28.9"W), KH3, KP2, MO3, OR1, PO1, TU1, and heard calling near TU9. Southern study region: POL1, BTC1. One, mostly two individuals together seen on all survey days foraging in *Polylepis* covered ravines or surrounding second growth scrubland at POL1. One individual observed in scattered scrubland along a stream ca two km west of BTC1.

Catamenia analis, Band-tailed Seedeater (Semillero Sencillo, Piquitodeoro Común).
Rarity score: 0.015. POL (14 individuals / sq. km): CK1, SM3, SM5. MIX (26 individuals / sq. km): KP1, KP3, LI3a, LI3b, PO2. EUC (7 individuals / sq. km): LI1, MO5. PIN (3 individuals / sq. km): LI2. Widespread in arid shrublands in the Andes, often near fields and houses. Forage on seeds in composite bushes or on the ground. Recorded at highest densities in native vegetation habitats, probably due to higher food availability there. Southern study region: SDE1, BTC1, SDE4, SDE5.

Catamenia inornata, Plain-colored Seed-eater (Semillero Sencillo, Piuitodeoro Grande).
Rarity score: 0.011. POL (4 individuals / sq. km): SM2, TU5. MIX (3 individuals / sq. km): KP3. PIN (3 individuals / sq. km): TU6. Widespread in Andean puna zone on grassland and open bushlands. Often seen in large flocks near streams, even at very high altitudes. Occurs probably only accidentally in *Polylepis*. The species was recorded mainly in areas with open tree vegetation, and with bunch grass as understory. Southern study region: POL1.

Arremon flavirostris, Saffron-billed Sparrow (Cerquero de Collar).
Rarity score: 0.005. Southern study region: SDE5, SDE6.

Sicalis olivascens, Greenish Yellow-Finch (Jilguero Oliváceo).
Rarity score: 0.010. POL (23 individuals / sq. km): SM3, SM4, SM5, TU4. MIX (5 individuals / sq. km): LI3b, PO4. Widespread in open montane shrubland often in rocky areas near fields and villages. Also found in open *Polylepis* woodlands. Several birds was recorded in the *Polylepis besseri* woodlands near San Miguel village. Southern study region: POL1, BTC1.

Sicalis flaveola, Saffron [Yellow-] Finch (Jilguero Dorado).
Rarity score: 0.002. EUC (3 individuals / sq. km): LI1. PIN (9 individuals / sq. km): TI4. Widespread and common in South American lowlands and Andean valleys and basins. Inhabits dry open woods, savannahs, gardens and parks in urban areas. It was recorded in two exotic plantations. One area (LI1) was close to a tourist area and riverbed. Southern study

region: SEC1, BTC1.

Phrygilus atriceps, Black-hooded Sierra-Finch (Fringilo de Cabeza Negra, Comesebo Cabeza Negra)
Rarity score: 0.024. POL (40 individuals / sq. km): KH2, KH3, SM2, SM3, SM4, SM5, TI1, TU5. MIX (59 individuals / sq. km): KH1, KP1, LI3a, LI3b, OR1. EUC (3 individuals / sq. km): LI1. PIN (3 individuals / sq. km): CU1. Distributed in puna zone of southern Peru, Bolivia and northern Argentina in bushlands and considered to be associated with *Polylepis* (Fjeldså and Kessler 1996). However, the highest densities were recorded in habitats classified as mixed native vegetation. Southern study region: POL1.

Phrygilus plebejus, Ash-breasted Sierra-finch (Yal Chico).
Rarity score: 0.010. Southern study region: SDE1, POL1, BTC1.

Phrygilus unicolor, Plumbeous Sierra-Finch (Fringilo Plomizo, Yal Plomizo).
Rarity score: 0.005. POL (30 individuals / sq. km): CK1, KH2, OR2, SM1. MIX (8 individuals / sq. km): KH1. EUC (7 individuals / sq. km): CA1. PIN (21 individuals / sq. km): CA2, CU1, TI2. Widespread in puna or páramo zone of the Andes. Often seen in small flocks feeding near streams or bogs. Occurs in rocky terrain and in *Polylepis*. The highest densities were recorded in dry, open *Polylepis* woodlands often near fields. Apparently avoid habitats with dense vegetation, and in general also *Eucalyptus* plantations.

