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Peru's humid eastern montane forests:

An overview of their physical settings, biological diversity, human use and settlement, and conservation needs

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

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Preface

This report presents an overview of the biological conservation of the humid montane forests of Peru's eastern Andean slopes. The main aim of the report has been to attract more attention to this diverse region and to the natural processes that create and maintain biological diversity. The report also deals with the social, political, and historical forces that have modified these forests through time. A better understanding of the ways in which human land-use affects the montane forests of the Andes might help mitigate the impacts of future development. The report is premature in the sense that much of the data is incomplete. Hopefully, this effort will be viewed charitably by those who are experts on the respective topics. In fact, the authors hope that such readers will bring other relevant studies and projects to their attention.

Flemming Skov

Co-ordinator, DIVA

Centre 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 interconnected and interdisciplinary 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.

The DIVA team in Oyacachi, Ecuador.

Summary

The humid eastern montane forests of Peru form an ecological and biological system of global importance for the conservation of biodiversity and natural resources. There are large tracts of forest little altered by humans, with unique biological diversity, especially among the bryophytes, ferns and fern allies, orchids, melastomes, spiders, frogs, tyrant flycatchers, tanagers, hummingbirds, and rodents. High precipitation, numerous disturbances, and great heterogeneity in bedrock and topography help to create and maintain this diversity.

National, regional, and international biodiversity planning should include the eastern montane forests as a high priority for protection and research. Much basic data on the physical environment is still lacking. Little is known about the plant and animal species present, and specifically about their distributions and abundances in relation to elevation, topographic position, and forest dynamics.

This is a poor place for agriculture due to shallow soils, steep slopes and heavy rainfall. Extensive human-caused forest degradation has chiefly occurred during the last 40 years and has been caused by the extraction of timber, often followed by conversion to low-quality rangeland. Most of this impact occurs with several kilometers of roads and is either associated with recent colonists or with those using the roads as access in order to extract resources from state-owned lands. However, there are montane forest sites in northern Peru that were apparently used sustainably for many centuries before the arrival of Europeans caused depopulation and abandonment from diseases. Presently, there is no evidence of resident indigenous population in the study area.

Solutions to current biodiversity loss must include an improved national park and nature reserve system. Some protected areas are too small and others have not been made operational. The respective government agencies could better coordinate their shared interests. This could be promoted with a more active involvement by conservation and development non-governmental organizations and with local communities.

Specific recommendations are to 1.) design international and collaborative efforts to protect these and similar forests in the eastern Andes, 2.) make the eastern slope region of the highest priority for biological conservation within Peru, 3.) direct both human and financial resources to applied and pure research topics concerning the eastern montane forests, and 4.) develop strategies for the integrated protection of eastern montane forest sites.

Resumen

El bosque húmedo montano oriental del Perú constituye un sistema ecológico y biológico de importancia global para la conservación de la biodiversidad y de los recursos naturales. Existen áreas grandes de bosque poco alteradas por el ser humano, con una diversidad biológica singular, especialmente entre briófitos, helechos y plantas afines, orquídeas, melastomatáceas, arañas, sapos, tiránidos-atrapamoscas, tángaras, picaflores y roedores. La alta precipitación, las numerosas perturbaciones y la alta heterogeneidad en geología y topografía contribuyen a crear y mantener esta diversidad.

La planificación de la biodiversidad nacional, regional e internacional debería incluir el bosque montano oriental como de alta prioridad para la protección e investigación. Muchos de los datos básicos del ambiente físico se desconocen. Poco se sabe de las especies de plantas y animales allí presentes, específicamente sobre sus distribuciones y abundancias en relación a la altitud, posición topográfica y dinámica del bosque.

Para la agricultura, este es un lugar pobre debido a lo somero de los suelos, laderas con pendientes pronunciadas y lluvias torrentosas. Una extensa degradación del bosque, causada por el ser humano, ha ocurrido principalmente durante los últimos 40 años y ha sido promovida por la

extracción de madera, seguida frecuentemente por la conversión del bosque a pastizales de baja calidad. La mayor parte de este impacto ocurre dentro de varios kilómetros colindante a caminos carrozables y está asociado con colonos recientes o con aquellos que usan los caminos como vías de acceso para extraer recursos de las tierras del estado. Sin embargo, existen lugares de bosque montano en el norte del Perú que fueron aparentemente usados en forma sustentable por muchos siglos antes de la despoblación causada por la llegada de los europeos y el abandono debido a las enfermedades. En la actualidad no hay evidencia de poblaciones indígenas residentes en el área de estudio.

Soluciones a la pérdida actual de biodiversidad deben incluir un sistema mejorado de parques nacionales y reservas naturales. Algunas áreas protegidas son muy pequeñas y otras no han sido puestas en operación. Las agencias gubernamentales correspondientes podrían coordinar mejor sus intereses comunes. Esto podría promoverse con una participación más activa, a las organizaciones no gubernamentales de conservación y de desarrollo y a las comunidades locales.

Recomendaciones específicas son 1.) diseñar esfuerzos colaborativos internacionales para proteger este bosque y otros similares en los Andes orientales, 2.) reconocer a la región de la vertiente oriental como de más alta prioridad para la conservación biológica en el Perú, 3.) canalizar recursos humanos y económicos a temas de investigación aplicada y pura que conciernen al bosque montano oriental y 4.) desarrollar estrategias para la protección integral de lugares en el bosque montano oriental.

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We are grateful to the Danish Environmental Research Programme for this opportunity to study and present our findings on Peru's eastern montane forests. We thank the many institutions that helped us, especially the Institute of Systematic Botany at the University of Aarhus, the Natural History Museum of London, the Missouri Botanical Garden in St. Louis, the Field Museum of Chicago, the Museo de Historia Natural UNMSM of Lima, the Herbarium Vargas of Cusco, and the National Herbarium in La Paz. We began this project with the support and guidance of Thomas Veblen, and gratefully acknowledge our many debts to him. We express our thanks to Asunción Cano, Sandra Knapp, Efraín León S., James Mallett, Benjamin and Katrine Øllgaard for their help. We also acknowledge with gratitude previous financial assistance from the John D. and Catherine T. MacArthur Foundation, Pew Charitable Trusts, and the National Science Foundation (SES-8713237 and EAR-9422423). We thank Sergio Solari and Paul Velazco for reviewing the mammal data, and Michael Kessler for general comments. Unless otherwise indicated, the photographs were taken by the authors. The maps and graphics were produced by Diane Lorenz and Cartographic Services of the University of Maryland, Baltimore County, headed by Joseph School and assisted by Eric Brossert, Jack Cibor, Lonnie Lanham, Kevin Moore, Beth Richardson, Kim Treadway, Will Wiley, and Greg Ugiansky.

1. Introduction

The eastern slopes of the Peruvian Andes have been recognized as of global importance for biological diversity by Myers (1988), Dinerstein and others (1995), Stotz and others (1996), and Young & León (1997), among others. This due to the presence of numerous ecological zones and species packed into 5000 vertical meters of elevational relief in a narrow zone that stretches north-south along more than ten degrees of the tropics. In addition, considerable portions of isolated watersheds still have intact forest cover and, by almost any standard, represent some of the last forested wilderness of South America.

The study area treated in this report is the humid montane forest belt of the eastern slopes region (Fig. 1). The forest belt is found from 1500 m to altitudinal timberline, often located at around 3500 m (León and others 1992, Young 1991a, 1992). This belt (Figures 2 and 3) is of particular interest for conservation for several reasons. First, forests there protect the upper watersheds of Peru's Amazon, and indeed much of the upper watershed of

Altitudinal timberline is the upper forest limit. The limit may be caused by natural phenomena (especially temperature) or it may be a result of human activities, such as burning.

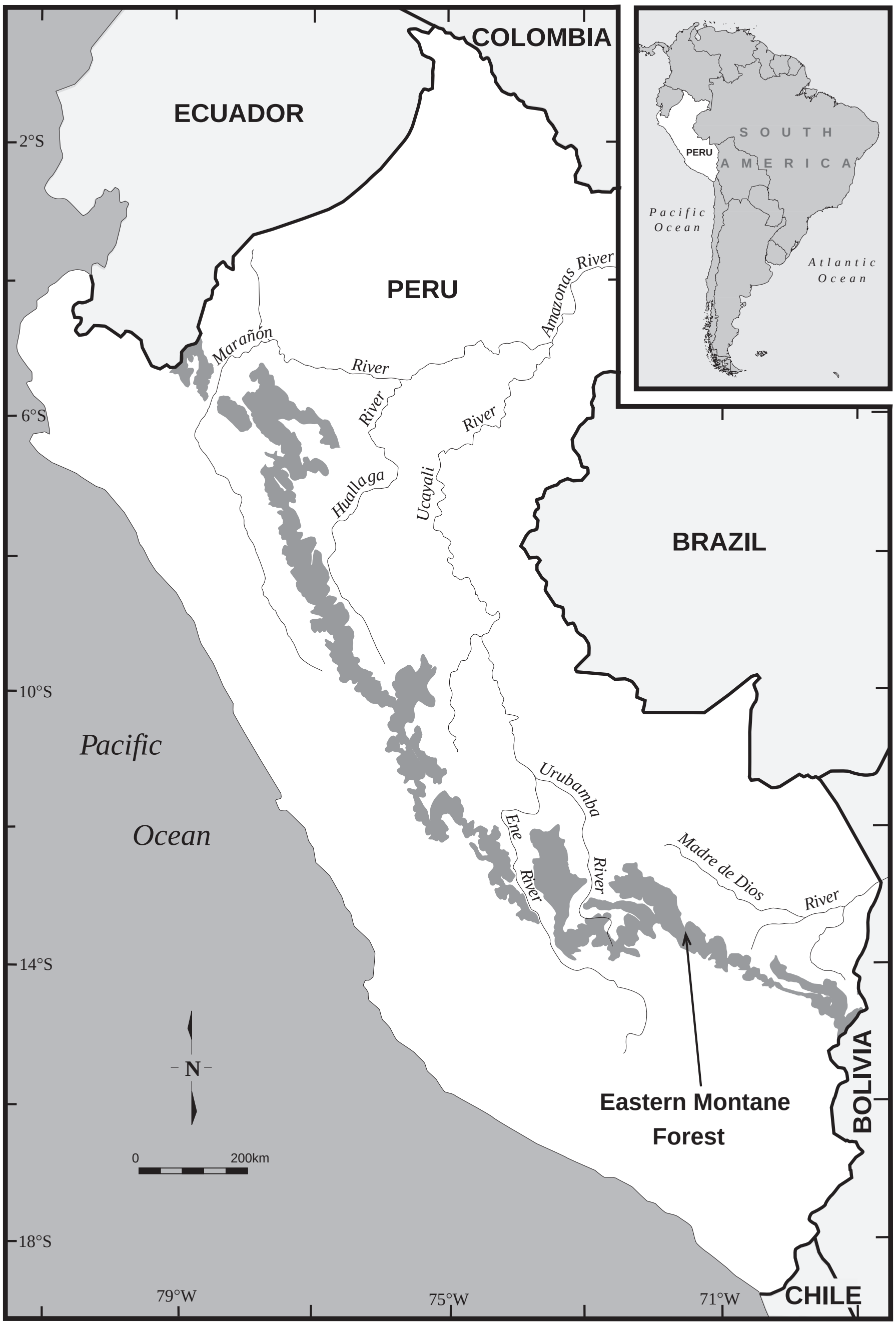


Figure 1. Location of the study area: the humid montane forest belt of the eastern Andes of Peru.

Figure 2. Rough topography and steep slopes characterize the eastern montane forests.

western Amazonia. It is difficult to imagine holistic conservation planning for the Amazon basin that omits the upper watersheds. Furthermore, as will be documented in this report, the montane forests include numerous species, especially from such moisture-loving groups as mosses, ferns, orchids, and frogs. Because of the steep slopes and rough topography, movements of many organisms between watersheds are restricted, which over time has led to the development of local variants and endemism.

Figure 3. When exposed to frequent fogs, these forests develop large mats of mosses, ferns, and other epiphytic plants.

Finally, the montane forest belt includes areas exposed to the massive cloud systems that originate with the condensation of water vapor carried up from the Amazon lowlands by prevailing easterly wind flows. These are cloud forests and for the most part are not ideal places for modern colonization efforts because of the high precipitation, limited area with low slopes, and poor soils. Thus, most of the efforts exerted in the 1960s and 1970s by the Peruvian government to transform the eastern slopes into new agrarian production zones, bypassed the montane forests and instead modified the forest belts below 1500 m.

In summary, the eastern montane forests of Peru offer important conservation opportunities of interest nationally and internationally. The goal of this report is to synthesize available information needed for conservation planning, with particular emphasis on the major areas of humid forests. Although other natural resources in eastern Peru are also of concern, especially those involving water resources, this report concentrates on the biotic resources, and specifically on biological diversity.

The organization of the report is as follows: First, the physical environments of humid montane forests and other habitat types are described, using the often coarse data available at regional and national scales. Then biological diversity is discussed in terms of the organisms found, and also in reference to the biological communities they form and the ecosystems and landscapes they occupy. When possible, the number of species, genera, and families of the organisms are indicated. Species of special concern are noted, especially those that are known to be useful, endemic, threatened, or that can act as pests or nuisances. The history of human use and settlement in the montane forests is outlined. This is followed by an overview of past and present conservation efforts, plus policy recommendations for future program design. It is our hope that this document will help orient planning efforts at regional, national, and international levels.

2. Physical setting

In Peru, most large areas of intact montane forests are associated with the humid forest belt found on the eastern slopes of the Andes, since interandean valleys and the western slopes are typically drier and dominated by nonforested or previously forested landscapes (Weberbauer 1945, Young & León 1995, Young 1998a). Humid montane forest would be the vegetation formation expected between 1500 and 3500 m on the eastern slopes (Figures 4 and 5), that is at those elevations in (from north to south) the departments of Amazonas, San Martín, Huánuco, Pasco, Junín, Ayacucho, Cusco, and Puno (Fig. 6), and the adjacent portions of Apurímac and Madre de Dios. Of course, there are also nonforested ecosystems present, such as aquatic systems, those found in very rocky sites, or those disturbed by natural or anthropogenic processes. In this report, most of the information will deal with the predominant land cover, the continuous montane forests. When appropriate, however, other ecosystem types will also be mentioned. We exclude the high Andean forests found above timberline, such as those forests dominated by Polylepis; these were recently discussed by Fjeldså & Kessler (1996), and we refer interested readers to that report.

The lower elevational limit of 1500 m that we use in this report is arbitrary, but is meant to correspond with a major ecotone between forests with highland Andean species and those forests with species found in the Amazon lowlands. Both the use of the Holdridge life zone system for recognizing vegetation formations (Tosi 1960, ONERN 1976) and that system developed independently by Grubb (1974, 1977) and many others (review by Webster 1995) put the altitudinal limit between tropical montane forests and lower elevation vegetation types at 1500 to 2000 m.

In addition, a biotic changeover at 1500 m has been recognized in Peru in several empirical studies. One by Terborgh (1971, 1977) found a major

Figure 4. Lower montane forests are relatively tall, with canopies often 20 to 30 m tall.

Figure 5. Upper montane forests are often shorter. Shown here is the ecotone between the tropical alpine grassland and a timberline forest at 3350 m elevation in northern Peru.

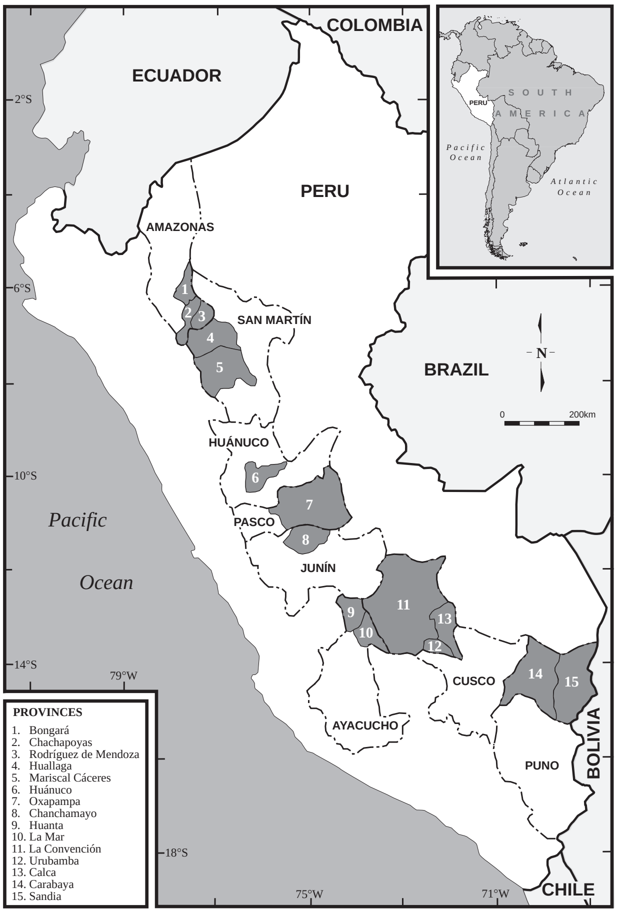


Figure 6. Political departments and provinces found principally in the montane forest belt of the eastern Andes of Peru. The provinces chosen were those with most population found in or adjacent to the montane forest zone.

shift in bird composition around 1500 m, despite the lack of any conspicuous change in the physiognomy of the vegetation in southern Peru. Cadle & Patton (1988) reported dramatic changes in the composition of sigmodontine rodents around 1800 m along an altitudinal gradient down to the lowlands of southern Peru. Lamas (1997) found little overlap among the butterfly species found below 1500 m and those above 1500 m on the Cordillera del Condor in northern Peru. Patterson and others (1998) document much change in species composition of birds, bats, and mice at around 1500 m. Both Gentry (1992) and Young (1996) discuss major changes in floristic composition at about 1500 m, in the former based on data from trees on thousand square meter plots and in the latter from whole flora surveys extracted from the taxonomic literature, including the compendium of Brako & Zarucchi (1993).

Both Gentry and Young discuss major changes in floristic composition at about 1500 m.

The upper limit of 3500 m is approximate and marks the altitude at which altitudinal timberline is commonly approached (Young 1993a). Arboreal vegetation above that elevation is most commonly found as forest isolates or as woodland or scrub in the study area. Human impact often lowers timberline (Young 1993b), so there are also numerous situations where nonarboreal vegetation can be found below 3500 m. These cases are also included in this document, though the emphasis is on the forests, and specifically on the closed, continuous forests found in the wettest areas.

Human impact often lowers timberline.

Geology and topography

The eastern montane forest belt of Peru is long, narrow, and oriented roughly north-south along the outer flanks of the Andes mountains (Fig. 1). There are some major features prominant at a macro-topographical scale that can be used to subdivide this region.

The Cordillera del Cóndor is a topographic feature located at about 4ºS on the border between Ecuador and Peru (Fig. 7). Most of its highest elevations are below 1500 m and so belong to the premontane forest belt of eastern Ecuador and Peru (Schulenberg & Awbrey 1997). However, there is a high

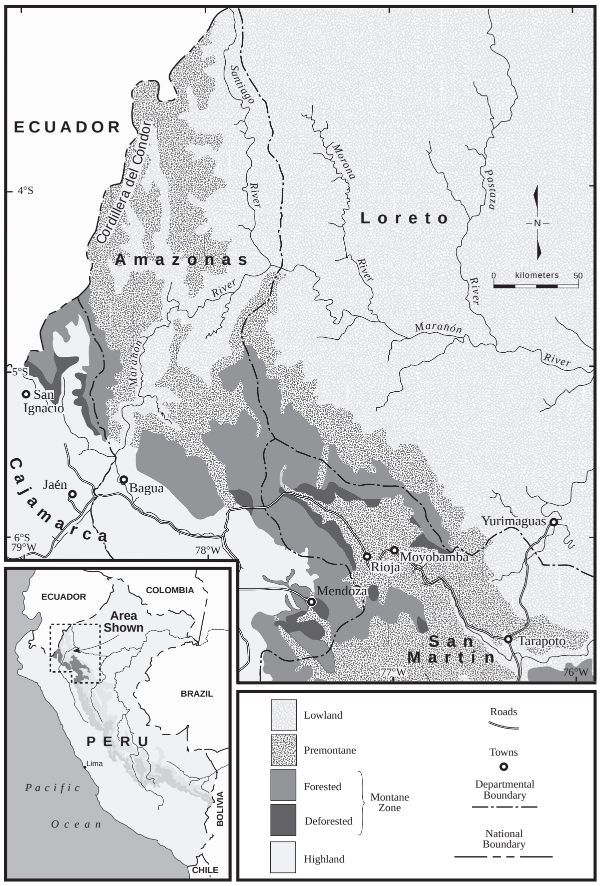


Figure 7. Montane forest zone in northernmost Peru.

ridge that runs southward from the Ecuadorian border for 50 km in the department of Amazonas before it is stopped by the eastward bend of the Marañón River (Fig. 8). The national geologic map (Instituto de Geología y Minería 1975) gives the bedrock as mostly undifferentiated pluton. To the west of that ridge are a complex series of additional ridges and low mountains in the departments of Cajamarca, Piura, and Lambayeque that Young & León (1995) considered part of the northern Peru montane forest region, and which are not discussed in detail in this report (for more information, see Barnes and others 1995, Best & Kessler 1995, Young & Reynel 1997). Those features and the deeply entrenched Marañón River form the Huancabamba Depression or Deflection (Vuilleumier, 1977), which among other phenomena, results in the separation of the Cordillera del Cóndor's montane forest from the next sector to be described.

To the east of the Marañón River, between about 5 and 6.5ºS, the relief consists of four partially interconnected ridges that trend from northwest to southeast, over an area of about 200 by 200 km in the departments of Amazonas and San Martín (Fig. 7). The highest elevations are only about 3500 m. Much of the bedrock is sedimentary and dates from the upper Paleozoic, the Jurassic, and the Cretaceous (Instituto de Geología y Minería 1975).

From 6.5 to 9.5ºS, the montane forest belt is narrow, often only 50 km wide and divided by steep canyons eroded by eastward flowing rivers (Fig. 9). The highest elevations are to the west and are set by the eastern cordillera of the Andes at about 4000 m. The departments included are San Martín and Huánuco. The national geologic map (Instituto de Geología y Minería 1975) indicates large areas of Precambrian metamorphics, plus Triassic sedimentary and Tertiary volcanics. Fieldwork (Rodbell 1991) has revealed much local complexity with limestone cliffs, and extensive beds of metamorphic and igneous rock types.

Contiguous, but set at opposing angles are the outlying ridges of the eastern Andean cordillera at 9.5 to 10.5º S, which spread out 50 km in northeasterly and southeasterly directions to form a triangle in the

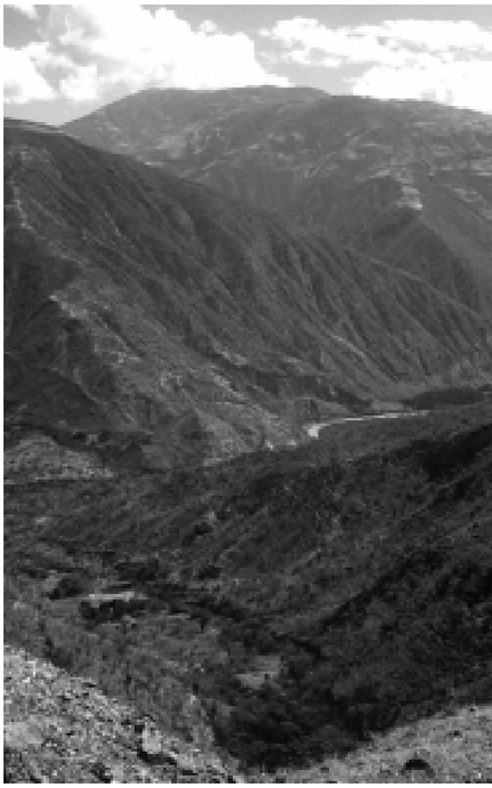


Figure 8. The deeply entrenched Marañón River in northern Peru is an important biogeographical barrier.

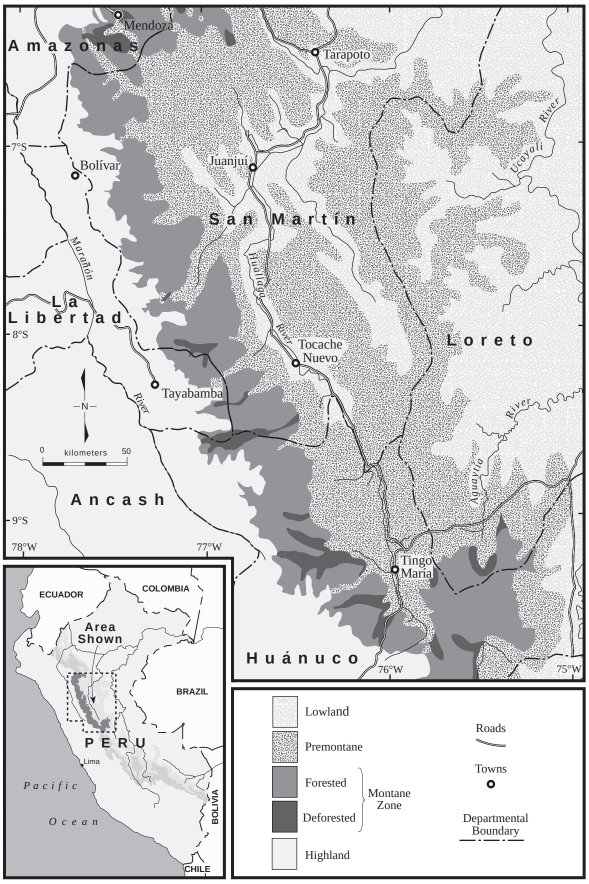


Figure 9. Montane forest zone in north-central Peru.

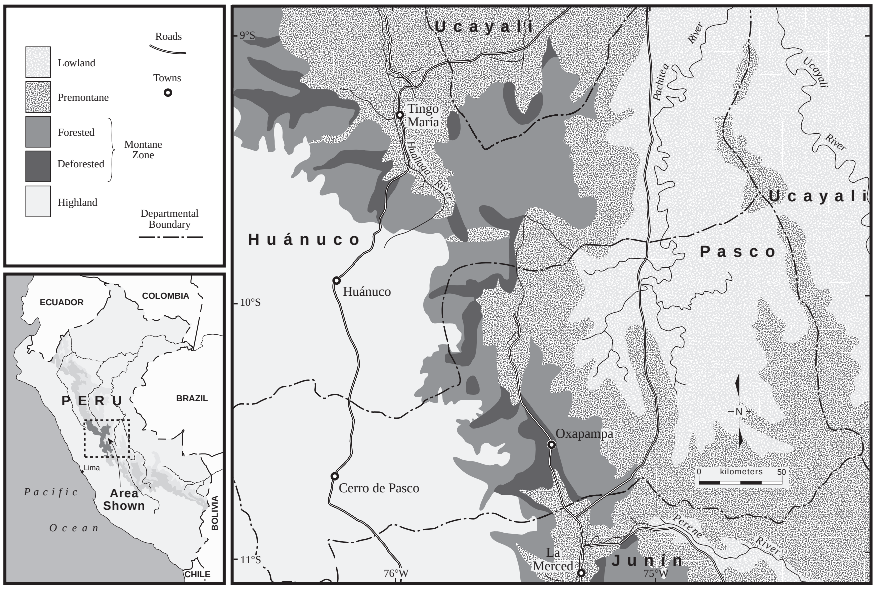


Figure 10. Montane forest zone in central Peru.

departments of Huánuco and Pasco with the apex pointing towards the city of Cerro de Pasco (Fig. 10). The highest elevations are set back on the main cordillera and go to 5000 m. Geology in this portion is quite complex, with Paleozoic and Mesozoic undifferentiated plutons and granites, and Triassic and Cretaceous sedimentary (Drewes 1958, Instituto de Geología y Minería 1975).

From 10.5 to 13ºS, the eastern Andes are cut by the northerly flow of several large tributaries of the Ucayali River and the relief can only be described in relation to their drainage basins (Fig. 11). The first of these is formed by the Tambo River, which receives waters from the easterly flowing Perené River, those of the Mantaro River emptying out of its deeply incised interandean valley, and those of the Apurímac and Ene Rivers that flow in a

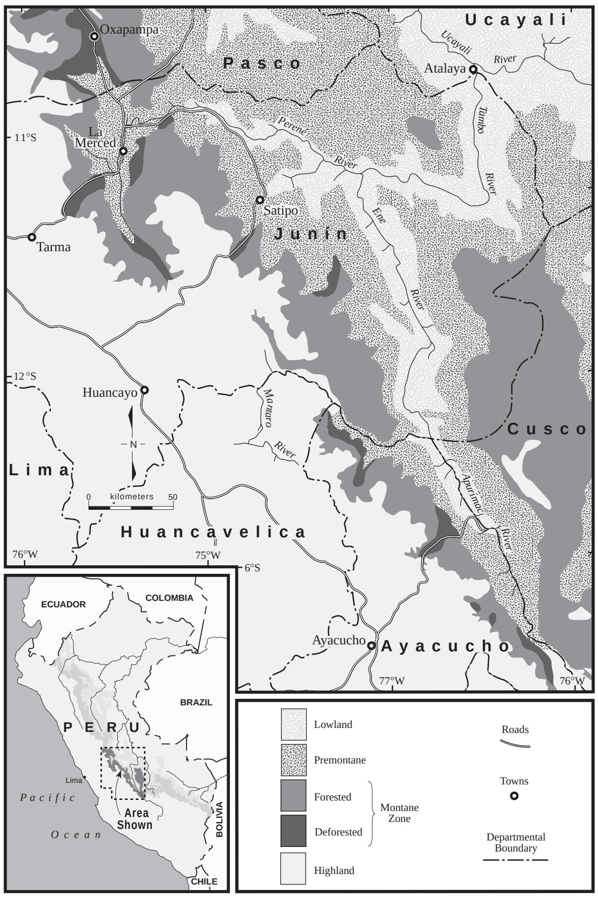


Figure 11. Montane forest zone in the Ucayali River drainage basin.

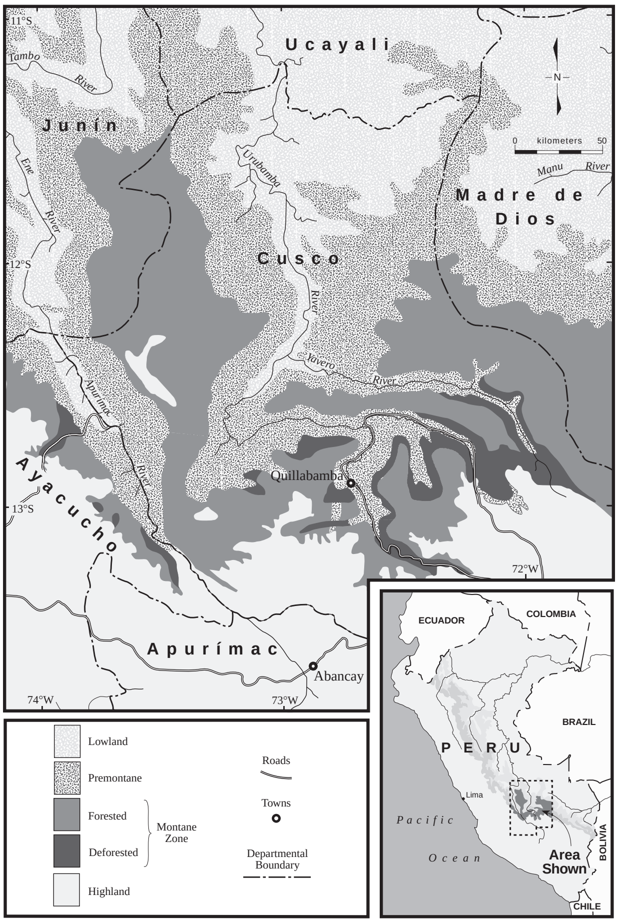


Figure 12. Montane forest zone in the Urubamba River drainage basin.

northwesterly direction. The relief associated with these rivers is also complex and set at various directions. The montane belt of concern here can be found on the Andean cordillera at 11.5°S in the Chanchamayo province belonging to the department of Junín, and as part of a 100 km long outlier delimited to the north by the Chanchamayo River and to the south by the Mantaro River. Elevations reach about 4500 m. Also present are a small mountain at 11°S and 74°W, called the "Cordillera del Sira", the montane zone on both sides of the upper reaches of the Apurímac River, and the 150 km long Vilcabamba Cordillera, which is oriented due north. Bedrock types are mostly Paleozoic sedimentary and granites, and Cretaceous sedimentary (Instituto de Geología y Minería 1975).

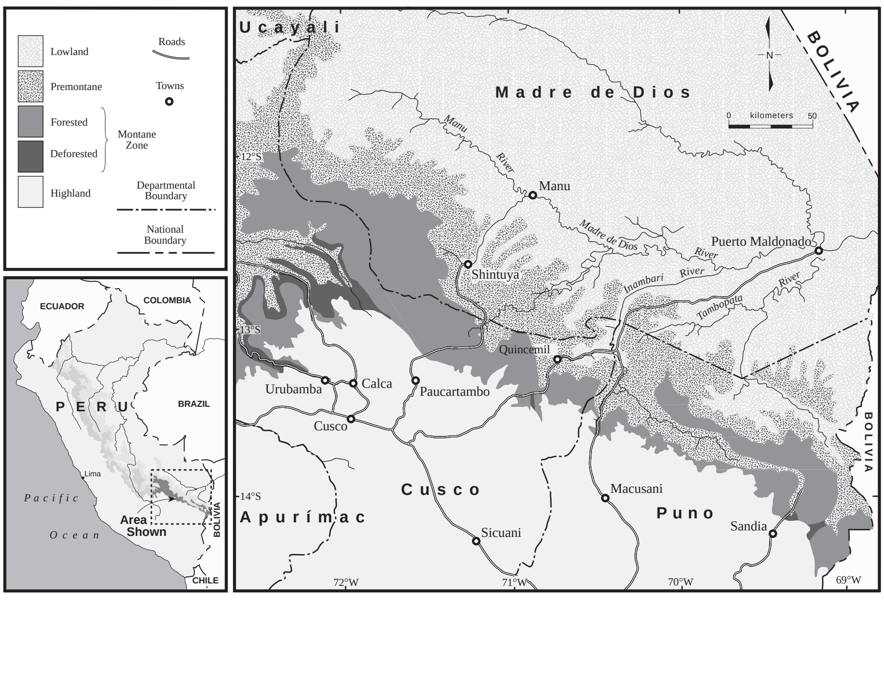


Figure 13. Montane forest zone in southernmost Peru.

Figure 15. Tree seedlings often assume a curved form on slopes, which results in adult trees with basal curvatures in their trunks. Shown is a young seedling of Hedyosmum scabrum (Chloranthaceae).

The second major tributary of the Ucayali River is the Urubamba, associated with a 100 km wide area of montane relief in the department of Cusco from 11.5 to 13ºS (Fig. 12). The western side of the "U" is formed by the Vilcabamba Cordillera, the east-west wall created by the 5000 to 6000 m peaks of the Vilcanota mountain range, and the eastern side by the Paucartambo mountains, which are often less than 4000 m tall. Bedrock types include Paleozoic sedimentary, with enclaves of undifferentiated plutons.

Finally, the eastern montane forest belt resumes its mostly north-south trajectory between 12 and 14.5ºS (Fig. 13). The actual orientation is from northwest to southeast, thus following the shift in orientation of the Andes at 13 to 14ºS that corresponds to a change in the direction of plate subduction (Barazangi & Isacks 1979). This is the narrowest montane belt in the eastern Peruvian Andes, often only 30 to 50 km wide. The highest peaks are near 6000 m, so there can be as few as 50 km separating snow-capped peaks from Amazon lowlands. Bedrock is varied, with sedimentary rock from the Carboniferous, Paleozoic, and Cretaceous, plus Tertiary volcanics.

Today the predominant geomorphic and geological processes in the eastern Andes are mass wasting and fluvial. It is common to observe about 10% of a forested watershed occupied by recent landslides (Fig. 14); unfortunately no study has yet documented this process in eastern Peru. Young & León (1990a) found that trees with curved bases and root masses displaced upslope were common; however, even though this is often used as an indicator of soil creep (Harker 1996), we suggested that other processes might also be of importance. For example, it appears that the stem curvatures in seedlings and saplings (Fig. 15) caused by the movements of fallen branches along the slope could persist in the shape of trunks of adult trees.

Figure 14. Landslides leave linear scars on the montane forest landscape, such as this one in southern Peru.

Enormous amounts of small and coarse particles are carried from the montane forest belt by rivers during rainy season. Some originate with landslides and rockfalls that reach the rivers. Much, however, comes from the movements of rivers during flood stage. This puts even large boulders into motion and destroys old river terraces and any associated vegetation. During the dry season, these same montane rivers appear choked with boulders and logs, or even complete dead trees (Fig. 16). River meandering is limited over centuries by resistant rock, although over longer periods of time even rocks become shaped by the erosive forces.

A most dramatic input of water and consequent fluvial erosion and transportation probably occurred between 10,000 and 12,000 years BP as ice caps and glaciers melted at the end of the Pleistocene and the start of the Holocene.

Glaciers were quite large on the eastern slopes in the Pleistocene because the prevailing winds from the Amazon would have deposited abundant snow during wet seasons (Fig. 17). Topographic maps at a scale of 1:100,000 show the expected east-west asymmetry (Young 1989), with valleys facing eastward being much longer than those facing interandean valleys. Based on the form of valleys and the presence of moraines, it is likely that glaciers extended to about 2600 to 3000 m on the eastern slopes. Below that elevation, the valleys are V-shaped and were formed by fluvial rather than glacial processes. Presently, only the central and southern peaks of the eastern Andean cordillera have permanent ice above about 5400 m.

Figure 16. The river beds are filled with large boulders in dry season. In rainy season the action of the water can put these rocks into motion.

Figure 17. Often the highest elevations include topography shaped by past glacial activity. Here shown is a U-shaped valley at 3500 m in northern Peru.

There were probably several major advances and retreats of ice in the central Andes during the Pleistocene, though only the moraines of the last glacial maximum and the Holocene have relatively good dating (Clapperton, 1984, Seltzer 1990). Glacial moraines have been dated in the uppermost elevations of eastern-slope drainages at 8°S (Birkeland and others 1989, Rodbell 1991, 1993), 11°S (Wright 1984, Wright and others 1989), and 14°S (Mercer & Palacios 1977). Recent paleoclimatic investigations using ice cores (Thompson and others 1979, 1985, 1992, 1994) have also demonstrated considerable fluctuations in precipitation in the late Holocene, which would have affected the advance or retreat of glaciers in the study area.

The Tertiary of eastern Peru has been little studied, though it was the period of the most important uplift of the Andes (Mégard 1984, Sébrier & Soler 1991, Räsänen and others 1987, Hoorn and others 1995). This was especially notable beginning about 30 million years ago (Silver and others 1998). The most recent major uplift was at the end of the Pliocene.

The early Mesozoic was characterized by an extensional regime associated with the separation of South America and Africa, and accompanied by extensive volcanism (Ramos 1989). By 100 million years ago, a compressive-tectonic regime had developed, subduction of the Nazca plate was active, and the Andes (proto-Andes) were beginning to develop, starting with the eastern Cordillera (Jordan and others 1983, Ramos 1989). The climate reconstructions of Parrish (1993) show subhumid, humid, and wet conditions for this part of western South America. Riccardi (1988) reviewed what is known about fossils and rock formation during the Cretaceous, but only for South America to the south of 14°S.

During the Paleozoic, what are now the eastern Andes must have been an offshore marine depositional environment, based on the nature of the oldest rocks. However, there is also some bedrock dating from the Paleozoic and Precambrian that is volcanic in origin, found in what is now north-central Peru. In addition, much of the sedimentary rock has been metamorphosed (Cobbing 1985).

Rivers and drainage basins

The major river systems in or near the montane forest belt are, from north to south:

1. The Marañón River (see Fig. 7), with southward and eastward flowing tributaries that originate on the Cordillera del Cóndor: Cenepa, Comaina, and Cumbaza Rivers.
2. Rivers that drain the montane forest belt of central Amazonas and northern San Martín (Figures 7, 9): Utcubamba, Imazu, and Nieva Rivers, which flow into the Marañón River; Mayo, Huambo, and Jelache, which enter the Huallaga River.
3. Eastward flowing tributaries of the upper Huallaga River (Fig. 9): Jepelache, Pajatén, Abiseo, Mishollo, Tocache, Chontayacu, Magdalena, and Monzón Rivers.
4. The Pachitea River and its upper tributaries (Fig. 10): Pozuzo, Palcazú, Cacazú, and Pichis Rivers.
5. The Ucayali River and major tributaries (Fig. 11): Chanchamayo, Perené, Pangoa, Ene, and Apurímac Rivers.
6. The Urubamba River and its major tributaries (Fig. 12): Alto Urubamba and Yavero Rivers.
7. The Madre de Dios River and its northward and eastward flowing tributaries (Fig. 13): Alto Manu, Manu, Alto Madre de Dios, Pilcopata, Inambari, Marcapata, Tambopata, and Candamo Rivers.

With the exception of the first listed, these are the same drainage basins used by Young (1992) to delimit a preliminary classification of physiographic provinces for the eastern slopes. The addition of the Cordillera del Cóndor in this report raises the number of physiographic provinces to seven. These are meant to be practical and objective subdivisions that allow for reference to intra-regional differences of interest. Leo & Romo (1992) and Leo (1995) found these subdivisions to be useful for regional evaluations and planning.

Climate

Mean annual temperatures are 7 to 15°C for areas that correspond to the upper montane forests and 15 to 19° for the lower montane forests.

The national maps prepared by SENAHMI and reproduced in Peñaherrera (1989) are apparently the most updated sources available for climate data of the study area. Mean annual temperatures are 7 to 15°C for areas that correspond to the upper montane forests (2500 to 3500 m) and 15 to 19° for the lower montane forests (1500 to 2500 m). No north-to-south differences are conspicuous. These values suggest a lapse rate of about 0.65°C / 100 m, which is that expected in general (Johnson 1976).

Annual precipitation totals vary from 400 to 7000 mm, suggesting considerable intraregional and elevational differences. Probably most of the study area receives 1500 to 3000 mm annually. Also, Cavalier (1996) reviewed studies that found that fog interception by cloud forest vegetation can double the amount of actual precipitation due to additional moisture deposited by fog and fog drip. This means that the cloud forest portion of the montane forest belt undoubtedly receives significantly more effective moisture than these numbers would suggest (Fig. 18).

Figure 18. Much of the moisture received by cloud forests comes in the form of fog and fog drip.

The humidity provinces of the Holdridge life zone system that are present in the study area are dry (400 to 700 mm / yr), moist (700 to 1100 mm / yr), wet (1100 to 2200 mm / yr), and rain (>2200 mm / yr). As mapped by ONERN (1976), the majority of the montane forest belt is wet or rain forest, with one large section of montane moist forest near the town of Chachapoyas, and some dry or moist forests in the interandean valleys that open out onto the eastern slopes.

It is worth cautioning readers that no metereological stations exist in the montane forest belt of the eastern slopes. This is a common problem in mountainous areas. Barry (1992, p. 1) writes " . . . the meteorology of most mountain areas is little known. Weather stations are few and tend to be located at conveniently accessible sites, often in valleys, rather than at points selected with a view to obtaining representative data". All climate variables discussed in the scientific and planning literature and used in the various ecological zonation schemes in Peru (Tosi 1960, ONERN 1976, Zamora 1996) are extrapolations from data available from stations at lower or higher elevations, or from other parts of the Peruvian Andes.

Data from these metereological stations (see Peñaherrera 1989) suggest that the eastern slopes have a relatively marked seasonality of precipitation, but with no conspicuous latitudinally related changes. There is a dry (or drier) season during the months from May to September, and a wet season from September to May. The wet season of a "rain" forest would usually be two or four months longer than that of a "dry" forest. This seasonality is caused by a shift in the Amazon convective zone as the Intertropical Convergence Zone changes position (Johnson 1976). The presence of fog ameliorates these effects, however, by reducing solar radiation, reducing temperature fluctuations, and increasing relative humidity. In some areas, fog forms virtually every day of the year, especially in late afternoon or early evening as air rising convectively or forced orographically is cooled to dew point temperature.

The eastern slopes have a dry (that is, drier) season from May to September and a wet season from September to May.

The prevailing tradewinds keep a constant train of air parcels moving upslope many months of the year. In addition, the heating of air by the sun adds additional uplift to these air masses. Banks of cumulus clouds forced upslope are common by mid-day, although their movements are often obscured to ground-based observers (Fig. 19). When dry season comes, southeasterly winds can pull air parcels in from the Andean cordilleras or plateaus. However, daily weather in dry season is often instead set by more

Figure 19. Even on sunny days, clouds often form in the afternoon over the eastern montane forests due to convection and orographic uplift.

localized updrafts in an easterly direction that can result in cumulus clouds developing by noon. Occasionally outbreaks of cold air masses originating in Argentina move far enough northward to influence southern Peru; these occur in the austral winter months (Marengo and others 1997).

Additional local air circulation patterns can be important (Johnson 1976). Valleys downslope of glaciers and ice caps will be affected by downslope winds produced by the cooling of air over the ice (katabatic winds). There will also be upslope winds in many areas during the day, which reverse at night and flow downslope (Barry 1992). These local wind systems will be present except when overridden by regional or synoptic scale atmospheric processes, or modified by the topography of the mountains.

The montane forest belt is exposed to severe weather including heavy rainfall, wind storms and lightning. Hail and frost occur near timberline.

The montane forest belt is often exposed to severe weather, especially that associated with heavy rainfall during the wet season. Wind storms and lightning are also common at these times. Hail and frost occur near timberline, with the latter especially likely during the dry season when skies are clear at night. The presence of forest ameliorates severe weather, with wind speeds much lower inside closed forests and damaging frosts much less likely.

Hansen & Rodbell (1995) suggested that current climatic conditions developed about 3500 years ago, based on interpretation of fossilized pollen and lake sediment characteristics of a site in north-central Peru. The middle Holocene record suggests warmer and wetter conditions (Hansen and others 1984, Markgraf 1989, Hansen & Rodbell 1995). The transition from glacial to interglacial conditions was disrupted by a 1000 year long reversal called the Younger Dryas (Alley and others 1993, Mayle & Cwynar 1995), which may have influenced at least several of the tropical Andean sites that have been examined (Hansen 1995).

The presence of ice caps and glaciers along the upper elevations of most of the eastern Andean cordillera during glacial periods of the Pleistocene must have meant dramatic, 500 to 1000 m shifts downward in the climatic zones found today. In addition, the ice would have produced katabatic winds that might have locally lowered timberline.

Soils

Because of the steep slopes and often heavy rainfall, thin soils and frequent disturbances due to slope failure are to be expected (Stallard 1992). Zamora (in Peñaherrera 1989) provided a national map of major soil types. Virtually the totality of the eastern montane belt falls within the category called „Litosoles-Cambisoles (utricos y districos)“. These are inceptisols and shallow soils developed over rock (lithosols). Some unique habitats are associated with sandy soils developed on sandstone ridges. In cloud forests, the development of a thick surficial organic (O) horizon is common (for example, Young & León 1990a), undoubtedly due to low decomposition rates (Grubb 1977).

Due to soil characteristics and steep slopes the entire eastern montane belt has been placed in a „protection“ class, whereby any agricultural or forest production use is considered uneconomic and inappropriate.

Due to these soil characteristics and steep slopes, a national map outlining appropriate land use by Zamora (in Peñaherrera 1989) placed the entire eastern montane belt in a „protection“ class, whereby any agricultural or forest production use is considered uneconomic and inappropriate.

Implications for plants and animals

The past and present physical environments within the eastern montane forest belt provide settings for the evolutionary and ecological processes that have shaped the composition and distribution of the biota and the ecosystems they inhabit.

These montane forests occupy a privileged biogeographical position.

There is no doubt that these montane forests occupy a privileged biogeographical position. They are located centrically, with possible access over millennia from Amazonia, the southern Andes, and the northern Andes (and indirectly from Central and Northern America). There are also topographic connections to other Andean cordilleras, to interandean valleys, and to the Pacific and Lake Titicaca drainage basins. The prevailing atmospheric circulation is exactly that needed to create a variety of humid to extremely humid environments, some with persistent fog.

Over thousands and millions of years, the most important changes have been those due to geologic processes such as uplift and erosion, which have modified the nature of topographic connectivity. That is, these processes have affected the size and continuity of particular elevational zones and their landforms and soils. They also acted to create or modify features that restrict the movements of living organisms, serving as partial or complete biogeographical barriers. The Huancabamba Depression is often considered the most important north-south biogeographical barrier in the Andes (Vuillemuir 1977, Baumann 1988), although Patterson and others (1992) pointed out that it can also serve as an important east-west dispersal corridor for some organisms, connecting the Atlantic and Pacific basins. The Apurímac River is another feature likely of regional importance as a barrier.

Graves (1985) found evidence in the distribution of variation in bird plumages that suggests that upper montane forests are more separated by barriers to gene flow than the premontane and lower montane forests. However, biogeographic barriers are created not only by relief, but by the vagility of the organisms in question. Thus, many of the intra-regional features of the eastern slopes could serve to isolate relatively nonvagile plants and animals, while others would be unaffected because of their ability to cross apparently inhospitable relief (for example bat species studied by Koopman 1978, Pacheco & Patterson 1992, Patterson and others 1992).

Climate change adds another dimension to forces shaping the biota, especially over centuries and millennia (for example Colinvaux 1987, Bush 1994). Shifts in prevailing winds, the location of clouds and fog, seasonality, and lapse rates are the principal mechanisms that could cause climate change. These can only be studied indirectly in the past by proxy data calibrated to temperature and humidity regimes. These sorts of data suggest that most long-term change in the study area has been elevational, that is involving upward and downward shifts in climatic zones, although the biological response to those shifts would have been complex and often species specific.

The steep slopes that characterize much of the study area are caused by continuing uplift and rapid downwasting due to fluvial and mass movement processes. One result is an ecological context of constant change caused by natural disturbances, sometimes triggered by extreme rainfall events or tectonic movements. Another consequence is the establishment of steep elevational gradients that structure biotic assemblages in relation to change in temperatures and other shifts in cloud cover, precipitation, and severe weather.

Even within one part of that elevational gradient, however, there are great differences in the natural disturbance regimes depending on local relief. For example, whether a particular forest is located on a convex or concave slope (Fig. 20), a cliff (Fig. 21), a ridge, or in a riverine context. Underneath this topographic complexity lies additional edaphic variations caused by differences in the minerology of the bedrock and in the soil depth and development achieved on a particular slope position. The relative exposure of a site to upslope and downslope winds and to the development of clouds and fog also will be of importance within a given slope position.