*Atlapetes fulviceps**, Fulvous-headed Brush-Finch (Matorralero de Cabeja Canela, Cerquero Cabeza Castaña).
Rarity score: 0.083. POL (4 individuals / sq. km): MO1+2, SM3. MIX (31 individuals / sq. km): OR1, PO2, TI5. PIN (6 individuals / sq. km): TU1. Near-endemic to semi-humid and humid woodlands in Bolivian Valles and north-western Argentina. The highest density was recorded in mixed native vegetation, often with *Alnus acuminata* admixed. The observations from the *Pinus* plantation (TU1), were of two birds foraging at the border area towards a ravine with dense mixed native vegetation including *Alnus* and *Buddleja.* Southern study region: SDE1, POL1, BTC1, SDE4, SDE5, SDE6.

Atlapetes torquatus, Stripe-headed Brush-finch (Cerquero Vientre Blanco).
Rarity score: 0.013. Southern study region: SDE1, SDE2, BTC1, SDE4, SDE5, SDE6.

Pheuticus aureoventris, Black-backed Grosbeak (Rey del Bosque).
Rarity score: 0010. Southern study region: SEC1, SDE1, SDE2, BTC1, SDE5.

Zonotrichia capensis, Rufous-collared Sparrow (Gorrión de Collar Rojizo, Pichisanka, Chingolo).
Rarity score: 0.001. POL (179 individuals / sq. km): CA3, CK1, KH2, KH3, KP2, LM3, MO1+2, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TI1, TU4, TU5. MIX (236 individuals / sq. km): KH1, KP1, KP3, LI3a, LI3b, LM1, LM2a, LM2b, OR1, PO2, PO4, TU2. EUC (77 individuals / sq. km): KP4, LI1, TI2, TU3. PIN (39 individuals / sq. km): CU2, LI2, MO3, MO5, TI3, TI4, TU9. One of South Americas most widespread species. Occurs in almost all terrestrial habitat types from city parks to puna zone at very high altitudes. The second most common species in this study with 230 recordings from 40 study areas. However, the native vegetation habitats still sustained the highest densities. The bird was often most abundant in areas with a mosaic of native woodland and fields. Southern study region: SEC1, SDE1, POL1, SDE2, BTC1, SDE4, SDE5, SDE6.

Poospiza hypochondria, Rufous-sided Warbling-Finch (Monterita de Lados Rufos, Monterita Pecho Gris).
Rarity score: 0.033. POL (11 individuals / sq. km): CK1, OR2, SM4. MIX (36 individuals / sq. km): KP1, KP3, OR1, PO4, TU2. Common in the Andes from Bolivia south to north-western Argentina in bushy areas with composite shrubbery, hedges along fields and sometimes in open *Polylepis.* This species was recorded in exotic plantations. Southern study region: SDE1, POL1, BTC1, SDE6.

Poospiza boliviana, Bolivian Warbling-finch. Low Risk, less concern.
Rarity score: 0.100. Recorded near *Liriuni* at 3390 m (17°16’47”S 66°18’48”W).
Southern study region: SDE4. At 1,600-3,000 m in dry scrubby hillsides and thickets along streambeds (Fjeldså & Krabbe 1990). Near tall dead herbs, in the ecotone between fields and woodland (Fjeldså & Maijer 1996). One pair recorded in scrub near streambed at SDE4.

Poospiza erythrophrys, Rusty-browed Warbling-Finch (Monterita Ceja Rojiza).
Rarity score: 0.048. POL (4 individuals / sq. km) MO1+2. Near-endemic distributed from Cochabamba, Bolivia south to northernmost Argentina inhabiting semi-humid shrubbery and second-growth in Andean ravines and valleys. Recorded once in humid and dense *Polylepis* vegetation of Quebrada Mojon. Southern study region: SDE1, SDE4, SDE5, SDE6.