Over ten degrees of latitude, it is also possible that there are biotic changes that could correspond to a complex latitudinal gradient in the study area. However, the available climate data do not suggest obvious environmental changes that are primarily due to latitude.

In conclusion, for the study area, environmental conditions related to elevation and slope position/exposure appear to be the two factors of particular interest in an ecological context and a temporal scale of days to decades. Over longer time periods, changes of those conditions due to climatic and geologic processes acting on and within topographic relief help determine how natural selection, adaptation, extinction, and speciation have affected the biota.

Figure 20. Often the tallest forests are found on mid-slopes, where the slope steepness is moderate and soils relatively deep.

Figure 21. Very steep slopes are also present. Even cliffs are partially vegetated, however.

3. Biological diversity

The complex physical conditions, plus ample supplies of moisture, have provided a heterogeneous and dynamic forest environment for the plant and animals species that thrive at relatively cool temperatures. In this section, we attempt to outline the composition and diversity of the plants and animals known or expected from the humid montane forests of eastern Peru.

Floristic diversity

Angiosperms

Most plant diversity is found among the flowering plants (angiosperms).

Most plant diversity is found among the angiosperms. By conservative estimates (Young 1991a, León and others 1992) there are about 2400 to 2800 species. The 145 families and 709 genera known to form the flora of the eastern montane forests and other associated vegetation types are listed in Appendix 1, although the totals will continue to change with new collections and information.

Especially speciose genera are found as epiphytes from the Araceae, Bromeliaceae (Fig. 22), Orchidaceae (Fig. 23), and Piperaceae (Fig. 24); as scandent herbs or lianas from Apiaceae, Araceae (Fig. 25), Liliaceae, Onagraceae, Oxalidaceae, Passifloraceae (Fig. 26), Piperaceae, and Scrophulariaceae; as forest understory herbs from Begoniaceae, Bromeliaceae, Poaceae, Solanaceae, and Urticaceae; as shrubs from Campanulaceae (Fig. 27), Ericaceae (Fig. 28), Melastomataceae, Piperaceae, Polygalaceae, Rubiaceae, Solanaceae, and Urticaceae; and as trees from Aquifoliaceae, Araliaceae, Chloranthaceae, Cunoniaceae, Fabaceae, Lauraceae, Melastomataceae, Moraceae, and Solanaceae.

Figure 22. Species of Tillandsia (Bromeliaceae) are common epiphytes on tree branches.

Young (1996) suggested that there is a unique mixture of species at middle elevations, including those restricted to those elevations, plus both highland and lowland groups that are present. Genera diverse below 2500 m, but little represented above that elevation include dicotyledons such as Acalypha, Casearia, Columnea, Ficus, Inga, Ipomoea, Psychotria, and Trichilia (Young 1991a). In turn, there are also plant groups that are more speciose and abundant in the upper montane forests. These include the monocotyledon genera Chusquea and Dioscorea, and the dicotyledon genera Brunellia, Calceolaria, Clusia, Gaultheria, Gynoxys, Oreopanax, Rubus, Senecio, Symplocos, Vaccinium, and Weinmannia (Young 1991a). Adding to considerable species turnover over elevational gradients (that is, high beta diversity), there is also important species turnover from drainage basin to drainage basin, with species replacement likely due to allopatric speciation caused by topographic dispersal barriers.

Gymnosperms

Tropical South America is not an important diversity center for gymnosperms. However, the montane forest belt is by far the most species-rich area for the gymnosperm familiy Podocarpaceae. The podocarps (Podocarpaceae) are important ecologically and economically. The approximately ten podocarp species are all trees and come from three genera: Podocarpus, Prumnopitys, and Retrophyllum (Veblen and others in press). Often they are found in relatively uniform stands above 2000 m elevation, perhaps associated with large-scale patch disturbances.

Ferns and fern allies

Almost a fifth of the diversity of vascular plants in the eastern montane forests is due to ferns and fern allies.

Almost a fifth of the diversity of vascular plants in the eastern montane forests is due to the ferns and fern allies (Appendix 2). This consists of 24 families, 74 genera and about 664 species, of which 102 are endemic to Peru (León &

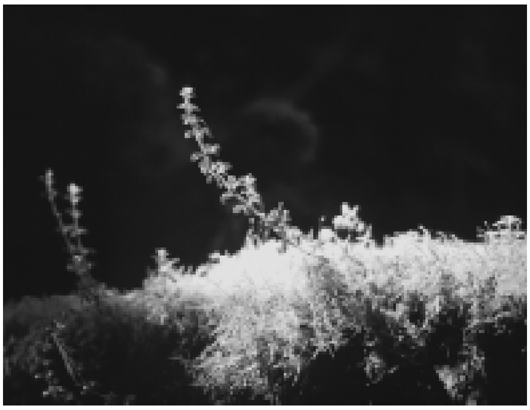


Figure 23 (upper left). Orchids (Orchidaceae) are by far the most diverse plant group in terms of number of species in the eastern montane forests. Many are epiphytic. Figure 24 (lower left). Peperomia (Piperaceae) is a diverse genus of epiphytes. Figure 25 (right). Many Anthurium (Araceae) species are bole climbers, which climb up the trunks of trees.

Figure 26 (left). Passiflora parviflora (Passifloraceae) is a common liana in timberline forests of northern Peru. Figure 27 (upper right). This Centropogon species (Campanulaceae) is pollinated by hummingbirds, based on the bright orange color and curved shape of the corolla. Figure 28 (lower right). Ericaceae is an important plant family for the study area. This shrub is Siphonandra elliptica and it grows at timberline in southern Peru.

Figure 29. The most diverse fern genus of the eastern montane forests is Elaphoglossum (Dryopteridaceae). Shown is a terrestrial species, although many others are epiphytes.

Young 1996). Especially diverse are epiphytes from Dryopteridaceae (Fig. 29), Hymenophyllaceae, Lycopodiaceae, and Polypodiaceae; and terrestrial herbs from Aspleniaceae (Fig. 30), Blechnaceae (Fig. 31), Dryopteridaceae, Gleicheniaceae, Pteridaceae, and Selaginellaceae. The tree ferns (Cyatheaceae) often locally dominate forest understories and can reach forest canopies or canopy openings at 8 to 12 m height (Fig. 32).

Most diversity is found from about 2000 m up to the altitudinal timberline (León & Young 1996). In fact, one study (Young & León 1991) showed that the highest pteridophyte diversity in a site in northern Peru was found in the timberline forests, where large organic mats on forest floors and tree limbs allowed normally epiphytic groups to be found as herbs and for normally terrestrial plants to be found above ground level as epiphytes. These were cloud forests where moisture is seldom limiting and where abundant and diverse populations of Elaphoglossum, Huperzia, and other genera could be found.

Figure 30. An example of Asplenium (Aspleniaceae), this A. squamosum grows as a terrestrial herb in montane forests of southern Peru.

Figure 31. This is a climbing fern of the family Blechnaceae (Blechnum binervatum).

Figure 32. Tree ferns are typically conspicuous members of the understory and subcanopy of eastern montane forests. Shown here is Cyathea pallescens (Cyatheaceae) in northern Peru.

Mosses and hepatics

The list of mosses of the eastern montane forest in Appendix 3 is far from complete, being based mostly on collections and research carried out on a altitudinal transect study in northern Peru (Gradstein & Frahm 1987, Frahm & Gradstein 1991). However, the diversity is impressive, with 38 families and 106 genera currently listed.

Similarly, a list of hepatics from Schultze-Motel & Menzel (1987), given in Appendix 4, also reveals much diversity with 28 families and 67 genera. Gradstein (1995) reports 250 hepatic species from the Chachapoyan forests in Amazonas, with most diversity from 2500 to 3250 m.

All authors agree (Gradstein 1992, Churchill and others 1995, others cited in this section) that the bryophytes are very diverse and conspicuous in wet neotropical montane forests, but they are so poorly known that urgent floristic, taxonomic, and ecological research is called for. Probably they serve important hydrological functions in the cloud forests (Pócs 1980).

Figure 33. Lower montane forests are relatively diverse and forest canopies are often 20 to 30 m tall. Shown is lower montane forest in central Peru.

Algae

No published information appears to exist for this important group in the study area.

Lichens and fungi

Although fungi play an important role as decomposers and as participants in mutualisms with plants, very little is known about them in the study area. From data assembled by Mueller & Halling (1995), it appears that possible Agaricales fungi for the study area are from the family Boletaceae and the genera Austroboletus, Boletellus, Chalciporus, Fistulinella, Gyrodon, Gyroporus, Phlebopus, Phylloporus, Pulveroboletus, Strobilomyces, Tylopilus, and Xerocomus. These authors stress how little is known about fungi in tropical montane forests.

Sipman (1995) estimates 1000 to 1500 species of lichens for Colombian montane forests. No similar estimates exist for Peru, but his estimate can be taken as an indication that lichens will also be diverse in the study area. In upper montane forests, we have observed conspicuous lichens of the family Collemataceae within the forest and of Cladionaceae in open places and on outer tree branches.

Vegetation

Zonal vegetation

It has been common to subdivide the eastern montane forest altitudinally into two forest belts: lower montane forests (roughly 1500 to 2500 m, Fig. 33) and upper montane forests (2500 to altitudinal timberline, about 3500 m, Fig. 34). This is more a matter of convenience than a categorization based on ample empirical evidence. The expectation would be for taller (10-35 m tall canopies) and more diverse forests (perhaps 30 to 60 tree species per ha) at the lower elevations of the montane zone. There are about 60% more vascular plant species known from 1500 to 2500 m than from 2500 to 3500 m (Young 1991a).

Figure 34. The upper montane forests are often shorter in stature and include fewer tree species. This forest is 8 to 12 m tall and has an understory dominated by Chusquea bamboos. It is located at 3400 m in northern Peru.

In addition, there are four humidity provinces recognized in the Holdridge life zone classification for the study area (ONERN 1976), meaning, as an example, that it would also be possible to distinguish lower montane wet forest from lower montane rain forest. Currently this can only be done crudely for the study area, with large areas of upper and lower montane wet forest to be found in the departments of San Martín, Huánuco, Pasco, and Cusco.

Finally, it might at times be useful to separate the altitudinal timberline zone from the upper montane forest below it and the grassland-dominated tropical alpine zone above it (see Fig. 5). Some authors have referred to this as a tropical subalpine zone (see Webster 1995), others simply as timberline (Young 1993a). What is clear from studies in northern Peru (Young 1993a, 1993b, 1998b) and in southern Peru (Cano and others, 1995) is that useful generalizations about this timberline forest are difficult to make because of great spatial heterogeneity in forest stature. There are areas where forest adjacent to high elevation grasslands is a dense tangle of shrubs two meters in height and other places where a 10 to 15 m forest is present with emergents to 20 m. Thus, it is neither useful nor correct to label all timberline forests as "elfin" or "dwarf" forests. Some of this heterogeneity is caused by edaphic conditions, specifically the texture and drainage of the soils, especially as affected by slope position, and another portion due to disturbance, including the influence of grassland fires set by people that maintain timberline forest margins and the resulting edge effects (Young 1993b). Understanding the ancient and present-day human impact in setting timberline is a critical issue in evaluating the upper montane forests. Only the most preliminary research has been carried out in this ecotone to date.

Azonal vegetation

Forest stature is probably correlated with steepness of slopes, soil depth, and persistent winds or fog.

Within the zones created by elevation and precipitation there is additional widespread heterogeneity in forest structure, stature, and species composition. We predict that the most direct relationship with forest stature will prove to be the steepness of the slopes and the soil depth, in addition to such environmental factors as persistent winds or fog, due in part to exposure on particular slope positions. Thus, an exposed ridge with little soil and affected by strong winds will have a short-statured forest or perhaps even a shrub- or herb-dominated plant community. Such areas have been mentioned for the Cordillera del Cóndor (Schulenberg & Awbrey 1997), Cerro Pajonal in Pasco (Stolze 1987), and elsewhere (Weberbauer 1945). In fact, sheer cliffs are abundant and fairly densely vegetated (see Fig. 21), although detailed descriptions are lacking. Further complicating this categorization is the fact that relatively dry interandean valleys come into contact with the humid montane forests in the river valleys that descend toward the east.

Midway down long slopes are often to be found the tallest forests (see Fig. 20). Soil has accumulated there due to mass movements and down wasting. Emergent trees can reach 40 m or more; even at 2900 m there were numerous 35 m tall Cedrela montana on this slope position in northern Peru (Young & León 1988, Fig. 35).

Near rivers, however, slope stability is altered by the dramatic changes in discharge between rainy and dry seasons, associated at high water stage

Figure 35. The largest tree in this picture taken at 2900 m in northern Peru is a 35-m-tall Cedrela montana (Meliaceae).

with bouts of river meandering and fluvial erosion. The terraces left behind by the rivers are colonized by trees and eventually a forest forms, but one that is often relatively short in stature and composed of plant species adapted to colonization after disturbance, such as Coriaria ruscifolia.

Wetlands also are present, although not conspicuous. There are a few small lakes that are associated with herbaceous wetlands. In a few sites there are Sphagnum bogs. In addition, there are also forested wetlands, dominated by arboreal species able to tolerate saturated soils. Some of the palm stands described by Robin Foster (personal communication) for central Peru are likely associated with such edaphic conditions.

Figure 36. Chusquea bamboos often dominate regrowing vegetation following deforestation. Shown here is Chusquea scandens at about 3000 m.

Another local variant is the frequent dominance by bamboos, typically of the genus Chusquea (see Fig. 34). Usually, a Chusquea species is a dominant understory component in most forests above about 2000 m. However, in cases where the canopy is low or open, the Chusquea species can become so dominant that it appears there is little space for other plants, especially for tree species that are intolerant of dense shade during seedling and sapling stages. We have seen numerous forest stands at 3000 to 3400 m dominated by Chusquea scandens (Fig. 36) and others at 2600 to 3000 m dominated by Chusquea picta. Whether tree regeneration is prevented by the bamboo or not depends on the autecology of both the tree and the bamboo species involved. Widmer (1997) speculated that Chusquea species could affect forest dynamics in Costa Rican montane forests and Stern (1995) found some evidence that Chusquea scandens affected tree growth in Ecuador. On the other hand, Young (1991b) tried but was unable to show such a relationship between a smaller (and as yet unidentified) Chusquea species found at 3450 m in northern Peru.

Plant species of concern

The most economically important plants are those used for timber. These principally consist of the podocarps (Podocarpus spp., Prumnopitys spp., Retrophyllum rospligliosii), the meliacs (Cedrela montana, Guarea kunthiana), and the lauracs (Nectandra spp., Ocotea spp., Fig. 37). There is no sustainable or rational extraction of timber anywhere in the eastern slopes. Where roads provide access, the timber is extracted and all valuable boles removed.

There is no sustainable or rational extraction of timber anywhere in the eastern slopes.

There is some extraction of ornamental plants, such as orchids (Orchidaceae) and bromeliads (Bromeliaceae) for the nursery and hobby trade. In theory, this is now prohibited or regulated by law. In addition, tree ferns (Cyatheaceae) are cut and the trunk and adventitious roots sold to be used as a growing substrate for epiphytic orchids. There is likely some extraction for medicinal plants. These plant groups are the ones that could most directly be threatened by human extraction. Needed are studies that

Figure 37. Trees of the family Lauraceae are important members of the canopy of the eastern montane forests. Their fruits are attractive to birds and their timber is often valuable commercially.

evaluate the degree and scale of use and that investigate possibilities for making that extraction sustainable, when legal and practical difficulties can be overcome. Other plants are threatened indirectly due to habitat alteration and degradation.

The montane forests include plants that will become increasingly important as genetic resources, particularly for the improvement of cultivated plant groups, and for a better understanding of the domestication and evolutionary history of plants. Debouck & Ferla (1995) discussed this issue for neotropical montane forests, and listed such genera as Carica (Caricaceae), Passiflora (Passifloraceae), Persea (Lauraceae), Prunus and Rubus (Rosaceae), and Solanum (Solanaceae), to which we would add Oxalis (Oxalidaceae) and Vaccinium (Ericaceae).

In terms of plants that can become nuisances, the slopes that have been partially deforested often become dominated by Chusquea bamboos (see Fig. 36) above about 2200 m and by Pteridium aquilinum ferns (Fig. 38) at lower elevations. These clonal species can aggressively occupy space and might act to prevent or modify forest regrowth. However, although these could thus be considered nuisance species, their role in preventing tree regeneration remains unproven. In fact, the slow recovery of human-disturbed montane forests might instead be due to soil compaction, loss of mycorrhizal fungi, and limited seed sources. Many of the slopes that are burned and grazed following deforestation become extensive and long-lasting areas of shrubs and grasses.

Figure 38. At elevations below 2000 m, disturbed areas can be covered by the fern, Pteridium aquilinum (Dennstaedtiaceae).

Faunal diversity

Mammals

Figure 39. Thomasomys daphne from upper montane forest in southern Peru. At least 120 species of mammals are found in the study area.

At least 120 species of mammals are found in the study area based on our preliminary tabulation (Appendix 5), out of the 460 species known from Peru (Pacheco and others 1995). The largest group consists of bats (five families, 26 genera, roughly 44 species), although this is but a small portion of the diversity found at lower elevations in humid premontane and lowland forests. A dramatic decline in bat diversity with elevation in Peru has been shown by Graham (1983, 1990) based on museum collections and by Patterson and others (1996, 1998) based on field work over a 4000 m elevational gradient in southeastern Peru.

There are 11 genera and more than 34 species of murid rodents in the montane forests, with particular diversity in Thomasomys mice (Fig. 39), with probably more than 15 species. The caviomorph rodents consist of eight species, with pacaranas (Fig. 40) and montane bamboo rats being especially typical, although not often seen. Probably much speciation is allopatric, with differences originating from dispersal barriers among the watersheds, at least as can be surmised from the several rodent genera examined by Patton and others (1990).

Other important groups include the carnivores, with ten species, and the marsupials with about twelve. Less diverse are the primates (five species), the deer (four species), armadillos (two species), a tapir, and a rabbit species.

Figure 40. This pacarana (Dinomys branickii) was taken from the wild.

Birds

This is an important area of diversity for birds, although specific studies are still relatively few. O'Neill (1992) estimated that about 55 to 60% of Peru's more than 1700 bird species were to be found in the montane and premontane forests of the eastern slopes of the Peruvian Andes. He reported the following groups to be especially diverse and characteristic of the eastern slope montane forests: psittacids, trochilids, ramphastids, funariids, contingids, tyrannids, and emberizids (Paulinae, Thraupinae, Emberizinae).

For this report, Niels Krabbe made a preliminary listing of 303 bird species likely to be found regularly in the upper montane forests of the study area above 2500 m (Appendix 6). Examination of additional sources (Parker and others 1982, Fjeldså & Krabbe 1990, Ridgley & Tudor 1989, 1994, Stotz and others 1996) suggests that at least 70 or 80 species would be added to the list by including the eastern lower montane forests down to 1500 m. Especially diverse groups include the hummingbirds (Trochilidae, Fig. 41), with 19 genera and almost 40 species, the ovenbirds and woodcreepers (Furnariidae) with 12 genera and 24 species, the tyrant flycatchers (Tyrannidae) with 18 genera and about 33 species, and tanagers (Thraupidae) with 23 genera and 53 species. Also relatively diverse are the hawks (6 species), parrots (10), woodpeckers (4), ground antbirds or antthrushes (13), tapaculos (12), contingas (6, Fig. 42), wrens (9), thrushes (8), wood warblers (10), and emberizine finches (22). These numbers represent a conservative assessment of which species should be included as members of the montane forest avifauna. Many additional species enter the area marginally, and future studies may reveal local populations that are well established within this ecological zone.

Figure 41. There are nearly 40 species of hummingbirds (Trochilidae) in the eastern montane forests. They are important pollinators for plants from such genera as Centropogon (Campanulaceae) and Fuchsia (Onagraceae).

Terborgh and colleagues (Terborgh 1971, 1977, Terborgh & Weske 1975) have done the most detailed studies on how bird communities change along the montane-premontane-lowland forest elevation gradient found in southern Peru. They proposed that biotic interactions, specifically competition, were at least as important as the physical environment in shaping the species composition along the gradient studied. Traylor (1985) documented elevational segregation among Ochthoeca species in the study area. In the last several years, Fjeldså and colleagues (Fjeldså 1992, 1994, 1995, Arctander & Fjeldså 1994, Fjeldså & Rahbek 1997, García-Moreno & Arctander 1998, Roy and others 1997) have used information about bird distributions and phylogenetic relationships to establish speciation patterns and locate centers of endemism, some of which are specific to the central Andes (see also Box 1, pages 32-33).

Figure 42. This Pipreola species (Contingidae) was found in a timberline forest in southern Peru. At least 303 bird species are occupants of the eastern montane forests above 2500 m.

Box 1. Birds as biodiversity indicators

by Jon Fjeldså

Birds have been classified and charted more completely than any other organismal groups and therefore can be used for detailed analysis to explain variations in species richness, and of how to prioritise conservation work. Bird data have been used in the DIVA project on three different levels:

1. In a close collaboration between DIVA and the Danish Centre for Tropical Biodiversity the distributions of all 3000 South American breeding birds were mapped and analysed (see Fjeldså & Rahbek 1997 and in press for details). We used the computer software WorldMap (Williams 1994) and a spatial resolution of one degree (1½), which is the finest resolution possible for continent-wide analysis considering the uneven sampling.

This study reveals that the eastern slope of the tropical Andes region is the ornithologically richest in the world, with the highest number of species found at the Equator. A full altitudinal transect, from the East Andean ridgecrest to the Amazon lowland can have more than 1000 bird species (Remsen & Parker 1995), which equals the number of bird species in the entire Amazonian lowland! The magnitude of the Amazonian species pool is partly a result of the enormous area of the biome (Rahbek 1997) and its habitat heterogeneity. While most Amazonian species are widespread, the Andes region is very complex with many many species inhabiting very small areas (endemic species) or segregated in different altitudinal bands. The data permits detailed analysis of relationships between species richness and environmental parameters.

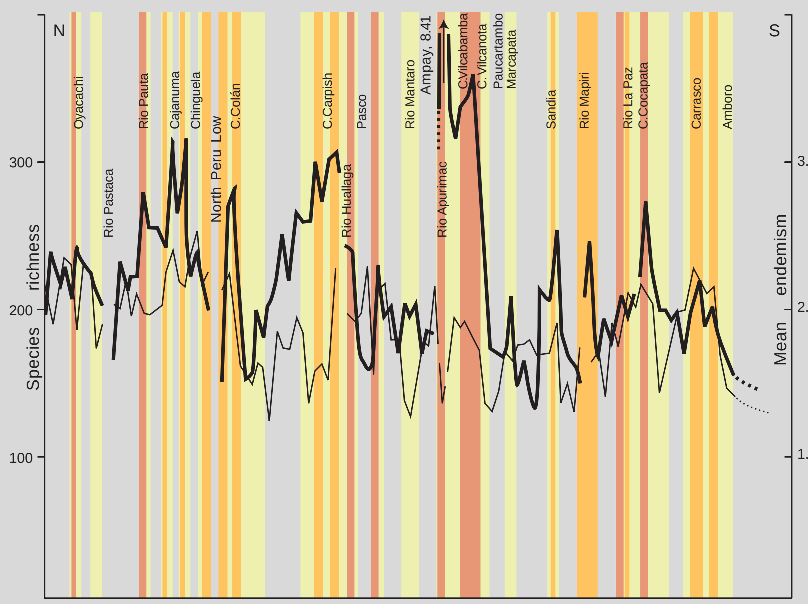
2. All birds breeding in the Andean region from the Caribbean Coast to the arid zone at 22½S in Argentina / Chile were mapped and analysed with a fifteen minute (15') geographical resolution, which is suitable for identifying places of special importance within our Andean study area

The figure illustrates the variation in avian diversity along the humid eastern Andean treeline. The variation in species richness relates mainly to variations in habitat complexity from cell to cell, and in general the upper montane forest has 200 bird species all the way from the equator through Peru to central Bolivia. The endemism, however, shows some remarkable peaks which reflect a highly nested distribution of species with very small ranges. In Peru, the main peaks of endemism are north and south of the North Peru Low, in Cordillera Carpish in Huánuco, at Nevado Ampay near Abancay (Apurímac) and in southern Cordilleras Vilcabamba and Vilcanota in Cuzco. The intervening areas are characterised mainly by widespread species.

The variation in species richness and endemism was compared statistically with data on ecological stability (interannual variability in the vegetation parameter NDVI, calculated month by month and resampled to 15' cells). The peaks of endemism correspond quite precisely with places which are ecologically stable (Fjeldså and others in press). The most important single factor responsible for this seems to be orographic moderation of the impacts of south polar winds. Presently manifesting as occasional winter freezes in the southern part of the tropical zone, these winds may have been a major determinant of vegetational changes during Pleistocene glacial periods. The correlations suggests that most endemics are relict populations which survived periods of global climatic change in places where these impacts were moderated.

What makes this finding particularly interesting is that these places are immediately adjacent to densely populated areas and centres of past high cultures. The current conservation strategy of reserving areas with few people therefore needs to be supplemented with actions to secure sustainable development in these densely populated areas. Although the causal nexus underlying the correlation between endemism and human populations needs to be explored in detail, the principal cause may be predictable climatic conditions (Fjeldså and others in press) and good soils in the adjacent rainshadow areas, where there is a balance between rainfall (soil leaching) and precipitation (Holdridge 1967).

3. During the DIVA fieldwork, methods were developed for rapid (2-3 days) assessment of species richness and community structure of birds for comparison of sites with different human activity. In general we found that a moderate selective cutting and extractivism did not seriously threaten the birdlife, as long as a mosaic vegetation with some patches of dense well matured forest was maintained.



Variation in species richness of birds (thin line) and endemism (heavy line) along the eastern Andean humid treeline of Ecuador, Peru and Bolivia (calculated for 15' cells). Endemism is calculated as the inverse range size for each species (the value 1 corresponds to the average range of all montane species (=789 cells)). The shading shows places characterised by very stable conditions (low interannual variability measured from a ten-year series of cloudfree composite scenes of meteorological satellite images; see Fjeldså and others in press).

Reptiles

Unfortunately, available summaries of Peru's reptiles only give those species found in the entire eastern slope region, thus combining both montane and premontane forest species (Appendix 7). What can be stated is that 27 lizard species and 48 snake species are known from 600 to 3500 m in eastern Peru (Carrillo de Espinoza & Icochea 1995). Especially speciose are tropidurid lizards of the genus Stenocercus and amphisbaenid lizards of the genus Amphisbaena. Speciose snake genera are colubrids of the genera Atractus,

27 lizard species and 48 snake species are known from 600 to 3500 m in eastern Peru.

Figure 43. Eleutherodactylus is an important genus of leptodactylid frogs in the eastern montane forests.

Figure 44. The rainbow trout (Oncorhynchus mykiss) has been introduced to many of the streams and rivers of the eastern montane area.

Figure 45. Among others, webs of the spider family Araneidae are commonly found on branches and tree trunks in montane forests. This photograph is of a web of an Alpaida species and was taken by Diana Silva.

Dipsas, Liophis, and Oxyrhopus.

Amphibians

The recent national survey of amphibians developed by Rodríguez and others (1993) presents data combined from both premontane and montane forests of the eastern Andes (Appendix 7). There are 107 frog species, two salamanders, and two caecilians listed from those elevations. It is clear that many of the frog species can be found in wet montane forests. Genera with more than four species are Atelopus and Bufo (Bufonidae), Cochranella (Centrolenidae), Colostethus, Dendrobates, and Epipedobates (Dendrobatidae), Gastrotheca and Hyla (Hylidae), and Eleutherodactylus (Fig. 43), Leptodactylus, and Phrynopus (Leptodactylidae).

Fish

Probable fish groups for the study area are those expected to be found in clear, fast-moving, and cold water. According to Ortega (1992) these are Astroblepus spp. (Astroblepidae) and Trichomycterus spp. (Trichomyteridae). Other likely residents of the streams and rivers are from the following groups: Chaetostoma (Loricariidae) and Acrobrycon, Bryconamericus, Creagrutus, Ceratobranchis, and Hemibrycon (Charicidae). Apparently no published inventory data exists for the study area.

In the last 30 years the carnivorous rainbow trout (Oncorhynchus mykiss) has been introduced to the headwaters of most river systems on the eastern slopes (Fig. 44).

Invertebrates

This is likely to be shown to be a globally significant area for the diversity and endemism of some invertebrate groups. For example, Silva (1992) reports more than 450 spider species from five montane sites above 1500 m on the eastern slopes of Peru. She found few shared species among those sites and often 90% of collected material came from undescribed taxa. Therefore, there must be many hundreds of highly endemic spider species in these forests out of the approximately 3000 species estimated for the country (Silva 1996).

Groups reported by Silva (1992) as characteristic of closed montane forests are the araneids, theridiids, and salticids, while open habitats have linyphiids, tetragnathids, dictynids, and amaurobiids. The most speciose genera are Dubiaranea (Linyphiidae) and Chrysometa (Tetragnathidae). Spider families with at least ten species in the study area are orb weavers from the Araneidae (Fig. 45) and Tetragnathidae, sheet-web weavers from the Linyphiidae and Theridiidae, cursorial hunters from the Anyphaenidae and Salticidae, and ambush predators from the Thomisidae (see Silva 1992 and Silva & Coddington 1996).

Ramírez (1996) listed families of the terrestrial molluscs for the forests of the eastern slopes of the Peruvian Andes. Some of these are likely to be inhabitants of the eastern montane forests, although others are from premontane and lowland forests. The families are Bulimulidae, Amphibulimidae, Megalobulimidae, Systrophiidae, Helminthoglyptidae, Spiraxidae, Subulinidae, Euconulidae, Camaenidae, Solaropsidae, Pupillidae, Vertiginidae, Succineidae, Clausiliidae, Ferussaciidae, Endodontidae, Helicinidae Ceresidae, Poteriidae, Megalamastomidae, Diplommatinidae, and Veronicellidae.

The streams and rivers have been little sampled to date. For example, Louton and others (1996) only report two Odonata species from two genera in a stream located at 2200 m near Manu National Park in southern Peru: Cora (Polythoridae) and Aeshna (Aeschnidae). However, Flint (1990) studied the caddisflies (Trichoptera) in the same area. Even though he only sampled four days at two sites (2200 and 3420 m), he found at least 15 species, suggesting relatively high diversity for this group. The genera and families reported were Atopsyche (Hydrobiosidae), Mortoniella (Glossosomatidae), Chimarra (Philopotamidae), Austrotinodes (Ecnomidae), Polycentropus (Polycentropodidae), Centromacronema, Leptonema (Hydropsychidae), Atanatolica, Grumichella, Nectopsyche (Leptoceridae), Banyallarga (Calamoceratidae), Marilia (Odontoceridae), and Contulma (Anomalopsychidae).

Animal species of concern

Useful animals include those that are hunted for their meat or fur, such as the Andean bear and the deer species. In addition, we have observed commercial butterfly collectors in the study area, although their impact is likely minimal.

The only sustainable or at least nondestructive use of vertebrates that we have witnessed is ecotourism at a lek of cock-of-the-rock (Rupicola peruviana) located near 1800 m on the road to Atalaya and the low elevations of Manu National Park. The extravagantly plumed males display in the understory of the forest, attracting both females of its species and tourists.

Figure 46. Lestoros inca (Caenolestidae), the Inca marsupial mouse, is a narrow endemic that is restricted to montane forests of southern Peru, but is fairly common in its habitat.

The most threatened species are those that are endemic to areas affected by deforestation, especially if they are also susceptible to hunting. Mammal species that have very narrow distributions include the Junín red squirrel (Sciurus pyrrhinus), only known from montane forests in central Peru, the woolly armadillo (Dasypus pilosus), found in upper montane forests, and Lestoros inca, the Inca marsupial mouse (Fig. 46), found only in the montane forests of southern Peru. Although the Andean bear (Tremarctos ornatus) has a wide potential distribution and is a habitat generalist, it has become restricted to remote montane forests because of poaching and habitat encroachment (Peyton 1980).

Three mammal species that are threatened are the woolly tapir (Tapirus pinchaque), found only in the upper montane forests found to the north of the Marañón River and the Huancabamba Depression, the yellow-tailed woolly monkey (Lagothrix flavicauda, Fig. 47), known only from intact montane forests above 2000 m in Amazonas and San Martín (Leo 1980, 1984), and a night monkey (Aotus miconax), known only from Amazonas (Hershkovitz 1983, Ford 1994).

Figure 47. The yellow-tailed woolly monkey, a threathned species, has a range restricted to northern Peru montane forests. Protected populations can be found in Río Abiseo National Park. Shown is an individual held briefly in captivity in the early 1980s.

Birds endemic to small areas in the eastern montane forests and dependent on mature montane forests are thus at risk from deforestation or forest degradation. Information on these species can be extracted from Stattersfield and others (1998). An example would be Aulacorhynchus huallagae, the yellow-browed toucanet, which is inexplicably restricted to several forest watersheds of the departments of San Martín and La Libertad, even though apparently suitable habitat is found to the north and south (Schulenberg & Parker 1997). Other species at risk because of very small distributions would include most

Almost half of the frogs, birds, and mammals endemic to Peru are found in humid tropical montane forests, with the majority further restricted to cloud forests.

of the frogs listed in Appendix 7 and many of the spiders. In a pioneering attempt, Leo (1995) found almost half of the frogs, birds, and mammals endemic to Peru are found in humid tropical montane forests, with the majority further restricted to cloud forests. The recent analysis of Patterson and others (1998) shows that the distributions of species will depend on the group sampled: bird and bat diversity patterns along an elevational gradient in southeastern Peru were similar, but the patterns shown by mice were quite distinct. This suggests that numerous groups need to be examined when making conservation recomendations.

Research in Ecuadorian montane forest by Marsh & Pearman (1997) showed that local population sizes of several frog species were affected by forest fragmentation, which reduces area of forest patches and isolates them by increasing distances to neighboring patches. Various authors have demonstrated dramatic effects of human-caused forest fragmentation on tropical montane birds in the northern Andes (Kattan 1992, Arango-Velez & Kattan 1997, Restrepo and others 1997, Restrepo & Gómez 1998). These kinds of investigations are needed in the study area.

Montane forest animals that are at times of concern because they can cause economic damage (Young 1997) include the puma (Felis concolor) and Andean bear, which occasionally kill livestock, and parrots (Psittacidae), which can damage fruit and grain crops. The introduced rainbow trout (Oncorhynchus mykiss, see Fig. 44) has probably devastated populations of native fish and frogs in most montane rivers and streams in the study area.

Global importance of the eastern montane biota

Probably the most notable feature of the biological diversity is the species richness found in certain groups.

Probably the most notable feature of the biological diversity is the species richness found in certain groups. The eastern montane forests either provide habitat that is unique or which is a critical part of species distributions along the elevation gradient of the eastern slopes.

The plant groups most diverse in Peru's eastern montane forests are the mosses, hepatics, the pteridophytes, the orchids, and Lauraceae, Melastomataceae, Piperaceae, and Solanaceae. These are also the groups with the most endemic species, most of which are found in mature, closed forests. Although endemism is hard to quantify and evaluate, probably about 10 to 20% of the flora is found no where else, not even at lower elevations of the eastern slopes or in the montane forests of Ecuador or Bolivia. Some plant groups contain genomes of interest as genetic resources for the improvement and understanding of cultivated plant species. For example, recently Emschweiler & Doyle (1998) have begun to tease apart the complex relations that point to a role of montane forests as the habitat of some of the wild species of Oxalis related to the cultivated oca (Oxalis tuberosa).

Probably about 10 to 20% of the flora is found no where else.

Vertebrate diversity is particularly noteworthy among the bats and rodents, the hummingbirds, ovenbirds and woodcreepers, the tanagers, the tyrant flycatchers, and the frogs. Endemism is again hard to evaluate, but there is no doubt that dozens of mammal, bird, and frog species are found no where else and are dependent on the existence of large tracts of montane forests undisturbed by human settlement and exploitation.

As in other tropical forests, there is much interdependence of plants and animals, so entire ecosystems must be set aside for conservation purposes.

As in other tropical forests, there is much interdependence of plants and animals, so entire ecosystems must be set aside for conservation purposes. The majority of the seeds produced by the montane angiosperm and gymnosperm species are dispersed by animals, particularly by birds and bats. Most of the flowering plants are pollinated by insects and hummingbirds (see Figures 27 and 41). Remsen (1985) showed that fruit and nectar resources, plus habitat provided by bamboo thickets and epiphytes, were important explanations of relatively high bird species diversity in humid timberline forests in Bolivia.

Overlooked by many conservationists are the montane rivers and streams, in whose waters are found very poorly known floras of algae and faunas of aquatic invertebrates and fish (Allan & Flecker 1993). The headwaters in the study area are in tropical alpine and montane forest vegetation types. The water in the streams is cold and fast moving. During dry season these are clear and boulder-lined (see Fig. 48). During rainy season, they become dynamic and occasionally turbid water courses carrying thousands of cubic meters of water and tons of rocks, boulders, and logs. These dramatic seasonal changes have important consequences for the aquatic organisms (for example, Flecker & Feifarek 1994).

Together, the forests and rivers of the eastern slopes constitute a wilderness area unique in its characteristics and size within Peru. Because of relatively high endemism, similar natural environments in neighboring countries, such as Ecuador and Bolivia, will have rather different floras and faunas, especially at the species level. Interestingly enough, however, the eastern montane forests have not served as an important area for human settlement over the past millennia, and as far as we know, there are presently no indigenous settlements in the study area.

The forests and rivers of the eastern slopes constitute a unique wilderness area.

As far as we know, there are presently no indigenous settlements in the study area.

Figure 48. Rivers and their conservation are integral parts of holistic planning for the eastern slopes of the Peruvian Andes. Shown is a river bed during dry season in a montane area of southern Peru.

4. Human use and settlement

The earliest traces of humans in central South America are along the coast (Keefer and others 1998, Sandweiss and others 1998) and at the highest elevations (Rick 1988, Bruhns 1994), in the corridor formed by the Andean cordilleras. In the mountains, the ice would have been retreating in the late Pleistocene and early Holocene while small groups of hunters and gatherers encountered new environments with a fauna unprepared for humans possessing weapons, dogs, and fire. There was a window of opportunity when temperatures warmed 12000 years ago that apparently served for these people to move along the Andes. Possibly this occurred even earlier, as Dillehay (1989) found a settlement in temperate rain forest in what is now Chile that predates this time period.

In the millennia that followed, other settlements appeared in the seasonally dry eastern Amazon forest (Roosevelt and others 1996), in northern South America (Barse 1990), and in the arid Peruvian coast (Moseley 1992). By 11000 BP, at least some parts of the Andes were experiencing a 1000-year-long return to glacial conditions known as the Younger Dryas (Lowell and others 1995, Hansen 1995). About this same time, much of the South American megafauna went extinct. These included gomphotheres, saber-toothed cats, horses, giant ground sloths, large vultures, and a giant spectacled bear (Lemon & Churcher 1961, Martin & Klein 1984, Hofstetter 1986), which are not found in more recent sites.

The eastern montane forests probably never were an important settlement area.

The eastern montane forests probably were not an important settlement area or resource zone for people during this time of great social and environmental fluxes. And this situation may have continued up through history. Census data since 1876 (Appendix 8) reveal that less than 6% of Peru's population has been found on the eastern slopes; and most of these residents lived (or live) at lower elevations and not within the montane zone itself. In fact, human history seems to have left tangible changes only at the highest elevations in the ecotone with tropical alpine environments and at the lowest elevations where montane forests grade into premontane forests. The conservation opportunities still possible for this region at the end of the 20th Century are due to the light touch of humanity on these landscapes over the millennia, something not true for other montane forests in the central Andes (Ellenberg 1979, Young 1998a).

In this section, we attempt a chronological review of what is known about human settlement of the eastern montane forests. Then we outline the use of natural resources of the region for those same time periods. Although the most conspicuous modifications have occurred since 1960, it is also important to develop a long-term perspective on the role of humans in shaping the eastern montane biota.

History of settlement

Precolonial

Figure 49. Manachaqui cave, shown here, has been excavated and studied by archaeologist Warren Church.

There is a cave in the east-west trending Manachaqui valley in northern Peru that has served as a shelter for travelers crossing or following the eastern Andean cordillera for the last 9000 years (Fig. 49). Church (1996) excavated this cave and has analyzed in detail the habitation and use levels in reference to cultural development from about 4000 years BP to 1500 years BP. He finds, as an example, evidence of early long distance trade in the form of obsidian brought to the cave in preceramic times from 1000 km to the south. At some points in time there were travelers using the cave and leaving behind artifacts, especially ceramics, which originated to the east in montane and premontane forests, to the west in the highlands, to the north, as far as present-day

Ecuador, and to the south, as far as present-day southern Peru.

The abundant archaeological sites located within the eastern montane forests in the departments of Amazonas and San Martín are not well dated, but many appear to belong to the 500 to 1000 year period before arrival of the Incas and Europeans (Box 2, page 40). Lennon and others (1989) and Church (1994) provide a date almost 1000 years earlier from fill within a major building in the Gran Pajatén site, which indirectly indicates human residence in the montane forests over a 2000 year period, although no information on population sizes is available. These sites are associated with terraces that could have supported such crops as maize, bean, and squash. It is likely that potatoes and camelids were raised at higher elevations in the tropical alpine zone.

There appear to be fewer pre-Inca sites in central Peru's eastern montane forests. Raymond (1985) reports an absence of sites in the lower Apurímac valley from 1500 to 3000 m, with most at 600 to 800 m. Hastings (1985) found 110 sites in the valleys to the east of Tarma, of which 40 were at elevations where montane forests could potentially grow. Other information for this area is based on research by Lathrap (1970) and known settlements are below 1000 m, often in flat valleys opening out to the Amazon basin.

In the south, terracing has been described (Isbell 1968, Donkin 1979), but is undated and appears to be related to coca cultivation and hence at a relatively low elevation in the premontane forest zone.

The establishment of the Inca empire caused many changes in land use, settlement patterns, and economic processes in the Andes (Bruhns 1994, Schjellerup 1997). Although most of the Inca's early expansion was on the cordilleras, in inter-Andean valleys, and on the coast, there came a time when the Inca ordered military advances into the eastern slopes. Machu Picchu is the best known Incan outpost and is situated in the splendid topography of the montane forest zone of the upper Urubamba River valley (Fig. 50). While this was apparently an important site for rituals, other localities served an economic function, allowing an upward trade of lowland products in return for the upland items of interest to the indigenous groups living in the east Andean foothills.

The story is quite different in northern Peru where the Incas found an ancient and well-developed regional cultural group associated with the montane forests that was not interested in being dominated. Half a century of combats ensued before the Incas were successful in their goals and such sites as Cuelap and Gran Pajatén were incorporated into the empire (Schjellerup 1997). This brought changes in the transportation system (such as improved trails that connected to the empire's system of llama trains and messengers) and new economic processes (e. g., tributes to the empire).

Figure 50. Machu Picchu is the best known of the eastern montane archeological sites.

Box 2. The Chachapoyas

by Inge Schjellerup

In the north-eastern Peru on the eastern slopes of the Andes in the montane forest a totally new settlement pattern emerged in the Chachapoyas province from the beginning of the ninth century and through the fifteenth century. Large scale monumental stone structures were erected reflecting a new socio-cultural identity with characteristic geometric designs in forms of triangles, rhombi, meanders and square ornaments which appear on the round houses in stone friezes within a defined geographical area. Most of the sites are nuclear settlements concentrated in the Jalca on saddle ridges, mountain tops, and steep mountain slopes and always with a good visibility to the area around them. The Chachapoyas political organization was a segementary system divided into many sub-groups in the form of different curacazgos, chiefdoms, of various sizes, each sharing a basically common value system. There may have been a strong competition for cultivable land between the curacazgos in the area. The impression is a society of internal warfare. The settlements were placed above or next to productive land in a patchwork pattern, and they developed sophisticated agricultural techniques on land affected by relief and drainage problems such as earth terracing systems and special stone drainage systems. Agriculture was supplemented by herding, hunting and fishing.

The Chachapoyas were famed for being sorcerers and herb doctors with a profound knowledge of the medicinal virtues of many plants, and even today most of the inhabitants in the region have a general knowledge of medicinal plants found in the region. Powerful witchcraft plants to cure or to bewitch are reserved for the curandero (healer). Curanderos from the coast come to collect certain plants.

The Inca conquest and colonization period from 1470 that preceded the Spanish conquest brought many changes in the landscape. The Inca administrative center Cochabamba was placed in the southern Chachapoyas province and many smaller and larger Inca installations for control and lodging and accommodation for Inca officials were placed along the rivers flowing eastwards in to the amazon forest, further east than hitherto has been known. The Incas also seem to have constructed large stone terracing systems in this area. They put more emphasis on the exploitation of the Quechua zone with the cultivation of maize and on the Yunga zone with the cultivation of coca.

Colonial

This Incan incorporation, however, was only to last about a century. When the Spaniards arrived in what is now Peru, many of the cultural groups held by the Incan empire intrigued against their former rulers (Rostworowski 1988). One of the first to ally itself with the Spaniards was the Chachapoyan cultural group in the northern Peruvian Andes (Schjellerup 1997).

But the history of the early years of the colony is not only that of the dismantling of an indigenous empire and its transformation into a Spanish dependency. It is also a history of disease and depopulation (Cook 1981, 1998, Denenvan 1992). Many parts of the Andes, and for that matter most of the New World, had declines of more than 70% in population, leaving many settlements abandoned or underpopulated.

Apparently this was the case for all of the precolonial eastern montane settlements, with the exception of some of those located in the dry to moist habitats in the Chachapoyas area. Cuelap, Gran Pajatén, Machu Picchu, and numerous smaller or lesser known sites were abandoned in the decades following the Conquest. In no case was this the result of actual occupation of the sites by the Spaniards. In fact, many of the montane sites were not recorded by the chroniclers and never became integrated into the resettlements (“reducciones”) and taxing systems established by the colonial government. The likely explanation is abandonment due to depopulation caused by introduced diseases. Most of the sites were covered by forest and only in the 19th and 20th centuries have they been rediscovered and described: Cuelap in the 1840s (Bandelier 1907, Narvaez 1988, Schjellerup 1997), Machu Picchu in the 1920s (Bingham, 1948), Gran Pajatén in the 1960s (Bonavia 1968). To our knowledge, no indigenous groups have had settlements in these forests since that time.

Most of the eastern montane forest was depopulated in the decades following the conquest, probably due to introduced diseases.

The location of Jesuit outposts is another indication of the depopulation of the eastern montane forests during colonial times. These settlements were established in the western Amazon basin in the 1600s in sites that gathered together large indigenous populations. Later many of these were taken over by the Franciscans (Ortiz 1975, 1978, Tibesar 1989). All of the eastern Andean missions were located below 1000 m and most were at the outer reaches of the Andean foothills, below 500 m, indicating a lack of large populations in the eastern montane forests.

It was only in the late 1700s that the eastern montane forest acquired an international commercial importance for quinine, extracted from the bark of several Cinchona tree species. Access was by trail systems that ran eastward from the Andes down into the piedmont. Apparently little settlement was associated with this trade, as the bark was carried to highland towns and cities for processing, sale, and further shipment.

Early republic

The first serious attempts to colonize the eastern part of Peru began in 1845 under Castilla’s government (Ortiz 1975, 1978, but see also Martinez Compañon 1978-1991). Large plantations (“haciendas”) were developed in several places in the piedmont where the temperatures were ideal for coffee, tea, or sugar cane (Bowman 1931, Gade 1973). Colonization by non-Peruvian settlers was encouraged. Access and trade with these haciendas was directed towards the Andean highlands through winding footpaths. The haciendas produced sugar and coca, and were typically self-sufficient in beans and maize. Population in the provinces that include the study area was 156,840 in the 1876 census (Appendix 8, see Fig. 6 for location of the provinces used for census data).

Of course, the plantation owners (“hacendados”) were not alone in the foothills. The indigenous groups there had variable experiences with these settlers. Large groups, especially those known for warfare, were able to maintain their cultural and territorial integrity. These were the Aguaruna in the north, the Ashaninkas (Campas) in the center, and the Machiguengas in the south. Other groups were able to coexist, but were forced on to marginal lands. An example is the Yanesha (Smith 1985), also called Amuesha. It is likely that other ethnic groups had disappeared by this time due to introduced diseases. The rubber trade in lowland Amazonia had reached into every watershed below 500 m in these years and had severely impacted native groups, but the control of this economic and social process originated in Iquitos and access was from the east on the rivers (Barham & Coomes 1996).

1900-1960

The haciendas and indigenous groups were still the principal social groups organizing geographical space in the early 1900s. In addition, however, several cities had also reached a level of regional importance. These were Chachapoyas, Moyobamba, Tarapoto, Tingo María, La Merced, and Quillabamba, all of which had at least 5000 inhabitants and served as regional centers of trade and commerce (see Figures 7, 9-12). Total population for the provinces in the study area had reached more than 500,000 inhabitants by

Figure 51. Roads provide access to the Amazon basin, but also open up the montane and premontane forests to inappropriate and destructive land uses.

the 1961 census (Appendix 8). However, many of these were residents of the lower elevations, in lowland and premontane areas. The eastern montane zone represented the principal barrier between the social actors of the lower elevations of the eastern slopes and of the Andean highlands. The zone would have also been the source of environmental disasters, such as inundations and debris flows that could endanger low-lying settlements and fields.

It was in the 1940s that the first road was forced down the eastern Andean slope, from Huánuco to Tingo María, and then on to Pucallpa. Because bulkier objects could now be shipped, it became feasible to transport cattle, plantains, citrus fruits, and timber from the piedmont to the highlands and even on to coastal Peru. Wilson (1987) documented the influence of these changes on Tarma, a central highland town near the eastern montane forest. In the case of Quillabamba, it was the construction of a railroad that provided similar access and opportunities.

1960 to the present

The last forty years have brought tremendous change to the eastern slopes. These changes have principally been catalyzed by road construction (for example, Barclay and others 1991, Frías 1995, Santos & Barclay 1995). In particular, there was an attempt to not only develop penetration roads into Amazonia from the Andes (Fig. 51), but to interconnect them in a grand scheme called "la Carretera Marginal", or the Marginal Highway (Denevan 1966, Belaunde 1994, Fig. 52).

It was as if the indigenous groups did not exist for the respective decision makers. All planning of routes was apparently done strictly in relation to topography and the need to connect the towns and haciendas to trading partners upslope. The lack of consideration of rights of native peoples of the Amazon has a long history in Peru (Remy 1994). However, to clarify this issue for purposes of this report, note that there are no such groups residing in the montane forests discussed here.

Figure 52. Network of roads in eastern Peru and their connections to the country's major roads

In most cases the constructed roads quickly replaced rivers as trade routes. Agrarian reform in the late 1960s and early 1970s was also important, as it resulted in the conversion of many haciendas into collectives or split them into numerous small land holdings (Hopkins 1981, Matos Mar & Mejia 1984).