Poospiza garleppi, Cochabamba Mountain-Finch (Monterita de Cochabamba). Endangered.
Rarity score: 0.500. POL (14 individuals / sq. km): SM3, SM4, SM5. MIX (5 individuals / sq. km): KP3, OR1. Endemic to the Cochabamba Basin and adjacent valleys, where it inhabits *Polylepis* woodlands, and mixed forest and shrub habitats. The species was recorded in habitats with native forests and bushes including *Polylepis*. Several times the birds were observed feeding on newly ploughed fields. The species is probably one of Bolivia’s most endangered birds due to the restricted range and the rapid destruction of habitats. The species is dependent on

presence of native woody vegetation but can apparently accept quite intense agriculture. The bird was never observed in exotic plantations. After visiting many study areas it is obvious that most graminivors including *Poospiza garleppi* does not favour exotic plantations. For protection of this species regeneration and reforestation with native species of bushes and trees is needed. Such projects will in particular benefit the species if the native plantations are established near agricultural fields. Furthermore, the species was recorded at: KP1 with a single bird, two birds just outside SM4, and two birds near the school building in San Miguel (17°16'11.5"S 66°19'42.4"W). Southern study region: POL1. Two pairs observed on all observation days at POL1 in *Polylepis* patches. One individual seen preening in the early morning sun, sitting in the crown-edge of a *Polylepis* tree. At dawn and dusk one pair seen foraging in bushes in the surrounding open scrubland.

Poospiza melanoleuca, Black-capped Warbling-finch.
Rarity score: 0.007. Southern study region: SDE4, SDE5, SDE6.

Poospiza torquata, Ringed Warbling-finch (Monterita de Collar).
Rarity score: 0.012. Southern study region: SEC1, SDE2, BTC1, SDE4, SDE5, SDE6.

Sicalis luteocephala, Citron-headed Yellow-Finch (Jilguero Corona Gris). Near threatened.
Rarity score: 0.143. In arid, rocky area near CK1 between Arani and Vacas. Southern study region: BTC1.
Locally common in Cochabamba Department (Fjeldså & Krabbe 1990), judged to be common and widespread in the drier open areas of Chuquisaca Department by Krabbe and others (1996). Found in arid open scrub and agricultural areas at 2,600-3,500 m. Feeds for seeds on the ground and in low herbs and bushes (Fjeldså & Krabbe 1990). Two seen together 14 may 1995 in agricultural land near BTC1.

Sporophila caerulescens, Double-collared Seedeater (Corbatita Común).
Rarity score: 0.002. Southern study region: SEC1, SDE2.

Carduelis magellanica, Hooded Siskin (Jilguero de Cabeza Negro, Chaiñita).
Rarity score: 0.002. POL (167 individuals / sq. km): CK1, KH2, KH3, MO4, OR2, SM1, SM2, SM3, SM4, SM5, TI1, TU4, TU5. MIX (226 individuals / sq. km): KH1, KP1, KP3, LI3a, LI3b, LM1, OR1, TI5. **EUC** (110 individuals / sq. km): CA1, KP4, LI1, MO5, TI2, TU10. PIN (118 individuals / sq. km): CA2, CU1, CU2, LI2, TI3, TI4, TU7, TU8, TU9. Widespread in the Andes and adjacent lowlands in western Peru, southern Brazil and Argentina. Inhabits a broad range of habitats in urban, agricultural and forested areas. Occurs also in *Polylepis*. The most abundant bird species in this study with 255 individuals recorded from a broad range of habitats. However, highest abundance was recorded in native vegetation habitats. The species was often seen feeding on bare fields close to native bushes or trees which provided hides. In plantations, birds were often observed perched at treetops singing or resting. SEC1, SDE1, POL1, SDE2, BTC1, SDE4, SDE5.

Additional bird species recorded

The records listed below are not included in the data analysis. Whenever possible, area code or co-ordinates is used for location of the following observation(s). If not available, a detailed description of the locality is given. Densities for these additional species have not been assessed.

Nothoprocta ornata, Ornate Tinamou (Perdiz Cordillerana, P'isaka).
Recorded in puna zone (>3,800 m) near Lag. Wara Wara, *Parque Nacional Tunari* (17°16'S 66°07'W), and Est. Templo (17°10'S 66°20'W).

Podiceps occipitalis, Silvery Grebe (Macá Plateado, Chullumpi).
In small lagoons 8 km south of Cocapata (~16°55'S 66°38'W).

Plegadis ridgewayi, Puna Ibis (Ibis de la Puna, Yanavico).
On pastures just outside Misicuni village (17°06'04.5"S 66°19'28.9"W).