Most new settlements in this time period were built below 2000 m, in relatively flat areas made accessible by the new road systems. Where roads existed, however, timber and other forest products also could be extracted. Deforestation formed corridors of several kilometers to each side of the road, unless blocked by some natural barrier such as a river or cliffs (for example, Works 1985, see also Figures 7, 9-13). The regionally important cites doubled or tripled their populations (Kent 1994). Populations of many provinces doubled or nearly doubled during this time period (Appendix 8). The exceptions are due to administrative decisions that led to the splitting off of new provinces (in the case of the department of San Martín) or depopulation due to political violence (in the department of Ayacucho).

The national government put considerable human and economic resources into this attempt to colonize the upper Amazon of Peru (Bedoya & Klein 1996). Much of the money came from international banks, adding to a national debt that is still increasing due to accumulating interest. Politically this was possible because at that time there was a national consensus that eastern Peru needed to be colonized: that it was cruel to deny modern conveniences to the towns isolated from terrestrial transportation systems. An unstated principle was that all the roads led eventually to Lima, thereby helping to consolidate and centralize Lima's ability to control the country's natural resources.

During the 1960s and 1970s the national government put considerable human and economic resources into colonization of the upper Amazon of Peru.

The readiness of the international community to finance this effort may have a geopolitical explanation in the state of the Cold War in the 1960s and 1970s. The United States and its allies could justify loans and donations for colonization if the result was to be increased access to the resources of eastern Peru. In addition, there was an active marxist guerrilla movement in the eastern slopes, principally near Quillabamba, from the 1940s to the early 1960s. Although this insurgency was put down, it is not implausible that an integrated road system was viewed both nationally and internationally as a long-term solution to rural unrest.

The land made available to colonists was arable, but only for certain plant species tolerant of acidic soils and high precipitation. For many areas, the most profitable crop quickly became coca, leaves of which are processed into cocaine (Morales 1989, Bedoya 1995). Ironically, almost all the valleys opened to colonization in the 1960s and 1970s became sources of cocaine in the 1980s and 1990s. Most of the world's cocaine comes from the Huallaga Valley, which was made accessible by the Marginal Highway. Deforestation due to coca/cocaine is ongoing and a primary threat to biological diversity found in the premontane forests (Young 1996), although some montane forests have also been cut to about 2400 m elevation. Parts of the premontane and lowland areas in central Peru have been converted into coffee plantations (Santos & Barclay 1995).

The land was arable, but only for certain plant species tolerant of acidic soils and high precipitation. For many areas, the most profitable crop quickly became coca.

Several areas with montane forests were dedicated to conservation at this time, including Tingo María National Park (1965), Manu National Park (1973), Machu Picchu National Historic Sanctuary (1981), Río Abiseo National Park (1983), Yanachaga-Chemillén National Park (1986), and Ampay National Sanctuary (1987).

Use of natural resources

Precolonial

Perhaps the eastern montane forests represented a resource zone for the hunters and gatherers that first colonized South America. And perhaps these forests provided resources needed by early agriculturalists. However, there is no evidence this was the case, either indirectly or in the admittedly sketchy archaeological record. The megafauna of the montane forests went extinct as it did elsewhere, but not necessarily due to direct human impact (Grayson 1984). Coca was domesticated from Erythroxylon coca var. coca, which is a native understory shrub of the eastern slopes, but from below 2000 m (Plowman, 1984). It is also possible that Canna indica was domesticated from wild relatives growing on the eastern slopes (Ugent and others 1984), but in the foothills or lowlands.

Most likely the greatest impacts of the indigenous populations in the central and southern highlands of the eastern cordillera were indirect, caused by the grazing of camelids, burning, and agriculture in the tropical alpine zone.

Indigenous populations in the central and southern highlands of the eastern cordillera probably incorporated the upper montane forests as one of their natural resource zones, based on much more recent work by Camino (1982), Schjellerup (1989) and others. If distances were not too great, then the forests could have provided poles and other construction material, game, and perhaps firewood or medicinals and as additional sites for crop agriculture. It is likely that the greatest impacts on the forest were indirect, caused by the grazing of camelids, burning, and agriculture in the tropical alpine zone.

Indigenous populations in the eastern piedmont might have used the montane forests occasionally for harvesting game or other natural products. However, it is not clear what animals or plants would have been both unique to the montane zone and of sufficient importance to warrant the great effort required. Archaeological investigations of piedmont sites could possibly reveal whether remains of any such species ended up preserved in dwellings or middens.

The only major exception to the lack of evidence of pre-Inca use of resources is in the montane forests of northern Peru. There the presence of numerous archaeological sites in what are now forests, suggests not only long-term settlement, but at least a local impact on the landscapes. Certainly there would have been deforestation in areas used for dwellings, ritual centers, and agricultural terraces, all of which have been documented in Amazonas (Schjellerup 1985, Lerche 1995) and San Martín (Bonavia 1968, Lennon and others 1989, Church 1994). Most plant materials have not survived in archaeological contexts, but poles and roofing material likely came from the forest. The wooden idols of one site have survived centuries of exposure due to the microclimate offered by a rock overhang (Kauffman Doig 1980, Fig. 53); these were made from the trunk of a palm. Pearsall (1996) analyzed the plant remains found by Church (1996) in Manachaqui cave and reports on the remains of a sapotaceous fruit (Pouteria?) likely harvested in montane forest and then transported to the cave. Game present today include the yellow-tailed woolly monkey (Lagothrix flavicauda), deer (Mazama spp., Odocoileus virginianus, Pudu mephistoles), paca (Agouti taczanowski), and pacarana (Dionomys branickii); these all would have been available in the past

Figure 53. The Pinchudos archaeological site includes burial chambers adorned with carved wooden statues. It is located just uphill from the Gran Pajatén site.

also. Church (1996) found some bones in Manachaqui cave that likely came from rodents and deer killed in the montane forests.

Regionally, the Incas did convert the eastern montane forests into a resource zone for themselves, but only of secondary or tertiary importance (Le Moine & Raymond 1987). The most important products coming from the east were coca leaves and bird feathers, most of which came from elevations below our zone of interest. Machu Picchu includes numerous terraces, but not enough to have made the site self-sufficient, much less to have served as an exporter of food to the empire.

Again, the exception is in northern Peru where a hard-fought contest eventually ended in an Incan takeover. Tribute payments to the Inca meant that resources from the montane forest zone were sent to the empire. And tribute was not limited to foodstuffs: as part of their obligations, people were sent from Chachapoyas to live and work in Cusco (Schjellerup 1997).

Figure 54. The tree with large rounded leaves, is a Cinchona species (Rubiaceae) growing in secondary vegetation.

Colonial

Forest recovered during the colonial period, growing over sites that had been abandoned.

Large haciendas were established and managed by Spanish and then mestizo proprietors in the highlands throughout the 1600s and 1700s. Those located on the eastern cordillera must have included upper montane forests within their domains, but apparently had no major impact on them.

An important exception was that starting in the 1700s there was an international demand for quinine (León 1968, Steele 1982). In most cases the Cinchona trees were located and then cut down so that the bark of the trunk, branches, and even roots could be stripped off (Steere 1945, Hodge 1948). There were doubtless negative effects on Cinchona spp. populations during these times, and on the accompanying vegetation. Our informal observations in the field, however, suggest that at least some of the Cinchona species grow readily with openings in the canopy (Fig. 54) and there could have been regeneration and recovery locally as long as not all the mature trees were eliminated in a given locale.

Early republic

The upper montane forests continued to be of value for extraction of quinine, which was especially important economically in the last decades of the 19th century. Nugent (1997) also found evidence during this time of a hat-making industry in Moyobamba, which supplied hats to Italy, France, and Spain until early in the 20th century.

Some lower montane forest areas undoubtedly were converted into coffee, tea or cacao plantations in the haciendas developed in the eastern piedmont. But most coffee was grown at lower elevations and the principal use made of the eastern montane forests was simply for passage: horse and mule trains made their ways through them on trading trips up or down the eastern slope.

1900-1960

The quinine trade lasted until 1910. Cinchona seeds had been smuggled out of northern Bolivia and taken to Malaysia (Simpson & Ogorzaly 1986) for the establishment of tree plantations. By the early 20th century, the Asian production of quinine had ended the search for Cinchona trees in the Andes. Quinine briefly made a return to international and regional importance during the Second World War when extracts from the east Asian plantings were not available to the Allied countries. Cinchona spp. populations were once more located, evaluated for quinine content, and harvested (Steere 1945, Hodge 1948). Attempts were also begun to establish plantations. All these efforts were abruptly halted in 1945 as synthetic drugs made their appearance and

The upper montane forests were important for extraction of quinine from the 1700s and until 1910, when Cinchona plantations in Asia took over the world market.

as Asian geopolitics changed following the war.

Studies (Nuñez del Prado 1958, Webster 1971, 1973, Flores Ochoa & Fries 1989) in a small highland community known as Q'eros, located in the department of Cusco, provide interesting insights into how at least one traditional community incorporated the montane forest zone into their resource zones in this time period. The Q'eros are quechua-speaking farmers and herders whose main settlement is in a tropical alpine zone that looks out eastward toward the Amazon basin. Their livelihood comes from tuber crops and from their herds of llamas and alpacas. In addition, they extract some resources from the montane and premontane zones to the east, although they do not reside in any of the forested areas.

Once roads and railroads were built, one of the first types of bulky objects that could be extracted from the eastern slope forests was the dense timber in demand for use as railroad ties. Timber grown in the highlands, chiefly from Eucalyptus, is not the most suitable for this purpose. Fine timber for furniture and construction could have come from such montane tree species as Cedrela montana, Guarea spp., Nectandra spp., Ocotea spp., and the podocarps (Encarnación 1983). However, the relative importance of the montane forests for lumber, in contrast to premontane and lowland forests, was probably slight.

1960 to the present

Figure 55. Timberline forests are often influenced by fires set in the tropical alpine grasslands to improve grazing. Shown here is a large fire burning in 1991 near the high elevations of Manu National Park in Cusco.

Motorized vehicles require a wider, more stable surface than do cargo animals or pedestrians. This means that the physical imprint of roads on montane landscapes is much greater than the footpaths they replaced (see Fig. 51). In addition, trucks carry much more weight and bulk than can pack animals, so the construction of a road immediately changes the economics of extraction and trade. For one thing, the footpaths on the eastern slopes were soon abandoned. Interestingly, this has actually meant that less access exists now to the eastern montane forests than there was in the 1940s, because there are fewer roads than there were trails. Before, just about every valley had a trail that provided access to the eastern slopes. Now there are 14 roads that enter the study area and one railroad.

When roads are established, they often become associated with 1.) lowered timberlines because of increased use of the tropical alpine zone and the fires that accompany that use (Fig. 55), 2.) deforestation and forest degradation in the montane zone in areas made accessible by the road (Fig. 56), and 3.) wholesale deforestation in premontane and lower montane zones attractive either for colonization and agriculture or for transformation by cutting and burning into rangeland for cattle (Young 1994, Figures 57 and

Figure 56. Cutting trees for the establishment of an agricultural field at about 1600 m in central Peru along the Tingo María to Pucallpa road.

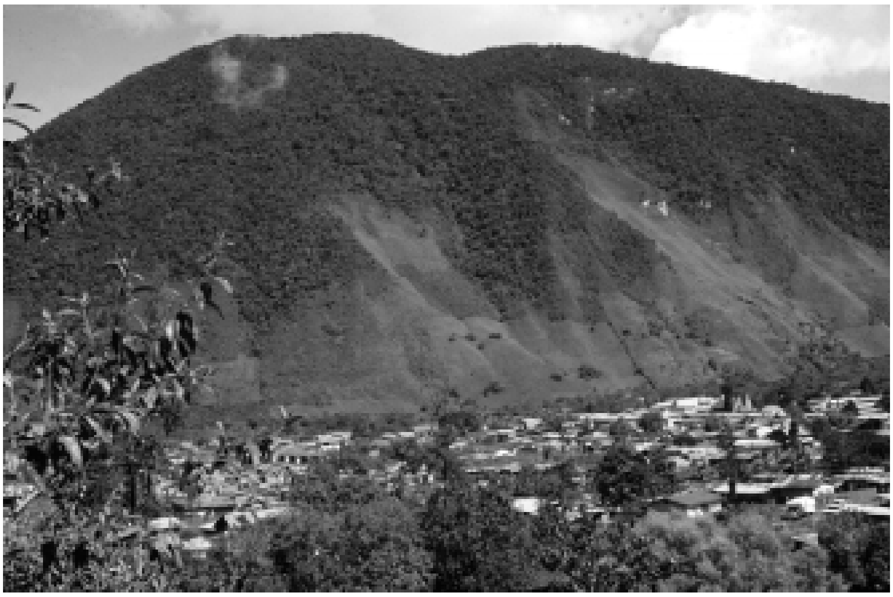


Figure 57. Deforestation near Oxapampa in Pasco is leaving the hill near town denuded.

58). In addition, the road surface increases erosion by collecting and channeling rain water, and the road cut increases slope instability, resulting in numerous landslides and rockfalls during rainy season.

Even without roads, traditional human communities located on the eastern cordillera make use of eastern montane forest zones. This has been described by Brush (1976), Malengreau (1987), Schjellerup (1986, 1989), Sørensen & Schjellerup (1995), and Young (1993b) for different communities in northern Peru and by Webster (1971, 1973), Yamamoto (1981), and Camino (1982) for several others in southern Peru. In all cases, the principal agricultural resource zone is in humid areas that face to the west, where tuber crops, maize, and wheat can be grown. The montane forests located on the eastern side of the divide only serve as occasional sources of timber, medicinals (Sørensen & Schjellerup, 1995), and game. Agrarian reform in the 1960s and 1970s changed the intensity of land use, in many cases actually lessening it because large land holders lost their rights and removed or sold their livestock. By the 1990s, the peasant communities (“comunidades campesinas”) had restored these livestock and land use intensity in the tropical alpine zone was once again relatively high, given the low carrying capacities of that zone.

Figure 58 Montane forest is being cut here in order to grow Capsicum pubescens („rocoto“, Solanaceae) for sale in Lima 300 km away.

Implications for the future

Although less than 10% of the population of Peru has ever been found on the eastern slopes of the Peruvian Andes, there have been notable recent population increases in some areas, especially along roads (Young 1992). The human impact associated with the increases is greater than at any time in the past, given the changes in technology and in national and international demands expressed through market forces.

Some of the negative consequences of human settlement and use have bypassed most of the humid eastern montane forests despite dramatic recent changes in the land cover of eastern Peru. This has especially been true for the upper montane forests because of environmental constraints such as steep slopes, relatively cool temperatures, and heavy rainfall, which limit construction, agriculture, and human welfare. This also because of the presence of more attractive places for colonization at higher and at lower elevations. Indeed other areas in the highlands with lesser slopes, relatively warmer temperatures, and / or drier climates were anciently deforested and converted into agropastoral ecosystems (Ellenberg 1979, Young 1998a).

However, this past history is not necessarily a good basis for planning for the future. All it takes is a change in technology, in supply and demand, or in population size for previously unattractive ecological zones to become of interest for colonization and exploitation. It is certainly ironic, for example, that the most threatened vegetation formations on the eastern slopes are those found in isolated sites with very steep slopes at 500 to 1500 m. Why? Because that is where coca grows best and where coca fields are not easily found and destroyed by narcotic control efforts (Young 1996).

The road system provides a spatial framework for organizing conservation initiatives (see Fig. 52, also Figures 7, 9-13). The presence of roads passing through montane forests signifies that there inevitably has been degradation due to road construction. In addition, the roads provide access to new lands that are essentially without owners and thus open to exploitation. Although technically all forests belong to the national government unless formally deeded to a colonist, the absence of residents invites illegal settlement. These forest clearings are connected by the roads to markets and it is no surprise that marketable products, chiefly timber, but also animal pelts, ornamental plants, and others are removed.

Most roads in the eastern Andes are oriented east-west. The areas located between roads represent localities of great interest to conservationists. Many times the steeply entrenched rivers or ridges in interfluves serve as barriers that block or limit deforestation and forest degradation. Watersheds that are separated from roads, and the impacts associated with those roads, would appear to be ideal locations to place protected areas for nature conservation.

The last forty years have demonstrated just how rapidly the forests of the piedmont can be converted when roads provide access, when national and international interests offer the capital and expertise, and when demand creates markets. The lower montane and premontane forests are the most threatened of the eastern slopes (Young & León 1997), certainly much more so than the Amazon lowland forests that are so often mentioned in conservation overviews.

The lower montane and premontane forests are the most threatened of the eastern slopes, much more so than the Amazon lowland forests.

Both past and present day observations also reveal that the location of the ecotone between upper montane forest and the herb-dominated tropical alpine vegetation types is not solely determined by environmental factors such as temperature and the degree of frost resistance of the plants. Instead, the balance towards grasslands can be tipped by fires set by people interested in increasing the size of areas that can be grazed by livestock (see Fig. 55). It is very probable that this is an ancient impact, begun as many as several millennia ago. Forage quality is improved by burning, at least over the short term, because new sprouts can have more digestible material and nutrients (Young 1993b). These fires lower timberline, especially on topographic positions that offer no protection to trees and shrubs from the flames. More livestock means lower timberlines. Indeed, in a few places local timberline appears to be located as much as 1000 m below that which would be expected due to climatic controls alone. The expansion of the tropical alpine zone at the expense of upper montane forests is the result of traditional practices by highland communities. Attempts to modify those practices are probably only warranted in strictly protected areas that are meant to conserve natural environments and processes. Outside of protected areas, there are opportunities to promote traditional land use that is potentially sustainable over long time periods.

A lesson from the settlement history of precolonial times is that some montane forests, at least those in northern Peru, can apparently be used sustainably over several centuries. In addition, once human populations had crashed or emigrated, these forests seem to have recovered during the colonial and post-colonial periods. Archaeological evidence shows that human settlements in this region were associated with careful design: houses were concentrated on ridges and terraces were used to expand the level surfaces available for planting (for example, Lennon and others 1989). We hypothesize that edaphic attributes of the northern forests were also favorable for sustainability and recovery, based on the fact that soils in the upper elevations of Río Abiseo National Park are quite acidic, but are well drained and resistant to erosion because of a thick mantle of silt formed of glacial loess (Rodbell 1991, Miller & Birkeland 1993). Modern colonization efforts that require mechanization to be profitable and that ignore edaphic limitations will be

Archaeological evidence shows that human settlements in this region were associated with careful design: houses were concentrated on ridges and terraces were used for planting.

unsuccessful. Further studies that look at issues of sustainability in the eastern montane forests in the past would be welcome.

Geopolitics, economics, and transportation explain many of the general features of human settlement and resource use in Peru's eastern slopes over the last 500 years. These social phenomena are also the origins of degradation processes of concern to conservationists today, especially given the intensity and speed of changes in the last few decades. Degradation processes are acting to reduce montane forests at high elevations due to grassland expansion, at low elevations due to colonization, and at middle elevations due to roads (Fig. 59).

Degradation processes are acting to reduce montane forests at high elevations due to grassland expansion, at low elevations due to colonization, and at middle elevations due to roads

It is critical to understand what social groups are involved and the nature of their relationships to the degradation processes. Otherwise the solutions offered may have no bearing on the real problems. What is more, there needs to be a spatial matching of the locations of degradation with the sites where the biological diversity of interest is located. The selection of appropriate conservation strategies for a given area or region depends on this kind of analysis. In the next section, we evaluate conservation efforts for the eastern montane forests.

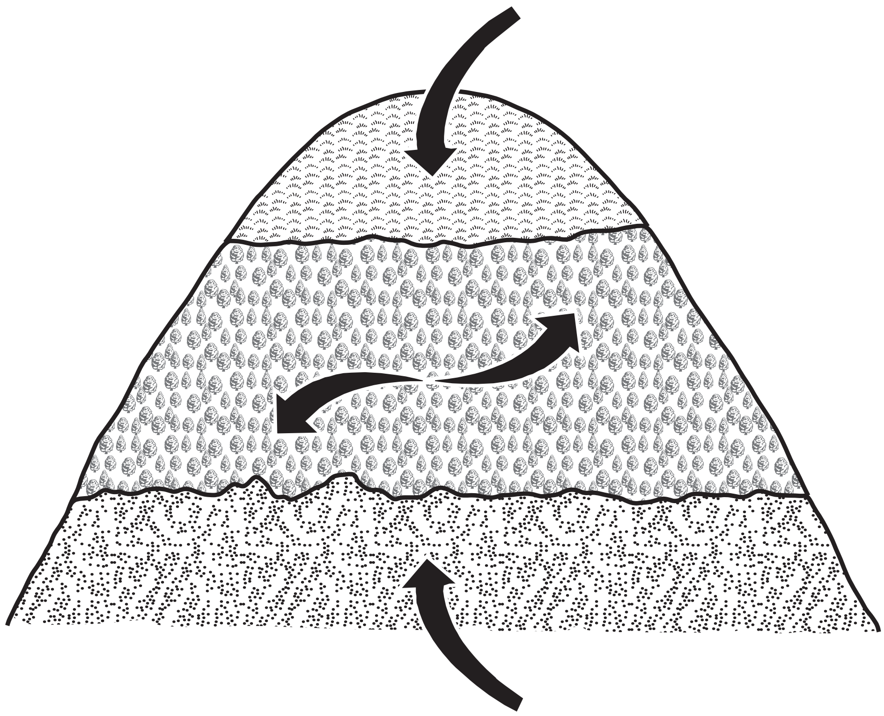


Figure 59. Schematic drawing of human impacts acting at high, middle, and low elevations to reduce the cover of humid eastern montane forests.

5. Conservation efforts

Private and governmental efforts to protect the biological diversity of Peru's eastern slopes since the 1960s have been partial and uncoordinated. The attention paid to the montane forests has been minimal, despite considerable efforts and investments in other parts of Peru. To date, the most important initiatives have come from the national government, which by decree has established several significant protected areas and some relevant legislation. These initiatives, however, were often poorly planned and implemented. There has been an absence of sustainable development in the eastern montane forest belt and little support for local projects or recognition of their potential.

There has been an absence of sustainable development in the eastern montane forest belt and little support for local projects or recognition of their potential.

Protected areas

There are four national parks that include portions of the eastern montane forest (Fig. 60). They differ in history and usefulness for the protection of biological diversity (see for example Box 3, pages 52-53). By legal definition, national parks are the highest ranking of Peru's protected areas in terms of "intangibilidad", or the concept that only natural processes should function inside those protected areas.

Tingo María National Park (Fig. 60) was established in 1965, only the second protected area to be so designated in Peru. Apparently this action was meant primarily to protect a cave located near the town of Tingo María that shelters a population of the oilbird (Steatornis caripensis) and surrounding habitats (Pulido 1991, Fig. 61). Although 180 km^2 are included within its legal limits, much consisting of perhumid lower montane and premontane forests, this park has received almost no protection since it was established. In fact, given the social unrest and active narcotics trade in that part of Peru, it is not clear how well (or if) this park is able to meet conservation objectives, other

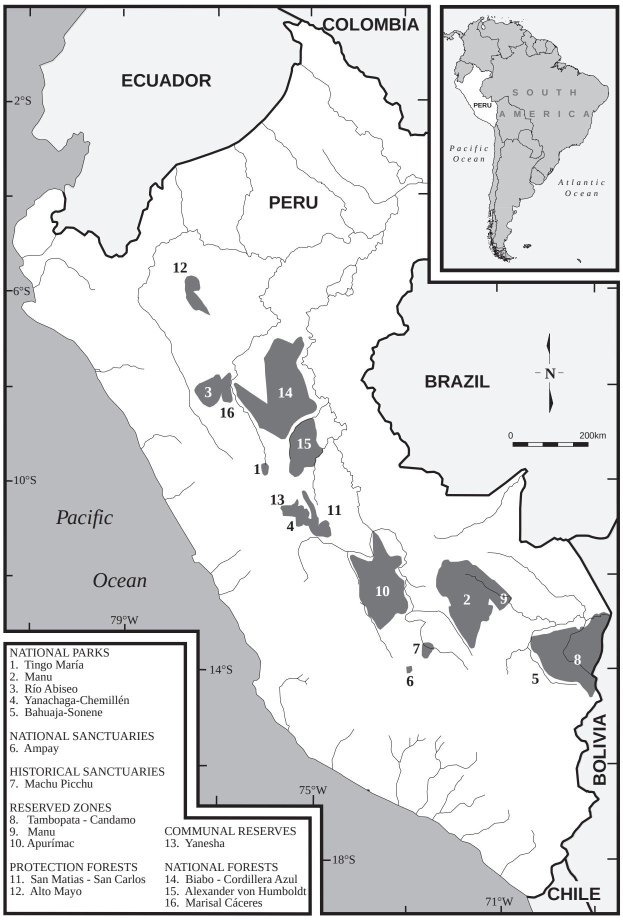


Figure 60. Protected areas found in the eastern Andes of Peru.

Figure 61. Tingo María National Park includes a large cave, known as the „Cueva de las Lechuzas“, because of the oilbirds (Steatornis caripensis) that nest within.

than some environmental education and recreation opportunities.

The other three national parks located in the eastern slopes do serve important conservation functions, although most protection is achieved passively, that is without active park protection programs. These parks depend on their remoteness and lack of accessibility to protect them, a protection that can vanish quickly when illegal settlement and resource extraction occurs.

Manu National Park (Fig. 62) was established in 1973 on an area of 15328 km^2 in southern Peru (Ríos and others 1986). Approximately 3800 km^2 consists of montane forests (Fig. 63). From the start (Cano and others 1995), it appears that only the lowland environments were meant to be protected given the

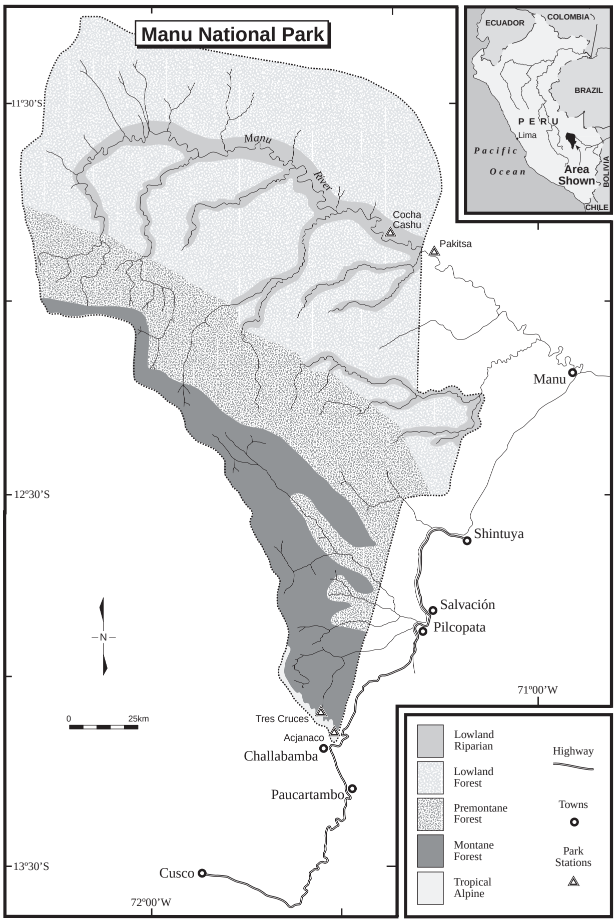


Figure 62. Manu National Park and its ecological zones.

Box 3. Priority sites for conservation

by Jon Fjeldså

The conservation of key areas for biodiversity often conflict with poverty-driven pressures on nature or with national development strategies. It is essential to designate land between conservation and development as efficiently as possible. Identification of representative networks of conservation areas requires good data about how the biodiversity is distributed – such as the bird datasets discussed in Box 1 (pp 32-33). Even so it is a complicated task. If we decide to protect the ten most bird species-rich East Andean treeline cells (each 15´ x 15´) these areas would contain altogether 390 species (with many species redundantly present in several cells). Choosing the ten top peaks of endemism would give 439 different species.

Using WorldMap the minimum area which covers all species can be identified using the principles of complementarity analysis (Austin & Margules 1986). Comparing all species distributions, the computer identifies irreplaceable and flexible cells (the latter may may be exchanged for other cells but this may require a larger area). In order to secure viable populations it was assumed in this analysis that each species should be represented in at least five cells. A total of 242 cells is then needed for Ecuador, Peru and Bolivia (119 on the eastern Andean slope) (see the figure, left map). In order to examine the adequacy of the protected areas system 167 cells of which more than half the area is National Park or National Reserve (omitting parks < 500 km^2 large) were preselected (right map on the figure). The right map shows that we still need new conservation actions in at least 198 cells (83 along the eastern Andean slope).

Those who planned the existing reserves did not have access to this kind of data, and their focus on sparsely inhabited areas resulted in that mainly widespread bird species were protected. These are redundantly conserved in many different places, while most of the rare and local bird species were left unprotected. The new top priorities, in terms of avifauna, are to be found around the North Peru Low (especially Cordillera Colán), around the upper Huallaga Valley, and around Abancay and Cordilleras Vilcabamba and Vilcanota, where rare and local species live close to densely populated areas. We cannot prevent extinction of species without concentrated actions in these places. This is not just a question of new protected areas, but even more of managing a political process, looking for links and connections within cultural landscapes and providing strong incentives for maintaining ecosystems which are essential for biodiversity and man alike.

Left map: a minimum set of areas need to protect all birds of the Andean zone of Ecuador, Peru and Bolivia (5 representations of each species), horizontal shading indicates humid montane forest. The right map shows conservation needs after preselecting the existing National Parks and National Reserves (vertical shading).

Figure 63. Manu National Park's high elevations include impressive cloud forests. Shown also is a warmly dressed visitor in cloud forest at 3300 m.

narrow wedge that corresponds to highland areas. It is the highland portion that borders on settled and occupied zones, but the only token protection offered is that provided by the personnel of the one park station in Acjanaco at 3400 m, which is chronically understaffed. The highland flora has been studied by Cano (1994), Young & Cano (1994), León (1991), and Cano and others (1995), while Pacheco and others (1993) and Solari (1997) provided data on the mammals. Rare birds protected within its boundaries include the montane species Leptosittaca branickii (Wege & Long 1995).

Galiano & Molleapaza (1986), Young & Cano (1994), and Cano and others (1995) drew attention to the degradation processes in the upper elevations: grassland fires, which often kill trees in timberline forests; poaching; overuse of visitor facilities; vandalism; timber extraction; and livestock grazing and agriculture within park boundaries. All of these problems appear to increase the further one walks away from the Acjanaco park station.

Río Abiseo National Park (Fig. 64) was established in 1983 based on an assessment of conservation opportunities in northern Peru by Ríos and others (1982) and a field survey by Leo & Ortiz (1982). Of the 2745 km^2 in the park, approximately 53% or 1455 km^2 is covered by montane forests (Young 1993a, Fig. 65). The flora and vegetation have been described by Young (1991b, 1993a, 1993b, 1998b) and Young & León (1988, 1990b), while the vertebrates have been studied by Leo and colleagues (Leo & Romo 1992, Leo & Gardner 1993, Leo 1995). This is the only protected area that includes populations of the yellow tailed woolly monkey (Lagothrix flavicauda). It is also the only protected area for the rare birds Aulacorhynchus huallagae and Buthraupis aureodorsalis (Wege & Long 1995).

Persistent problems remain for this park's management and protection, principally due to inadequate staffing and funding. A major part of the funding for the park has been invested in rural development projects in the buffer zones outside the park. While it is too early to dismiss this approach, the projects have not been designed to directly address the impacts affecting the park. The degradation threats identified by Leo (1992) and Young and others (1994) were due to the burning of high elevation grasslands associated with livestock grazing, inadequate visitor infrastructure, subsistence practices by several families living within the park, numerous mining claims that include portions of the park, and the latent possibility of forest conversion in the premontane zone for coca cultivation. The numerous archaeological sites are of special importance (Lennon and others 1989, Church 1994), but require currently nonexisting programs of archaeological rescue and restoration, and monument stabilization (Young and others 1994).

Figure 64. Río Abiseo National Park and its ecological zones.

The establishment of Yanachaga-Chemillén National Park (Fig. 66) in 1986 came about as part of a large, integrated colonization and development project. Anthropologists (Smith 1985, Santos 1991, Lázaro and others 1993, Staver and others 1994), ethnobotanists (Salick 1989, 1992, Salick & Lundberg 1990), zoologists (Ascorra and others 1989), and forest ecologists (Hartshorn 1989, Hartshorn & Pariona 1993) provided information of great value by working in the low elevation ecosystems of the Palcazú Valley either as part of that project or independently.

The national park itself received relatively little of that attention, although Brack (1987), Aguilar (1986), and Pacheco and others (1994) provide general overviews and insights. Schulenberg and others (1984) reported on unusual bird records from sites adjacent to the park, while La Torre (1998) recently provided a treatment of the grass species known for the park and surrounding areas. What is clear is that this 1220 km^2 park is mostly forested, with perhaps 730 km^2 of montane forest types (Fig. 67). Access is difficult, but this has helped protect these forests until now from the deforestation that has characterized much of the surrounding areas (Santos & Barclay 1995).

The remaining protected areas are less well known internationally than the national parks. As a result, they receive less funding, staffing, and attention. Nevertheless, some currently, or potentially, serve important conservation purposes.

Ampay National Sanctuary (Fig. 60) is a 36 km^2 reserve established in 1987 in the high elevations of the ice-capped peak of Nevado Ampay (Galiano 1987, Venero & Tupayachi 1989, Hostnig & Palomino 1997). Included is a remnant upper montane forest, dominated by Podocarpus glomeratus (Vargas 1957) and with at least two rare bird species, Nothoprocta taczanowskii and the

Figure 65. Río Abiseo National Park is well known for its archaeological sites. Shown here is the promentory (to the right, below the cliffs) upon which the Gran Pajatén site is located.

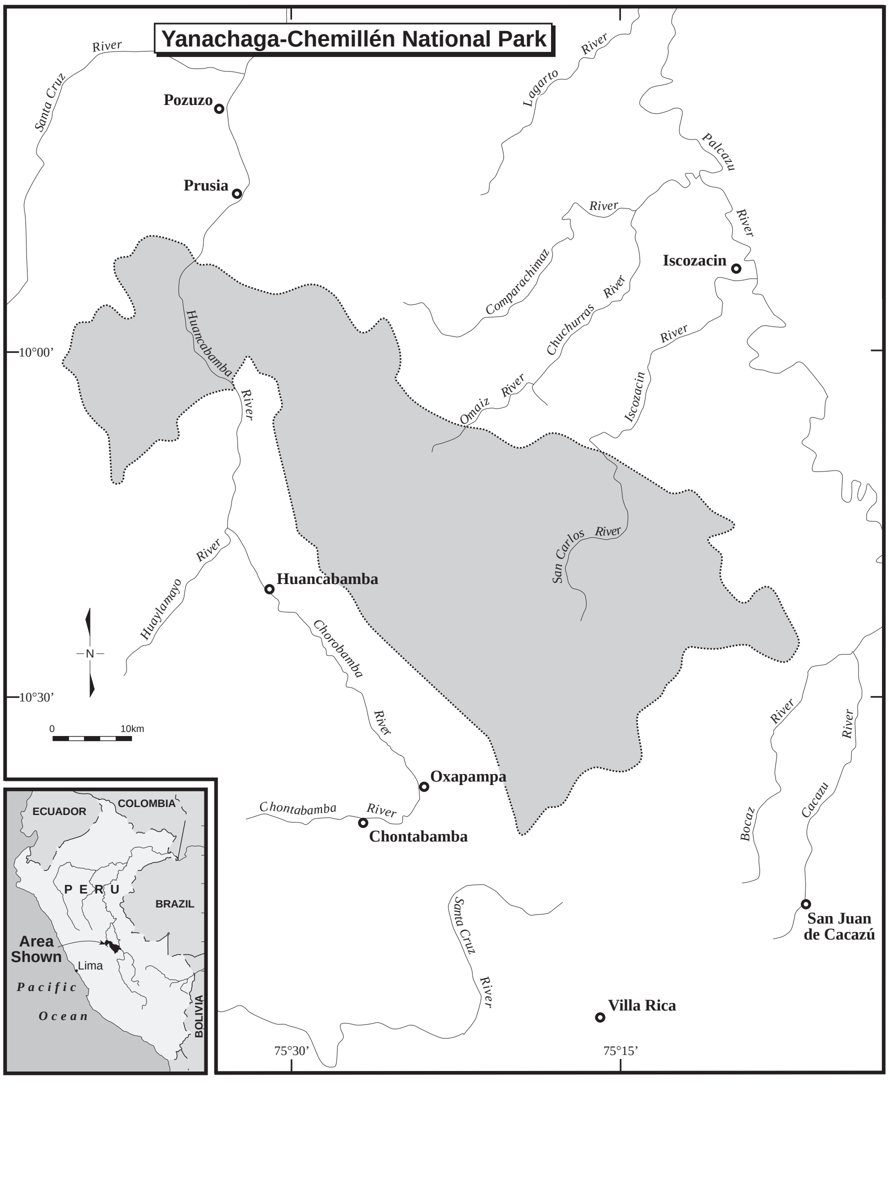


Figure 66. Yanachaga-Chemillén National Park and major nearby rivers and towns.

Figure 67. Yanachaga-Chemillén National Park has spectacular scenery and receives abundant precipitation.

Figure 68. Machu Picchu Historical Sanctuary is located to the left of the Urubamba River in this photograph. The main archaeological site is just around the bend of the river.

strictly endemic Synallaxis courseni (Wege & Long, 1995). Outside of the sanctuary, the lands have been extensively deforested and are used for agriculture and grazing. Unfortunately, agricultural fields and livestock are also maintained within the sanctuary (Hostnig & Palomino 1997).

The Machu Picchu Historical Sanctuary (Fig. 60) was established in 1981 on 326 km^2, most of which corresponds to montane forests (Fig. 68). The flora is partially known, due to the efforts of Herrera (1939), Peyton (1986) and Tupayachi & Galiano(1989). Peyton (1986) also made observations there on the habitat use and requirements of the Andean bear (Tremarctos ornatus). He concluded that the sanctuary was too small to support viable populations of the bear.

Another problem at Machu Picchu is that there has been inadequate coordination between the sanctuary as managed by the Ministry of Agriculture, and the archaeological sites (see Fig. 50) as controlled by the National Institute of Culture (Instituto Nacional de Cultura). For example, forests and scrub on the southwestern border are often burned by fires escaping from nearby agricultural fields. The approximately 20,000 to 50,000 people each year that walk the three-to-five day Inca Trail leave behind enough rubbish and other wastes to cause concern. As a result, we consider this sanctuary to be the poorest managed of any protected area in Peru, especially in light of the revenues generated by the hundreds of thousands of visitors to Machu Picchu each year. The problem is clearly not one of limited economic resources, but instead originates with the low priority given to the protection of biological diversity and the conflicting roles of the respective governmental institutions. If some of these problems are due to the nature of the "historical sanctuary" designation, then perhaps a more strictly protected area could be proposed to protect the natural ecosystems. For additional information, see Bouchard and others (1992).

Reserved zones (Fig. 60) in Peru are so designated as a temporary measure while further study is used to decide on a definitive legal classification and demarcation. The Apurímac Reserved Zone was established in 1988 on 16693 km^2 of the Vilcabamba Cordillera, at least half of which is montane forest. It doubtless contains unique taxa; for example, Weske (1985) described a new hummingbird subspecies and Weske & Terborgh (1981) a new species of screech owl for this area. However, no protection other than inaccessibility is currently provided. The Manu Reserved Zone was established to the west of Manu National Park in 1980 and includes 2570 km^2, though mostly of lowland environments. This is the zone that has been used for ecotourism (Groom and others 1991). Only one such ecotourism effort is located in the lower montane zone at 1800 m along the road.

The Tambopata-Candamo Reserved Zone (Fig. 60) was established in 1990 with 14789 km^2, including a significant tract of land in the upper watershed of the Tambopata River with montane forests. Foster and others (1994, p. 27) declared that " . . . it would be unfortunate to focus most of the effort to establish and maintain a protected area (national park) in the mountainous southwestern portion of the region, to the exclusion of the biologically distinct, more species-rich, and much more vulnerable lowland forests". Shortly thereafter, in 1996, Bahuaja-Sonene National Park was established on 5370 km^2, but specifically excluded all areas above about 1000 m, which were kept in reserved zone status so that petroleum exploration could continue.

Protection forests in Peru (Fig. 60) are generally on steep tracts of land that the state has decided should remain with forest cover permanently. The Alto Mayo and San Matías-San Carlos Protection Forests, both established in 1987, nominally protect 1820 and 1458 km^2, respectively, of lowland, premontane, and montane forests. However, they do this only on paper, as the forests are not demarcated on the ground and their use is essentially unregulated.

The national forests (Fig. 60) of Biabo-Cordillera Azul (1963; 20845 km^2), Pastaza-Morona-Marañón (1963; 3750 km^2), and Mariscal Cáceres (1963; 3370 km^2) all probably include some tracts of montane forest, but none are managed with conservation goals. In fact, these national forests are meant to be logged and then reforested, although the latter activity lags far behind the former.

Several authors have recently proposed additional areas as protected areas in the eastern slopes. Fjeldså and colleagues (for example Fjeldså & Rahbek 1997) used the distribution of endemic bird species to locate two centers of endemism on or near the eastern montane zone that are inadequately protected. Young (1992) suggested a new protected area be established in Amazonas and that the Ampay and Machu Picchu protected areas be greatly expanded in size. Rodríguez (1996) presents a consensus position on how the national protected area system should be improved. One of the figures reproduced from that book (Fig. 69) shows several eastern slope areas that could be considered for new protected areas. Note that these priority areas were determined based on the distribution of plant, invertebrate, and vertebrate groups. Thus, they were not based on any one particular taxonomic group. Much recent research has shown that distribution patterns differ widely among taxa, as shown in general (Flather and others 1998, Howard and others 1998, Lawton and others 1998, Reid 1998, van Jaarsveld and others 1998), and specifically for the study area by Patterson and others (1998). There is a need therefore to look at multiple sources and scales of biodiversity information.

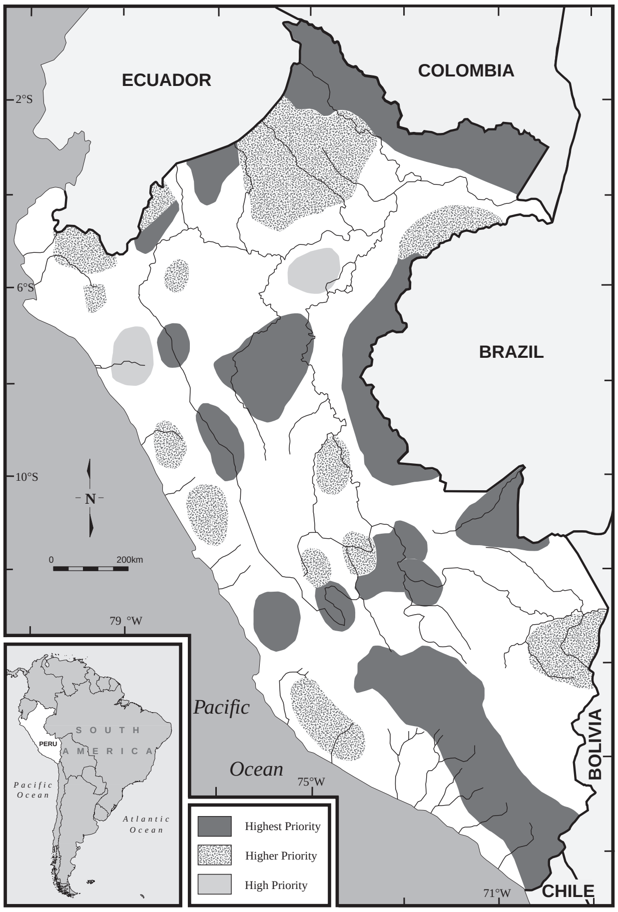


Figure 69. Consensus priority areas for conservation of biological diversity. Developed by Rodríguez (1996) through a participatory process that examined the case of numerous plant and animal groups.

Rare and endangered species

Most species in biological communities are rare (Gaston 1994). This means that any geographical region with a rich biota will also have numerous rarities. The presence of mountainous terrain adds to rarity, because it provide many different habitats in a relatively small area due to elevational changes, and to local differences in climate and soils. The heterogeneity of the physical environment further interacts with evolutionary processes and isolation over long time periods to produce local genetic differentiation and high speciation rates.

While rarity is to be expected in a diverse tropical montane biota, the rare species do not lend themselves to quantification or even identification. Many species are known only from their type specimen or from a single locality (for example, Young 1996). But does that mean that they are highly restricted in distribution? Or is the lack of other reported localities simply a consequence of the little research that has been done? Both possibilities occur: there are highly endemic species in the montane forest zone (for example Fuchsia sanmartinensis, Berry 1982; Cyathea concordia, León & Moran 1996), but there are also many that are fairly widely distributed, once researchers had searched for them in the entire montane forest belt (for example Thelypteris leoniae, Smith 1992). The latter situation is especially the case for altitudinal specialists, which are species that are adapted to a very narrow elevational zone, but that have relatively good dispersal and so are found in numerous valleys. Graves (1988) and Stotz and others (1996) discussed the long, but narrow distributions common for tropical Andean birds, as did Young (1995) for tropical montane organisms in general.

Rare montane species that are endemics or altitudinal specialists are particularly prone to the kinds of habitat alterations caused by roads and the associated deforestation.

Rare montane species that are endemics or altitudinal specialists are particularly prone to the kinds of habitat alterations caused by roads and the associated deforestation (Young 1994). The endemics might lose any suitable habitat, while the altitudinal specialists will have their distributions fragmented as once-continuous forest is turned into a series of isolated patches. In the case of the eastern montane forests, the result to date has been the subdivision of the forest belt into about a dozen large patches. There is every reason to be concerned about the threats to endemic and specialized species of the study area caused by this fragmentation.

Recognition of threatened species would be an important first step towards protecting them. In practice, the formal recognition of threatened and endangered species in Peru has not followed this logic. Instead, species considered at risk at a national or international level, for example by being included on a CITES appendix, have simply been listed by the national authorities. Examples include the critically endangered Lagothrix flavicauda, the endangered Dinonys branickii and Tapirus pinchaque, and the vulnerable Dasypus pilosus, Leptosittaca branickii and Tremarctos ornatus. Almost all of the listed species are birds and large mammals, very different from the overall diversity patterns for the study area discussed earlier in this report. This bias means that the most diverse groups in the area, the amphibians, invertebrates, and vascular and nonvascular plants, have been neglected.

In addition, there are no protection programs or action plans for any of the officially recognized threatened or endangered species that are found in the eastern montane forests. It is only by virtue of their occurrence within a protected area that they can be stated to receive some degree of attention (Pulido 1991, 1996). In fact, some of the protected areas were justified in their establishment because they contain critical habitat for such showy and endangered species as the yellow-tailed woolly monkey (Leo 1980, 1984, Leo & Ortiz 1982) found in Río Abiseo National Park. However, no ongoing programs exist to augment or even evaluate populations of those species. Outside of parks and reserves, conservationists have few tools available to promote recovery efforts.

Legally, all commerce of the officially listed species is prohibited in accordance with national and international agreements. In practice, there is little actual control except at points of embarkment to other countries. The exception is for researchers, even those proposing nondestructive observations, who are severely restricted in what and how they can study, both inside and outside the protected areas.

Sustainable development

Economic development in a manner that is ecologically and socially sustainable over the long term is an appealing prospect (Gow 1989, Ozório de Almeida & Campari 1995). Somewhat reducing its value has been the transformation of "sustainable development" into a slogan, used as a label for virtually any current development initiative, at least in Peru. The only empirical test for sustainability is to wait 20 to 30 years and evaluate the outcome of the use of a given practice or policy. Obviously this will prove difficult to do. In the meanwhile, projects can be developed that minimize environmental disruption and degradation (for example, Goodland and others 1984, Ledec & Goodland 1988)

Most sustainable development plans associated with the conservation of tropical forests have focused on the surroundings of protected areas (Wells & Brandon, 1992), typically using the reserve's buffer zones as sites for rural development programs and/or ecotourism visitation. Southgate & Clark (1993) pointed out several deficiencies with this approach, one of which is that it tends to concentrate economic activities and infrastructure in the very places that are ecologically the most sensitive. Because of this, Young (1993b) suggested that programs should be directed towards areas not immediately adjacent to a nature reserve, even though there should exist a publicly proclaimed linkage between the reserve's protection and the continuation of the programs.

There are some ongoing programs that would fit the sustainable development and ecotourism rubric in the buffer zones of Río Abiseo and Manu National Parks (for example, Groom and others 1991, Dunstone & O'Sullivan 1996). There are also some proposed for Yanachaga-Chemillén National Park (those described by Hartshorn & Pariona (1993) for adjacent lowland areas did not survive the social unrest of the late 1980s). Most of these projects are new and are directed towards ecological zones other than the montane forest zone.

Perhaps agroforestry or limited extractivism of forest products could be made sustainable. However, sustainable forestry projects on steep, wet slopes are unrealistic as this would require cable logging and long rotation cycles due to the relatively slow tree growth. Sustainable agriculture would require massive and well-designed terrace systems, but neither the possible crop species nor the potential markets would justify that kind of investment.

Other programs involve funding alternatives to the cultivation of coca. Not only are these at lower elevations, in the lowland and premontane zones, but these projects are also notoriously ineffective (Alvarez 1992, OTA 1993).

In summary, "sustainable development" appears to be a label now used for virtually any development project in Peru and, as such, of little usefulness. Despite the great national and international investments made in the eastern slopes for roads and colonization in the 1970s and 1980s, as described in the previous section of this report, little remains of these projects in the late 1990s. There are apparently no integrated development programs focused specifically on the montane forests, either inside or outside of the protected areas. The projects being carried out in highland, lowland, and premontane environments do not necessarily make useful models for trials in the montane zone given the differences in biological and physical environments described earlier.

"Sustainable development" appears to be a label now used for virtually any development project in Peru and, as such, of little usefulness.

Legal and institutional frameworks

The vertebrate species found in the Amazon basin of Peru have been legally protected since 1975, except the species commonly used for game, which can be hunted for noncommercial consumption. Orchids have been protected by administrative action the last several years. In practice, these rules have only meant that research is much more difficult, as researchers need a formal declaration from the minister of agriculture permitting them to study these species, even outside of protected areas and with species that are abundant. Other enforcement or control is infrequent or absent.

Peru has suscribed to at least 16 different international agreements that concern the protection of natural resources. These include agreements concerning migratory species, the Amazon Cooperation Treaty, the World Heritage Convention, and the Biological Diversity Convention. International funding agencies have become important players in this arena, requiring

Figure 70. Collecting plant specimens in southern Peru.