Theristicus caudatus, Buff-necked Ibis (Totachi, Tapacuru).
Overflying the valley of Rio Misicuni (17°06'04.5"S 66°19'28.9"W).

Vultur gryphus, Andean Condor (Cóndor, Mallku).
Recorded flying over several localities: LM1, LM2a, LM2b, MO4, SM4, SM5, and about 8 km south of Cocapata (~16°55'S 66°38'W).
Southern study region: SEC1, SDE2, BTC1, SDE4, SDE5, SDE6.

Cathartes aura, Black Vulture (Peroquí Cabeza Roja, Urubinchi).
At La Candelaria (CA1) resting in large *Eucalyptus* trees just behind the buildings of the Evangelic church.
Southern study region: SEC1, SDE1, BTC1, SDE4, SDE5, SDE6.

Circus cinereus, Cinereous Harrier.
Southern study region: SDE1, BTC1.

Accipiter striatus, Sharp-shinned Hawk (Esparvero Común).
Recorded at LM2a, LM2b and also in Quebrada Falsuri (17°19'05.5"S 66°19'09.2"W) in localities with mixed native vegetation. Never seen in exotic plantations, though, mature *Pinus* probably will provide nesting sites.

Accipiter bicolor, Bicolored Hawk.
Southern study region: SDE1, SDE6.

Buteo magnirostris, Roadside Hawk.
Southern study region: SDE1, SDE2, SDE3, SDE6.

Merganetta armata, Torrent Duck (Pato de Torrente).
One bird recorded in Rio Misicuni, just north-west of Misicuni (17°06'04.5"S 66°19'28.9"W). According to the school teacher in San Miguel (SM1-SM5) the species also occurs in Rio Jankho Khala.

Anas flavirostris, Speckled Teal (Pato Barcino, Unciallo).
In bofedales around Misicuni 17°06'04,5"S 66°19'28,9"W 3,750 m, 8 km south of Cocapata (~16°55'S 66°38'W).

Anas puna, Puna Teal (Soka, Yucsa, Chirokankana).
8 km south of Cocapata in a small lagoon (~16°55'S 66°38'W).

Vanellus resplendens, Andean Lapwing, (Tero Serrano, Leke-Leke).
In puna zone at Laguna Waka Waka, Parque Nacional Tunari (~17°16'S 66°07'W), and near the main road from Cochabamba to Oruro at km 92.
Southern study region: SDE1.

Thinocorus orbignyianus, Gray-brested Seedsnipe (Agachona de Collar, Pucu-Pucu).
In puna grassland near Laguna Waka Waka, Parque Nacional Tunari (~17°16'S 66°07'W).

Larus serranus, Andean Gull (Gaviota Andina, Kellua, Kellualla).
At Laguna Waka Waka, Parque Nacional Tunari (~17°16'S 66°07'W) and bofedale and river near Misicuni village (17°06'04.5"S 66°19'28.9"W).

Coccyzus melacoryphus, Dark-billed Cuckoo (Cucillo Canela).
In arid bushland with a few *Scinus molle* near Liriuni, 17°16'47"S 66°18'48" (3,390 m).

Picoides lignarius, Striped Woodpecker (Carpintero Bataraz Grande).
Above Liriuni on the new road to the Misicuni-Corani tunnel construction, in habitat of open *Polylepis* woodland with more dense vegetation in a small depression.
Southern study region: SDE1, SDE2, BTC1, SDE4, SDE5, SDE6.

Geositta tenuirostris, Slender-billed Miner (Caminera Picuda, Kiti-Kiti).
At bofedales near Laguna Waka Waka, Parque Nacional Tunari (~17°16'S 66°07'W).

Geositta cunicularia, Common Miner (Caminera Común, Kiti-Kiti).
Near the main road Cochabamba-Oruro at km 92.
Southern study region: BTC1.

Upucerthia jelskii, Plain-breasted Earthcreeper (Tubi-Tubi).
At Laguna Waka Waka in Parque Nacional Tunari (~17°16'S 66°07'W), and near Misicuni village (17°06'04.5"S 66°19'28.9"W).