Peru to include biological diversity concerns in projects they fund and demanding environmental impact assessments.

However, one thing is the passing of legislation, quite another is their implementation and administration. This has basically been left in the hands of the Ministry of Agriculture. Currently, implementation is carried out through a dependency of the Ministry called INRENA (Instituto Nacional de Recursos Naturales), whose personnel must develop procedures and assessment methods. It is here that otherwise well-intentioned laws or international agreements often founder due to understaffing and lack of presence in the field. There is an important potential role here for non-governmental organizations to fiscalize, critique, and participate in programs to implement legislation and policy.

Although the Ministry of Agriculture is the main governmental entity involved, there are also other parts of government whose areas of responsibility overlap in part, but whose policies are determined independently. The results are often negative for biological conservation. For example, it is not at all clear what can be done, either legally or practically, to better coordinate natural resource conservation by INRENA with cultural resource conservation done by the INC (Instituto Nacional de Cultura). In theory, conflicts between protected areas and the mining or petroleum claims overseen by the Ministry of Energy and Mines should legally be resolved in favor of the protected areas; in practice it is hard to find cases where this has been so. INRENA has a low political status in terms of its ability to affect the behavior or decisions made in ministries other than its own. In fact, even then there are often conflicts as the Ministry of Agriculture often continues to promote agricultural development in places that INRENA has been charged to protect for biological diversity.

Due to changes in political structure within Peru, several of the regional governments have become significant social actors in the eastern slopes. The most conspicuous example is in Manu National Park, where many park functions are administered by the regional government, often without considering national and international criteria, at least as far as funding and enforcement priorities are concerned.

Figure 71. Hammering aluminum numbered tags on trees in a permanent plot in a timberline montane forest in Manu National Park. Photograph by Phil Keating.

Future needs

Despite the criticisms that could be made of many of the decisions taken by the Ministry of Agriculture, through INRENA, the fact is that this is a social actor in the study area (Young & León 1995) that has had a positive impact, being directly responsible for the protection of approximately 6465 km^2 of eastern montane forests in national parks or sanctuaries, and having recognized another perhaps 10000 km^2 in less-strictly protected classifications such as the reserved zones, and the protection and national forests.

Needed are 1.) more parks and reserves to fill in unprotected stretches, 2.) the consideration of expansion of reserve boundaries for those less than 500 km^2 in size, 3.) more activist protection programs to control poaching, arson, and illegal colonization, 4.) a reassessment of how protection forests could be made more useful for biological conservation, and 5.) a careful evaluation of the potentials for biological conservation in those landscapes that have been converted for human use. To do this, INRENA needs to reach out to expertise available in the local communities and the private and university sectors, and should act to establish interministerial coordination on mineral and cultural resources. In addition, INRENA's weakest link continues to be on the ground: there is very little presence of park guards or other personnel in montane forest areas.

Country policies, perhaps set by Congress or the Presidency, need to promote development projects that consider longterm efforts and investments, that exclude environmentally sensitive areas such as perhumid montane areas, and that emphasize the areas that have had long and sustained traditional uses. This needs to be done in ways that promote interministerial coordination of policy related to natural resources. Often laws and programs directed towards improving the fairness of land tenure practices are helpful in this regard, especially if nature conservation were to be recognized as an appropriate land use by the government.

With some exceptions, non-governmental organizations (NGOs) have not provided effective leadership in the study area in the establishment of private nature reserves (none exist), or the independent evaluation of conservation practices and activities. These seem to be activities that NGOs could promote, especially in collaboration with the public sector and with the relevant scientific and educational institutions. The Peruvian Society for Environmental Law (SPDA) has helped to clarify many complex legal situations, though often problems have more to do with implementation and interpretation than the law per se.

Because so little is known, research opportunities are virtually unlimited, except, of course, for difficulties of finance and logistics. Grants and scholarships for research on the ecosystems, flora, and fauna would be useful ways to promote the needed research, including restoration of deforested areas, botanical inventories (Fig. 70), studies of tree growth and forest dynamics (Fig. 71), zoological inventories (Figures 72 and 73), and use and management of biological diversity. Donor agencies should be aware that numerous graduate programs have recently been established in the Peruvian universities. These offer excellent opportunities for financing research and thesis projects that have a bearing on the biological diversity and conservation of the study area. It is unfortunate that neither donors nor INRENA have used the research needs specified in the management plans of the protected areas (for example, Ríos and others 1986, Brack 1987) to formulate incentives for potentially interested scientists and students. These documents provide lists that could be added to other topics mentioned in this document to provide a blueprint for a research agenda directed towards the biological conservation of Peru's humid eastern montane forests.

Figure 72. Processing frog specimens collected in forest in southern Peru.

Figure 73. Mammal specimens obtained from the high elevations of Manu National Park.

6. Conclusions and policy recommendations

The eastern montane forests of Peru form an ecological and biological system that is of global importance for the conservation of biodiversity and natural resources.

We conclude that the eastern montane forests of Peru form an ecological and biological system that is of global importance for the conservation of biodiversity and natural resources. Humid montane areas should not be overlooked in any conservation decision making that concerns either the western Amazon or the central Andes.

On the eastern slopes of the Peruvian Andes there are large tracts of forest that have not been altered significantly by humans. There is unique biological diversity, especially in the plant and animal groups that are most speciose: bryophytes, pteridophytes, orchids, melastomes, spiders, frogs, hummingbirds, tanagers, rodents, and others. Because of its privileged biogeographical setting, over millennia this area has received floristic and faunistic elements from north, south, east, and west. High precipitation and great heterogeneity in bedrock and topography also help to create and maintain this diversity.

Because of topography, soils, and climate, the eastern montane belt is mostly unsuitable for human colonization and settlement.

Because of topography, soils, and climate, the eastern montane belt is mostly unsuitable for human colonization and settlement. This is a poor place to grow field crops, due to shallow soils, steep slopes, and often torrential rains. Currently, land degradation is chiefly due to extraction for forest products such as timber, often followed by abandonment or conversion to low-quality range. Almost all of this impact is localized within about 5 to 10 km of roads. This then is the challenge to the international conservation community: How can this degradation be limited? How should the remaining forest be conserved? What assessment programs should be established to permit monitoring and evaluation?

Recommendation 1

Design international and collaborative efforts to protect these and similar forests in the eastern Andes.

Design international and collaborative efforts to protect these and similar forests in the eastern Andes.

Regionally, the eastern-slope montane forests of the Andes are key to the protection of the upper watersheds of the western Amazon. Their inclusion in nature reserves or national parks is fundamental for the protection of long altitudinal gradients, such as is the case for Río Abiseo, Yanachaga-Chemillén, and Manu National Parks. The cloud forests of the eastern slopes are likely to have particularly important hydrological implications for the upper Amazon as the trees and other plants receive moisture from fog and rain, and in turn use that water for transpiration and photosynthesis. Because of high endemism in the most speciose plant and animal groups, the eastern montane forests of Peru are distinct in species composition from those of neighboring countries, although much is shared at the level of families and genera, in addition to strong similarities in forest physiognomy. Little has been done, however, to document and explain regional similarities and differences.

Recommendation 2

Make the eastern slope region of the highest priority for biological conservation within Peru.

Make the eastern slope region of the highest priority for biological conservation within Peru.

Nationally, there is no other large area in Peru that is so diverse biologically, but relatively unaltered by humans due to its unsuitability for agriculture, grazing, or forestry. Because this is an area universally accepted by planners to be inappropriate for large-scale colonization, especially on steep slopes, the critical need is to control destructive exploitation, while assuring the preservation of intact watersheds. It would be a helpful step to make "protection forests" a more meaningful conservation tool.

Recommendation 3

Direct human and financial resources to applied and pure research topics concerning the eastern montane forests.

Much basic data on the physical environment is lacking; as an example, there is not one functioning meteorological station in the study area. We have proposed that the primary controls on forest structure and composition are elevation, which affects temperatures and the pool of species present, and topographic position, which will influence soil depth, slope steepness and stability, and exposure to winds and fog; this hypothesis needs to be tested. This will require not only much more information on the distributions and ecological roles of the native plant and animal species, but such data gathered in relationship to topography, elevation, and climate. Data is also needed on the aquatic ecosystems.

Detailed studies on human use or abuse of the eastern montane forests have yet to be carried out. Although satellite imagery clearly shows that most deforestation is associated with the road system built in the last forty years, local case studies are lacking. Although sustainability of land use systems appears unlikely given current trends, the archaeological sites in northern Peru remind us that longterm human use of these forests is possible, although probably under different economic and social goals. All of these topics require more data, analyses, perspectives, and students. We invite donor agencies to find imaginative ways to stimulate the needed research.

Direct human and financial resources to applied and pure research topics concerning the eastern montane forests.

Recommendation 4

Develop strategies for integrated protection of eastern montane forest sites.

Solutions must include an improved national park and nature reserve system, but obviously cannot be limited to such strict conservation methods. Some protected areas are too small and others have yet to be made operational. Still others are incorrectly placed.

The respective government agencies need to better coordinate their shared interests and resolve their differences. It is also important that there be more active involvement by conservation and development non-governmental organizations and with local communities. Case studies of sustainable local uses of humid montane forests are needed as examples of what is possible. Policies that encourage the conservation of the eastern montane forests will also be valuable for extending such practices to other parts of the eastern slopes of Peru and elsewhere in the Andes.

Develop strategies for integrated protection of eastern montane forest sites.

Appendix 1. Flowering plants

Appendix 1 lists flowering plants of Peru's eastern montane forests. Given are families and genera, listed alphabetically. The diverse genera are marked with an asterix (*) and are defined as those that have at least ten species in the study area. Extracted from Young (1991a), Brako & Zarucchi (1993), and herbarium research.

Family	Genera
Monocotyledoneae (Liliopsida)	
Agavaceae	Furcraea
Amaryllidaceae	Eucharis, Eustephia, Hippeastrum, Urceolina
Araceae	Anthurium*, Asterostigma, Monstera, Philodendron, Rhodospatha, Spatisphyllum, Stenospermation, Syngonium, Xanthosoma
Arecaceae	Aiphanes, Bactris, Ceroxylon, Chamaedorea, Dictyocaryum, Euterpe, Geonoma, Hyospathe, Iriartea, Prestoea, Wettinia
Bromeliaceae	Aechmea, Fosterella, Greigia, Guzmania, Mezobromelia, Neoregelia, Pitcairnia*, Puya*, Racinaea*, Tillandsia*
Burmanniaceae	Burmannia, Dictyostega
Cannaceae	Canna
Commelinaceae	Callisia, Cymbispatha, Dichorisandra, Gibasis, Tinantia, Tradescantia
Cyclanthaceae	Asplundia, Carludovica, Dicranopygium, Sphaeradenia
Cyperaceae	Bulbostylis, Carex, Cyperus, Eleocharis, Fimbristylis, Kyllinga, Oreobolus, Rynchospora, Scirpus, Scleria, Uncinia
Dioscoreaceae	Dioscorea
Eriocaulaceae	Eriocaulon, Leiothrix, Paepalanthus, Syngonanthus
Iridaceae	Cipura, Cypella, Ennealophus, Hesperoxiphion, Mastigostyla, Orthrosanthus, Sisyrinchium
Juncaceae	Juncus, Luzula
Liliaceae	Anthericum, Bomarea*, Excremis, Isidrogalvia
Marantaceae	Calathea, Stromanthe
Mayaceae	Mayaca
Heliconiaceae	Heliconia
Orchidaceae	Altensteinia, Barbosella, Bletia, Brachystele, Brassia, Bulbophyllum, Catasetum, Centropetalum, Cochlioda, Comparettia, Cranichis, Cryptocentrum, Cyrtidiorchis, Cyrtopodium, Dichaea, Dresslerella, Dryadella, Elleanthus*, Encyclia, Epidendrum*, Epistephium, Eriopsis, Erythrodes, Eurystyles, Fernandezia, Galeandra, Galeottia, Gomphicis, Gongora, Govenia, Habenaria, Hapalorchis, Hofmeisterella, Houlletia, Kefersteinia, Lepanthes, Lepanthopsis, Liparis, Lockhartia, Lueddemannia, Lycaste, Malaxis, Masdevallia*, Maxillaria*, Miltonia, Mormodes, Mormolyca, Myoxanthus*, Neodryas, Notylia, Odontoglossum*, Oncidium*, Otoglossum, Pachyphyllum, Peristeria, Phragmipedium, Platystele, Pleurothallis*, Ponthieva, Porroglossum, Prescottia, Psilochilus, Pterichis, Restrepiopsis, Rodriguezia, Rusbyella, Sauroglossum, Scaphyglottis, Scelochilus, Schomburgkia, Sobralia*, Solenidiopsis, Stelis*, Stellilabium, Stenia, Stenoptera, Stenorrhynchos, Stigmatostalix, Systeloglossum, Telipogon, Trichopilia, Trichocentrum, Trichoceros, Trichocentrum, Trochosalpinix, Trisetella, Vargasiella, Xylobium, Zygopetalum
Poaceae	Aegopogon, Andropogon, Arthrostylidium, Arundinaria, Arundinella, Aulonemia, Axonopus, Briza, Chusquea, Cinna, Cortaderia, Dissanthelium, Eragrostis, Eriochloa, Festuca, Homolepis, Ichnanthus, Lasiacis, Melinis, Muhlenbergia, Nassella, Neurolepis, Olyra, Oplismenus, Pariana, Paspalum, Pennisetum, Poa, Polypogon, Pseudechinolaena, Rhipodocladum, Setaria, Sporobolus, Zeugites
Smilacaceae	Smilax
Typhaceae	Typha
Xyridaceae	Xyris
Zingiberaceae	Costus, Dimerocostus, Renealmia
Dicotyledoneae (Magnoliopsida)	
Acanthaceae	Aphelandra, Habracanthus, Hansteinia, Justicia, Mendoncia, Ruellia, Sanchezia
Actinidiaceae	Saurauia
Amaranthaceae	Alternanthera, Iresine
Anacardiaceae	Mauria, Tapirira, Toxicodendron
Annonaceae	Cremastosperma, Guatteria, Rollinia

Apiaceae	Arracacia, Hydrocotyle*, Neonelsonia, Sanicula
Apocynaceae	Allamanda, Mandevilla, Peltaste
Aquifoliaceae	Ilex
Araliaceae	Aralia, Dendropanax, Oreopanax, Schefflera
Aristolochiaceae	Aristolochia
Asclepiadaceae	Cynanchum, Ditassa, Metastelma, Oxypetalum
Asteraceae	Achyrocline, Acmella, Aequatorium, Ageratina, Ageratum, Ascidiogyne, Asplundianthus, Aristeguietia, Ayapana, Ayapanopsis, Baccharis, Badilloa, Barnadesia, Bidens, Brickellia, Cacosmia, Calea, Chaptalia, Chromolaena, Cronquistianthus*, Chrysactinium, Clibadium, Conyza, Cuatrecasanthus, Diplostephium, Elephantopus, Erato, Erechtites, Ferreyranthus, Fleischmannia, Gamochaeta, Gnaphalium, Grosvenoria, Gynoxys, Heliopsis, Hieracium, Jaegeria, Jungia, Kaunia, Liabum, Llerasia, Mikania, Monactis, Munnozia, Mutisia, Ophryosporus, Oyedaea, Pentacalia, Perezia, Polyanthina, Pseudogynoxys, Pseudonoseris, Raulinoreitzia, Schistocarpha, Schizotrichia, Senecio, Siegesbeckia, Smallanthus, Stevia, Tessaria, Verbesina, Vernonia, Viguiera, Wulffia
Balanophoraceae	Corynea, Helosis, Langsdorffia
Begoniaceae	Begonia*
Berberidaceae	Berberis
Betulaceae	Alnus
Bignoniaceae	Amphilophium, Arrabidea, Delostoma, Tabebuia, Tecoma, Xylophragma
Bombacaceae	Ceiba, Spirotheca
Boraginaceae	Amsinckia, Cordia, Cynoglossum, Hackelia, Heliotropium, Tournefortia
Brassicaceae	Brassica, Cardamine, Rorippa
Brunelliaceae	Brunellia
Buxaceae	Styloceras
Cactaceae	Rhipsalis
Campanulaceae	Burmeistera, Centropogon*, Diastatea, Lobelia, Siphocampylus
Capparidaceae	Capparis, Cleome, Podandrogyne
Caprifoliaceae	Sambucus, Viburnum
Caricaceae	Carica, Jacaratia
Caryophyllaceae	Arenaria, Drymaria, Stellaria
Cecropiaceae	Cecropia, Coussapoa, Pourouma
Celastraceae	Maytenus, Perrottetia, Schaefferia
Chloranthaceae	Hedyosmum*
Clethraceae	Clethra
Clusiaceae	Chrysochlamys, Clusia, Hypericum, Tovomita, Tovomitopsis, Vismia
Columelliaceae	Columellia
Convolvulaceae	Convolvulus*, Ipomoea, Merremia
Coriariaceae	Coriaria
Cornaceae	Cornus
Crypteroniaceae	Alzatea
Cucurbitaceae	Apodanthera, Cayaponia, Cyclanthera, Gurania, Guraniopsis, Psiguria
Cunoniaceae	Weinmannia*
Cyrillaceae	Purdiaea
Elaeocarpaceae	Vallea
Eremolepidaceae	Antidaphne
Ericaceae	Agarista, Bejaria, Cavendishia, Demosthenesia, Diogenesia, Disterigma, Gaultheria*, Gaylussacia, Macleania, Orthaea, Pellegrinia, Pernettya, Psammisia, Semiramisia, Sphyrospermum, Themistoclesia, Thibaudia, Vaccinium
Erythroxylaceae	Erythroxylum
Euphorbiaceae	Acalypha, Alchornea, Croton, Dalechampia, Hyeronima, Phyllanthus, Sapium, Tetrorchidium
Fabaceae	Bauhinia, Collaea, Crotalaria, Dalbergia, Dalea, Desmodium, Erythrina , Galactia, Inga*, Lathyrus, Machaerium, Mimosa, Mucuna, Otholobium, Phaseolus, Senna, Tephrosia, Vicia, Zygia
Flacourtiaceae	Abatia, Banara, Casearia, Hasseltia, Mayna, Neosprucea, Prockia
Gentianaceae	Gentianella, Halenia, Irlbachia, Macrocarpaea, Symbolanthus, Voyria
Geraniaceae	Geranium
Gesneriaceae	Alloplectus, Anodiscus, Besleria, Codonanthe, Columnea, Corytoplectus, Cremosperma, Diastema, Drymonia, Gasteranthus, Gloxinia, Kohleria, Monopyle, Paradrymonia, Phinaea
Grossulariaceae	Escallonia, Phyllonoma, Ribes
Haloragaceae	Gunnera
Hippocrateaceae	Cheiloclinium, Salacia
Hydrangeaceae	Hydrangea
Icacinaceae	Calatola, Citronella

Juglandaceae	Juglans
Lacistemataceae	Lacistema, Lozania
Lamiaceae	Hyptidendron, Hyptis, Lepechinia, Salvia, Scutellaria
Lauraceae	Aniba, Cinnamomum, Cryptocarya, Nectandra*, Ocotea*, Persea, Pleurothyrium, Rhodostemonodaphne
Lentibulariaceae	Pinguicula, Utricularia
Loasaceae	Caiophora, Klaprothia, Loasa, Mentzelia
Loganiaceae	Buddleja, Desfontainia, Strychnos
Loranthaceae	Aetanthus, Cladocolea, Gaiadendron, Ixocactus, Ligaria, Oryctanthus, Phrygilanthus, Phthirusa, Psittacanthus, Struthanthus, Tripodanthus, Tristerix
Lythraceae	Adenaria, Cuphea
Malpighiaceae	Banisteriopsis, Bunchosia, Byrsonima, Heteropterys, Stigmaphyllon, Tetrapterys
Malvaceae	Abutilon, Malvastrum, Pavonia, Sida, Wissadula
Marcgraviaceae	Norantea, Ruyschia, Schwartzia, Souroubea
Melastomataceae	Aciotis, Alloneuron, Axinaea, Blakea, Brachyotum*, Centronia, Clidemia, Graffenrieda, Huberia, Leandra, Meriania, Miconia*, Microlicia, Monochaetum, Myriaspora, Rhynchanthera, Tibouchina*, Tococa, Topobea
Meliaceae	Cabralea, Cedrela, Guarea, Ruagea, Trichilia
Menispermaceae	Cissampelos, Odontocarya
Monimiaceae	Mollinedia, Siparuna
Moraceae	Clarisia, Ficus*, Helicostylis, Morus, Perebea, Pseudolmedia, Sorocea
Myricaceae	Myrica
Myristicaceae	Virola
Myrsinaceae	Cybianthus, Geissanthus, Gentlea, Myrsine, Stylogyne
Myrtaceae	Acca, Myrcia, Myrcianthes, Myrteola, Psidium
Nyctaginaceae	Colignonia, Mirabilis
Ochnaceae	Ouratea, Sauvagesia
Olacaceae	Heisteria, Schoepfia
Onagraceae	Fuchsia*, Epilobium, Ludwigia
Oxalidaceae	Oxalis*
Papaveraceae	Bocconia
Passifloraceae	Passiflora*
Phytolaccaceae	Hilleria, Phytolacca, Trichostigma
Picramniaceae	Picramnia
Piperaceae	Peperomia*, Piper*
Plantaginaceae	Plantago
Polemoniaceae	Cantua, Cobaea
Polygalaceae	Monnina*, Polygala
Polygonaceae	Muehlenbeckia, Polygonum, Rumex, Triplaris
Primulaceae	Lysimachia
Proteaceae	Oreocallis, Panopsis, Roupala
Ranunculaceae	Clematis, Ranunculus, Thalictrum
Rhamnaceae	Gouania, Rhamnus
Rosaceae	Acaena, Alchemilla, Geum, Hesperomeles, Polylepis, Prunus, Rubus
Rubiaceae	Arcytophyllum, Borreria, Psychotria*, Chiococca, Cinchona, Coccocypselum, Condaminea, Coussarea, Elaeagia, Emmeorrhiza, Faramea, Galianthe, Galium, Gonzalagunia, Guettarda, Hamelia, Hillia, Hippotis, Hoffmannia, Isertia, Joosia, Kotchubaea, Ladenbergia, Malanea, Manettia, Nertera, Paederia, Palicourea*, Phitopis, Posoqueria, Randia, Retiniphyllum, Rudgea, Sabicea, Warszewiczia
Rutaceae	Esenbeckia, Zanthoxylum
Sabiaceae	Meliosma
Santalaceae	Cervantesia
Sapindaceae	Allophylus, Cupania, Paullinia, Serjania, Talisia
Sapotaceae	Chrysophyllum, Pouteria
Scrophulariaceae	Alonsoa, Calceolaria*, Leucocarpus, Sibthorpia
Solanaceae	Browallia, Brugmansia, Cestrum, Deprea, Iochroma, Larnax, Lycianthes, Nicandra, Nicotiana, Physalis, Salpichroa, Saracha, Sessea, Schultesianthus, Sessea, Solanum*, Trianea, Vassobia
Staphyleaceae	Huertea, Turpinia
Sterculiaceae	Byttneria, Melochia
Styracaceae	Pamphilia, Styrax
Symplocaceae	Symplocos
Theaceae	Freziera, Gordonia, Ternstroemia

Thymelaeaceae	Daphnopsis, Schoenobiblus
Tiliaceae	Heliocarpus, Luehea, Triumfetta
Tovariaceae	Tovaria
Tropaeolaceae	Tropaeolum
Ulmaceae	Lozanella, Trema
Urticaceae	Boehmeria, Myriocarpa, Phenax, Pilea*, Pouzolzia, Urera, Urtica
Valerianaceae	Valeriana
Verbenaceae	Aegiphila, Citharexylum, Duranta, Lantana, Lippia, Verbena
Violaceae	Hybanthus, Viola
Viscaceae	Dendrophthora, Phoradendron
Vitaceae	Cissus
Winteraceae	Drimys

Appendix 2. Ferns and fern allies

Appendix 2 lists ferns and fern allies of Peru's eastern montane forests. Given are families and genera, listed alphabetically. Diverse genera are marked with an asterix; these have at least ten species in the study area. Extracted from Young (1991a) and León & Young (1996).

Family	Genera
Aspleniaceae	Asplenium*
Blechnaceae	Blechnum*
Cyatheaceae	Alsophila, Cnemidaria, Cyathea, Sphaeropteris
Davalliaceae	Nephrolepis
Dennstaedtiaceae	Blotiella, Dennstaedtia Histiopteris, Hypolepis, Lindsaea, Lonchitis, Paesia, Pteridium, Saccoloma
Dicksoniaceae	Culcita, Dicksonia
Dryopteridaceae	Arachniodes, Athyrium, Ctenitis, Cyrtomium, Cystopteris, Diplazium, Dryopteris, Elaphoglossum*, Hemidictyum, Megalastrum, Polybotrya, Polystichum, Oleandra, Tectaria
Equisetaceae	Equisetum
Gleicheniaceae	Dicranopteris, Diplopterygium, Sticherus*
Hymenophyllaceae	Hymenophyllum*, Trichomanes
Isoetaceae	Isoetes
Lophosoriaceae	Lophosoria
Loxomataceae	Loxsomopsis
Lycopodiaceae	Huperzia*, Lycopodiella, Lycopodium
Marattiaceae	Danaea, Marattia
Ophioglossaceae	Botrychium, Ophioglossum
Osmundaceae	Osmunda
Plagiogyriaceae	Plagiogyria
Polypodiaceae	Campyloneurum*, Grammitis*, Niphidium, Pleopeltis, Polypodium*, Solanopteris
Pteridaceae	Adiantopsis, Adiantum*, Anogramma, Cheilanthes, Doryopteris, Eriosorus, Jamesonia, Pellaea, Pityrogramma, Pteris*, Pterozonium
Schizaeaceae	Anemia, Schizaea
Selaginellaceae	Selaginella*
Thelypteridaceae	Thelypteris*
Vittariaceae	Polytaenium, Radiovittaria, Vittaria

Appendix 3. Mosses

Appendix 3 lists mosses of the eastern montane forests of Peru. Families are listed phylogenetically and genera alphabetically. Derived from Menzel (1992). Note that this is a preliminary accounting, mostly based on fieldwork by Menzel and others in northern Peru (Frey 1987).