Asthenes modesta, Cordilleran Canastero (Canastero Pálido).
At Laguna Waka Waka in Parque Nacional Tunari (~17°16'S 66°07'W), and 8 km south of Cocapata (~16°55'S 66°38'W).

Asthenes maculicauda, Scribble-tailed Canastero (Espartillero Estriado)
At Laguna Waka Waka in Parque Nacional Tunari (~17°16'S 66°07'W).

Pseudocolopteryx acutipennis, Subtropical Doradito (Doradito Oliváceo).
Above Liriuni near LI3 at 17°17'23.1"S 66°17'17.9"W in mixed bushland in a pasture at 3,240 m.

Cistothorus platensis, Grass Wren / Sedge Wren (Ratona Aperdizada).
In bofedale with bunch grass near Misicuni village (17°06'04.5"S 66°19'28.9"W) at 3750 m.

Turdus fuscater, Great Thrush (Zorzal Grande)
In humid native vegetation with *Polylepis* in Quebrada Mojon (MO1+2). One bird was heard singing, and one was mistnetted by Fransisco Sagót Armonia / BirdLife Bolivia.

Turdus nigriceps, Slaty Thrush (Zorzal Plomizo).
One male and one female mist netted near MO1+2 in semi-humid mixed native vegetation by Fransisco Sagót, Armonía / BirdLife Bolivia.

Anthus hellmayri/bogotensis, Hellmayers / Paramo Pipit (Cachirla Pálida / Andina).
Recorded in puna zone vegetation at 3,920 m at Laguna Waka Waka (~17°16'S 66°07'W) in Parque Nacional Tunari, and in highest parts of Quebrada Mojon (MO4).

Leistes superciliaris, White-browed Blackbird (Tordo Pampero).
In bunch grass of puna zone at 3,920 m, Laguna Waka Waka (~17°16'S 66°07'W) in Parque Nacional Tunari. This observation is 900 m above altitude range stated by Fjeldså and Krabbe (1990).

Conirostrum ferrugineventre, White-browed Conebill.
In semi-humid native woodlands near KP2, at La Candelaria in fragmented *Polylepis* habitat in the ravine behind the buildings of the Evangelic church.

Thraupis sayaca, Sayaca Tanger (Sayubú, Sayí).
Near houses and gardens at KP3. Southern study region: SEC1,SDE1, SDE2, SDE4, SDE5, SDE6.
Sicalis uropygialis, Bright-rumped Yellow-Finch

(Jilguero Cara Gris, Kellunchu).
In puna areas at the pass above San Miguel (4,000 m), in rocky area on road between Misicuni and Icári (17°06'04.5"S 66°19'28.9"W), 3,750 m, and at puna grassland below rock wall with *Polylepis pepei*, Chorito (16°55'31.2"S 66°37'39.2"W), 4,000 m

Diuca speculifera, White-winged Diuca-Finch (Diuca Ala Blanca).
10 ind. at low grassland on the Quilacollo-Morochata Road (17°13'50.5"S 66°25'26.2"W) at 4,430 m, near Chorito at 4,000 m (16°55'31.2"S 66°37'39.2"W).

Idiopsar brachyurus, Short-tailed Finch (Yal Grande).
2 birds in small ravine with *Polylepis* at the road between Misicuni and Icari (17°04'28"S 66°20'00"W) at 3,840 m.

Lophospingus griseocristatus, Gray-crested Finch (Soldadito Gris). Low Risk, less concern.
Small groups at the old Cochabamba-Sta.Cruz Road about 25 km east of Cochabamba (near Sacabambilla). Southern study region: SEC1, SDE2, SDE4, SDE5, SDE6. At 1,000 - 2,500 m in arid regions with bare soil, scrubs and scattered trees. Feeds on the ground for seeds and insects (Fjeldså & Krabbe). Recorded SEC1, SDE2, SDE4, SDE5 and SDE6. Generally common in the southern study region in arid scrubland and agricultural areas.

Embernagra platensis, Great Pampa-Finch (Verdón).
Observed in agricultural areas admixed some native woody vegetation near KP4 and LI2. Southern study region: SEC1.

Carduelis atrata, Black Siskin (Negrillo, Chaiñita, Hallo-Hallo).
Near Misicuni village (17°06'04.5"S 66°19'28.9"W) at 3,750 m.

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