Family	Genera
Sphagnaceae	Sphagnum
Polytrichaceae	Pogonatum, Polytrichadelphus, Polytrichum, Steereobryon
Bryaceae	Brachymenium, Bryum, Epipterygium, Mielichhoferia, Rhodobryum
Hypopterygiaceae	Hypopterygium
Plagiomniaceae	Plagiomnium
Racopilaceae	Racopilum
Rhizogoniaceae	Leptotheca, Rhizogonium
Funariaceae	Enthostodon, Funaria
Splachnaceae	Splachnum
Orthotrichaceae	Macromitrium, Zygodon
Bartramiaceae	Anacolia, Bartramia, Breutelia, Leiomela, Philonotis
Amblystegiaceae	Amblystegium, Campylium, Cratoneuron, Drepanocladus, Vittia
Brachytheciaceae	Brachythecium, Kindbergia, Palamocladium, Rhyncho-stegium
Entodontaceae	Entodon, Erythrodontium
Fabroniaceae	Fabronia
Hylocomiaceae	Pleurozium
Hypnaceae	Ectropothecium, Hypnum, Mittenothamnium, Phyllodon
Leskeaceae	Leskea
Plagiotheciaceae	Plagiothecium
Sematophyllaceae	Acroporium, Aptychella, Sematophyllum, Trichosteleum
Thuidiaceae	Thuidium
Cryphaeaceae	Cryphaea, Schoenobryum
Hedwigiaceae	Hedwigidium
Neckeraceae	Homoliodendron, Neckera, Pinnatella, Porothamnium, Porotrichum
Meteoriaceae	Barbella, Meteoridium, Meteorium, Papillaria, Pilotrichella, Zelometeorium
Phyllogoniaceae	Phyllogonium
Prionodontaceae	Prionodon
Pterobryaceae	Jaegerina, Orthostichopsis, Pterobryon
Rhacocarpaceae	Rhacocarpus
Daltoniaceae	Daltonia
Hookeriaceae	Cyclodictyon, Hookeriopsis, Hypnella, Lepidopilum
Calymperaceae	Syrrhopodon
Pottiaceae	Barbula, Bryoerythrophyllum, Chenia, Hyophila, Leptodontium, Molendoa, Oxystegus, Pseudocrossidium, Streptocalypta, Streptopogon, Tortella, Tortula, Trichostomum
Dicranaceae	Angstroemia, Atractylocarpus, Campylopus, Chorisodontium, Chrysoblastella, Dicranella, Dicranodontium, Dicranium, Holomitrium, Microcampylopus, Oroweisia, Pilopogon
Ditrichaceae	Ceratodon, Distichium, Ditrichum
Leucobryaceae	Leucobryum
Fissidentaceae	Fissidens
Grimmiaceae	Racomitrium

Appendix 4. Hepatics

This list of hepatics of the eastern montane forests of Peru is derived from a transect study in San Martín and Amazonas done by Schultze-Motel & Menzel (1987). Families are listed phylogenetically and genera alphabetically.

Family	Genera
Lepicoleaceae	Lepicolea
Herbertaceae	Herbertus, Triandrophyllum
Pseudolepicoleaceae	Blepharostoma, Chaetocolea
Trichocoleaceae	Trichocolea
Lepidoziaceae	Arachniopsis, Bazzania, Kurzia, Lepidozia, Micropterygium, Telaranea
Calypogeiaceae	Calypogeia
Adelanthaceae	Adelanthus
Cephaloziaceae	Cephalozia, Odontoschisma
Cephaloziellaceae	Cephaloziella
Jungermanniaceae	Anastrophyllum, Andrewsianthus, Cryptochila, Jamesoniella, Jungermannia, Lophozia, Syzygiella
Scapaniaceae	Scapania
Geocalycaceae	Heteroscyphus, Leptoscyphus, Lophocolea
Plagiochilaceae	Plagiochila
Arnelliaceae	Gongylanthus
Acrobolbaceae	Lethocolea, Tylimanthus
Balantiopsidaceae	Isotachis, Neesioscyphus
Radulaceae	Radula
Porellaceae	Porella
Jubulaceae	Jubula
Lejeuneaceae	Anoplolejeunea, Blepharolejeunea, Brachiolejeunea, Ceratolejeunea, Cololejeunea, Colura, Dicranolejeunea, Diplasiolejeunea, Drepanolejeunea, Frullanoides, Harpalejeunea, Lindigianthus, Lejeunea, Lopholejeunea, Neurolejeunea, Omphalanthus, Prionolejeunea, Stictolejeunea, Symbiezidium, Taxilejeunea
Pelliaceae	Noteroclada
Pallaviciniaceae	Jensenia, Symphyogyna
Aneuraceae	Riccardia
Metzgeriaceae	Metzgeria
Monocleaceae	Monoclea
Wiesnerellaceae	Dumortiera
Aytoniaceae	Asterella, Plagiochasma
Marchantiaceae	Marchantia

Appendix 5. Mammals

This list of mammals of the eastern montane forests of Peru has been derived from Emmons (1997), Pacheco and others (1995), and Patterson and others (1996). These are species and genera likely to occur, though in many cases their presence has yet to be confirmed.

Taxonomic group	English name	Spanish name
Marsupialia	marsupials	marsupiales
Didelphidae	opossums	zarigueyas
Didelphis spp.	opossums	zarigueyas
Marmosa murina	murine mouse opossum	comadrejita marsupial ratona
Marmosops spp.	slender mouse opossums	comadrejitas marsupiales
Metachirus nudicaudatus	brown four-eyed opossum	rata marsupial de cuatro ojos
Micoureus sp.	mouse opossum	comadrejita marsupial reina
Monodelphis spp.	short-tailed opossums	colicortos marsupiales
Caenolestidae	marsupial mice	musarañas
Lestoros inca	Inca marsupial mouse	musaraña marsupial incaica
Xenartha	**anteaters, sloths, armadillos**	**armadillos, perezosos, osos hormigueros**
Dasypodidae	armadillos	armadillos
Dasypus spp.	armadillos	armadillos
Chiroptera	bats	murciélagos
Emballonuridae	sheath-tailed bats	murciélagos
Peropteryx spp.	doglike sac-winged bats	murciélagos de sacos
Mormoopidae	leaf-chinned and mustached bats	murciélago
Pteronotus sp.	mustached bat	murciélago bigotudo
Phyllostomidae	leaf-nosed bats	murciélagos
Phyllostominae	spear-nosed bats	murciélagos
Micronycteris spp.	little big-eared bats	murciélago orejudo
Mimon sp.	hairy-nosed bat	murciléago de hoja nasal peluda
Phyllostomus spp.	spear-nosed bats	murciélagos hojas de lanza
Glossophaginae	long-tongued bats	murciélago
Anoura spp.	hairy-legged long-tongued bats	murciélagos longirostros
Lionycteris spurrelli	chestnut long-tongued bat	murciélago longirostro pequeo
Lonchophylla sp.	spear-nosed long-tongued bat	murciélago longirostro
Carolliinae	short-tailed and little fruit bats	murciélagos fruteros
Carollia spp.	short-tailed fruit bats	murciélagos fruteros
Stenodermatinae	neotropical fruit bats	murciélagos
Artibeus sp.	large fruit-eating bat	murciélago frugívoro
Chiroderma sp.	big-eyed bat	murciélago
Dermanura glauca	dwarf fruit-eating bat	murciélago frugívoro
Platyrrhinus spp.	white-lined fruit bats	murciélagos de listas
Sturnira spp.	yellow-shouldered fruit bats	murciélagos
Uroderma bilobatum	tent-making bat	murciélago constructor de toldos
Vampyressa spp.	yellow-eared bats	murciléaguitos de listas
Vampyrodes caraccioli	great stripe-faced bat	murciélago de listas pronunciadas
Desmodontinae	vampire bats	vampiros
Desmodus rotundus	common vampire bat	vampiro común
Diphylla ecaudata	hairy-legged vampire bat	vampiro peludo
Vespertilionidae	vespertilionid bats	murciélagos
Eptesicus spp.	big brown bats	murciélagos
Histiotus spp.	big-eared brown bats	murciélagos
Lasiurus spp.	hoary bats	murciélagos
Myotis spp.	little brown bats	murciélagos negruzcos
Molossidae	free-tailed bats	murciélagos
Molossus sp.	mastiff bat	murciélago
Tadarida brasiliensis	Brazilian free-tailed bat	murciélago mastín

Primates	**primates**	**primates**
Cebidae	monkeys	monos
Aotus miconax	night monkey	musmuquis
Ateles paniscus	black spider monkey	maquisapa negro
Cebus sp.	capuchin monkey	machín
Lagothrix spp.	woolly monkeys	monos choros
Carnivora	**carnivores**	**carnívoros**
Canidae	dog family	perros
Pseudalopex culpaeus	Andean fox	zorro colorado
Ursidae	bears	osos
Tremarctos ornatus	Andean bear	oso andino
Mustelidae	weasel family	comadrejas
Conepatus spp.	hog-nosed skunks	zorrinos
Eira barbara	tayra	tejón
Mustela spp.	weasels	comadrejas
Felidae	cat family	gatos
Herpailurus yaguarondi	jaguarundi	yaguarundi
Panthera onca	jaguar	otorongo
Puma concolor	puma	puma
Perissodactyla	**odd-toed ungulates**	**perisodáctilos**
Tapiridae	tapirs	tapires
Tapirus pinchaque	woolly tapir	pinchaque
Artiodactyla	**even-toed ungulates**	**artiodáctilos**
Cervidae	deer family	venados
Mazama spp.	brocket deer	venados
Odocoileus virginianus	white-tailed deer	venado de cola blanca
Pudu mephistophiles	pudu	pudu
Rodentia	**rodents**	**roedores**
Sciuridae	squirrels	ardillas
Microsciurus sp.	dwarf squirrel	ardillita
Sciurus pyrrhinus	Junín red squirrel	ardilla rojiza
Muridae	murid rodents	ratones y ratas
Sigmodontinae	sigmodont rodents	ratones y ratas
Oryzomyini	rice rat tribe	ratones
Microryzomys spp.	rice rats	ratoncitos arrozaleros
Neacomys sp.	spiny mouse	ratón espinoso
Nectomys sp.	water rat	rata nadadora
Oecomys sp.	arboreal rice rat	ratón arrozalero
Oligoryzomys sp.	pygmy rice rat	ratón arrozalero
Oryzomys spp.	rice rats	ratones arrozaleros
Thomasomyini	paramo mouse tribe	ratones y ratas
Rhipidomys spp.	climbing rats	ratas trepadoras
Thomasomys spp.	Thomas' paramo rats	ratones montarazes
Ichthyomyini	water rat tribe	ratas de agua
Chibchanomys trichotis	Chibcha water rat	rata chibcha de oreja peluda
Akodontini	grass mouse tribe	ratones campestres
Akodon spp.	grass mice	ratones campestres
Oxymycterini	long-nosed mouse tribe	ratones
Oxymycterus spp.	long-nosed mice	ratones hocicudos
Caviomorpha	**caviomorph rodents**	**roedores**
Dinomyidae	pacarana	pacarana
Dinomys branickii	pacarana	pacarana
Agoutidae	pacas	pacas
Agouti taczanowskii	Taczanowski's paca	paca de Taczanowshi

Dasyproctidae	agoutis	añujes
Dasyprocta spp.	agoutis	añujes
Echimyidae	spiny rats, tree rats, bamboo rats	ratas
Dactylomys peruanus	montane bamboo rats	cono-cono peruano
Echimys saturnus	dark tree rat	rata de espinas oscuras
Mesomys leniceps	spiny tree rat	rata espinoza
Lagomorpha	**rabbits and hares**	**conejos y liebres**
Leporidae	rabbits	conejos
Silvilagus brasiliensis	Brazilian rabbit	conejo

Appendix 6. Birds

by Niels Krabbe

Appendix 6 lists birds regularly occuring in the eastern montane forests of Peru above 2500 m. The scientific and English names are mainly according to Fjeldså & Krabbe 1990, whereas Spanish names are those suggested by M. A. Plenge (pers. com, 1998). The column "category" provides additional information regarding IUCN threat category (IUCN 1994, Collar, Crosby and Stattersfield 1994) and marks restricted range species (range - 50.000 km^2).

Abreviations
rr: Birds with a restricted range of 50.000 km^2 or less
r: Rare species
1: Protection almost non-existing
2: Some protection in reserves, within or outside Peru

IUCN Categories
c: Critically endangered
e: Endangered
v: Vulnerable

Lower risk categories:
cd: Conservation dependent
nt: Near threatened
lc: Least concern

Scientific name	English name	Spanish name	Category
Tinamidae	tinamous	tinamues	
Nothocercus julius	tawny-breasted tinamou	perdiz de cabeza roja	lc, 2
Nothocercus nigricapillus	hooded tinamou	perdiz cabecinegro	nt, 2
Crypturellus obsoletus	brown tinamou	perdiz rojiza	lc, 2
Nothoprocta taczanowskii	Taczanowski's tinamou	perdiz de Taczanowski	rr, r, v, 1
Ardeidae	herons	garzas	
Tigrisoma fasciatum	fasciated tiger-heron	evetigre oscura	lc, 2
Cathartidae	American vultures	galinazos	
Coragyps atratus	black vulture	gallinazo de cabeza negra	lc, 2
Cathartes aura	turkey vulture	gallinazo de cabeza roja	lc, 2
Anatidae	ducks & geese	patos	
Merganetta armata	torrent duck	pato de los torrentes	nt, 2
Accipitridae	hawks, eagles, kites	gavilanes & aguillas	
Chondrohierax uncinatus	hook-billed kite	milano pico garfio	lc, 2
Accipiter striatus	sharp-shinned hawk	gavilán andino	lc, 2
Accipiter ventralis	plain-breasted hawk	gavilán de pecho llano	lc, 2
Buteo albigula	white-throated hawk	aguilucho de garganta blanca	lc, 2
Buteo leucorrhous	white-rumped hawk	aguilucho de rabadilla blanca	lc, 2
Buteo magnirostris	roadside hawk	busardo caminero	lc, 2
Buteo platypterus	broad-winged hawk	aguilucho de ala ancha	lc, 2
Oroaetus isidori	black-and-chestnut eagle	aguila de copete	nt, 2
Cracidae	guans & curassows	paujiles & pavas	
Penelope barbata	bearded guan	pava barbada	rr, v, 2
Penelope montagnii	Andean guan	pava andina	lc, 2
Odontophoridae	woodquails	codornizes	
Odontophorus balliviani	stripe-faced wood-quail	codorniz de ballivian	rr, lc, 2

Scolopacidae	sandpipers, snipes & woodcocks	avefrias & chorlos	
Gallinago imperialis	imperial snipe	becasina imperial	nt, 2
Columbidae	pigeons and doves	palomas	
Columba fasciata	band-tailed pigeon	paloma de nuca blanca	lc, 2
Claravis mondetoura	maroon-chested ground-dove	palomita de pecho rojo	lc, 2
Leptotila verreauxi	white-tipped dove	paloma de frente blanca	lc, 2
Geotrygon frenata	white-throated quail-dove	paloma-perdiz de garganta blanca	lc, 2
Psittacidae	parrots	guacamayos & loros	
Ara militaris	military macaw	guacamayo militar	v, 2
Leptosittaca branickii	golden-plumed parakeet	loro de mejillas doradas	v, 2
Aratinga mitrata	mitred parakeet	cotorra de cara roja	lc, 1
Bolborhynchus lineola	barred parakeet	perico barreteado	lc, 2
Bolborhynchus orbygnesius	andean parakeet	perico andino	lc, 1
Hapalopsittaca melanotis	black-winged parrot	lorito de orejas negras	lc, 2
Hapalopsittaca pyrrhops	red-faced parrot	lorito de cara roja	rr, e, 2
Pionus seniloides[subsp. of p. Tum.]	white-capped parrot	loro de corona blanca	lc, 2
Pionus tumultuosus	plum-crowned parrot	loro de cabeza rosada	lc, 2
Amazona mercenaria	scaly-naped amazon	loro verde	lc, 2
Strigidae	owls	buhos & lechuzas	
Otus albogularis	white-throated screech-owl	lechuza de garganta blanca	lc, 2
Glaucidium jardinii	Andean pygmy-owl	lechucita andina	lc, 2
Ciccaba albitarsus	rufous-banded owl	lechuza de patas blancas	lc, 2
Caprimulgidae	nightjars & nighthawks	chotacabras & añaperos	
Lurocalis rufiventris	rufous-bellied nighthawk	chotacabras de vientre rufo	lc, 2
Caprimulgus longirostris	band-winged nightjar	chotacabras serrano	lc, 2
Uropsalis segmentata	swallow-tailed nightjar	chotacabras de cola horquillada	lc, 2
Nyctibiidae	potoos	nictibios	
Nyctibius maculosus	Andean potoo	nictibio andino	r, 1
Apodidae	swifts	vencejos	
Streptoprogne rutila	chestnut-collared swift	vencejo de cuello castaño	lc, 2
Streptoprocne zonaris	white-collared swift	vencejo de collar blanco	lc, 2
Aeronautes montivagus	white-tipped swift	vencejo montañez	lc, 2
Trochilidae	hummingbirds	colibris	
Phaethornis syrmatophorus	tawny-bellied hermit	erminaño ventrileonado	lc, 2
Eotoxeres condamini	buff-tailed siclebill	pido-de-hoz colihabano	lc, 2
Colibri thalassinus	green violetear	oreja-violeta verde	lc, 2
Colibri coruscans	sparkling violetear	oreja-violeta de vientre azul	lc, 2
Adelomyia melanogenys	speckled hummingbird	colibrí moteado	lc, 2
Agleactis cupripennis	shining sunbeam	rayo-de-sol brillante	lc, 2
Aglaectis castelnaudii	white-tufted sunbeam	rayo-de-sol acanelado	rr, lc, 1
Lafresnaya lafresnayi	mountain velvetbreast	colibrí tercipelo	lc, 2
Pterophanes cyanopterus	great sapphirewing	ala-zafiro grande	lc, 2
Coeligena torquata	collared inca	colibrí-inca de collar	lc, 2
Coeligena lutetiae	buff-winged starfrontlet	colibrí-inca de ala canela	lc, 2
Coeligena violifer	violet-throated starfrontlet	colibrí-inca de garganta violeta	lc, 2
Ensifera ensifera	sword-billed hummingbird	colibrí pico espada	lc, 2
Boissonneaua mathewsii	chestnut-breasted coronet	colibrí de pecho castaño	lc, 2
Heliangelus amethysticollis	amethyst-throated sunangel	angel-d.-sol de garg. amatista	lc, 2
Heliangelus micraster	flame-throated sunangel	angel-d.-sol de garg. dorada	rr, lc, 2
Heliangelus viola	purple-throated sunangel	angel-d.-sol de garg. púrpura	rr, lc, 2
Eriocnemis vestitus	glowing puffleg	colibrí-pantalón verde	lc, 2
Eriocnemis luciani	sapphire-vented puffleg	colibrí-pantalón de frente azul	lc, 2
Eriocnemis alinae	emerald-bellied puffleg	colibrí-pantalón de vientre esm.	lc, 2
Ramphomicron microrhynchum	purple-backed thornbill	pico-espina de dorso púrpura	lc, 2
Metallura aeneocauda	scaled metaltail	colibrí de escamas	rr, lc, 2

Metallura eupogon	fire-throated metaltail	colibrí de garganta roja	rr, lc, 1
Metallura theresiae	coppery metaltail	colibrí cobrizo	rr, lc, 2
Metallura odomae	neblina metaltail	colibrí de neblina	rr, nt, 2
Metallura tyrianthina	tyrian metaltail	colibrí verde de cola roja	lc, 2
Chalcostigma ruficeps	rufous-capped thornbill	pico-espina de gorro rufo	lc, 2
Chalcostigma stanleyi	blue-mantled thornbill	pico-espina de espalda azul	lc, 2
Chalcostigma herrani	rainbow-bearded thornbill	pico-espina arco-iris	lc, 2
Opisthoprora euryptera	mountain avocetbill	colibrí pico de avoceta	lc, 2
Aglaiocercus kingi	long-tailed sylph	sílfide de cola larga	lc, 2
Loddigesia mirabilis	marvellous spatuletail	colibrí maravilloso	rr, r, v, 1
Acestrura mulsant	white-bellied woodstar	estrella de vientre blanco	lc, 2
Acestrura bombus	little woodstar	estrella chica	rr, r, e, 1
Trogonidae	trogons & quetzals	trogones & quetzales	
Trogon personatus	masked trogon	trogón enmascarado	lc, 2
Pharomachrus auriceps	golden-headed quetzal	quetzal de cabeza dorada	lc, 2
Ramphastidae	toucans & toucanets	tucanes	
Aulacorhynchus huallagae	yellow-browed toucanet	tucancito de ceja amarilla	rr, nt
Aulacorhynchus coeruleicinctis	blue-banded toucanet	tucancito de pecho celeste	lc, 2
Andigena hypoglauca	gray-breasted mountain-toucan	tucan-andino de pecho gris	nt?, 2
Andigena cucullata	hooded mountain-toucan	tucan-andino encapuchado	rr, nt?, 2
Picidae	woodpeckers	carpinteros	
Veniliornis nigriceps	bar-bellied woodpecker	carpintero de vientre rayado	lc, 2
Veniliornis fumigatus	smoky-brown woodpecker	carpintero pardo	lc, 2
Piculus rivolii	crimson-mantled woodpecker	carpintero de espalda carmesí	lc, 2
Campephilus pollens	powerful woodpecker	carpintero poderoso	lc, 2
Furnariidae	ovenbirds & allies	horneros & colaespinas	
Cinclodes aricomae	royal cinclodes	churrete real	rr, c, 1
Leptasthenura yanacensis	tawny tit-spinetail	tijeral leonado	rr, nt, 2
Leptasthenura xenothorax	white-browed tit-spinetail	tijeral de ceja blanca	rr, c, 1
Leptasthenura andicola	Andean tit-spinetail	tijeral andino	lc, 2
Schizoeaca fuliginosa	white-chinned thistletail	cola-cardo de barbilla blanca	lc, 2
Schizoeaca griseomurina	mouse-colored thistletail	cola-cardo murino	rr, lc, 2
Schizoeaca palpebralis	eye-ringed thistletail	cola-cardo de ojo anillado	rr, lc, 2
Schizoeaca vilcabambae	Vilcabamba thistletail	cola-cardo de vilcabamba	rr, lc, 1
Schizoeaca helleri	puna thistletail	cola-cardo de la puna	rr, lc, 2
Synallaxis azarae	azara´s spinetail	cola-espina de azara	lc, 2
Synallaxis (azarae) elegantior	elegant spinetail	cola-espina elegante [s.sp. S. Azarae]	lc, 2
Synallaxis courseni	apurimac spinetail		rr, v, 2
Synallaxis unirufa	rufous spinetail	cola-espina rufa	lc, 2
Hellmayrea gularis	white-browed spinetail	cola-espina de ceja blanca	lc, 2
Cranioleuca baroni	southern line-cheeked spinetail	cola-espina de baron	lc, 2
Cranioleuca marcapatae	marcapata spinetail	cola-espina de marcapata	rr, lc, 2
Cranioleuca albiceps	light-crowned spinetail	cola-espina de corona clara	rr, lc, 1
Asthenes urubambensis	line-fronted canastero	canastero de frente listada	rr, nt, 1
Thripophaga berlepschi	russet-mantled softtail	cola-suave de espalda bermeja	rr, nt, 1
Margarornis squamiger	pearled treerunner	corredor-de-arbol perlado	lc, 2
Pseudocolaptes boissonneautii	streaked tuftedcheek	barba-blanca rayado	lc, 2
Syndactyla rufosuperciliata	buff-browed foliage-gleaner	limpia-follaje de ceja anteada	lc, 2
Thripadectes flammulatus	flammulated treehunter	trepa-palo flamulado	lc, 2
Thripadectes scrutator	buff-throated treehunter	trepa-palo peruano	lc, 2
Dendrocolaptidae	woodcreepers	trepadores	
Dendrocincla tyrannina	tyrannine woodcreeper	trepador tiranino	lc, 2
Xiphocolaptes promeropirhynchus	strong-billed woodcreeper	trepador de pico fuerte	lc, 2
Lepidocolaptes lacrymiger	montane woodcreeper	trepador montano	lc, 2
Campylorhamphus pucherani	greater scythebill	pico-guadaña grande	r, 1

Formicariidae	antthrushes	bataráes	
Chamaeza mollissima	barred antthrush	rasconzuelo barreteado	lc, 2
Grallaria squamigera	undulated antpitta	tororoi ondulado	lc, 2
Grallaria ruficapilla	chestnut-crowned antpitta	tororoi de corona castaña	lc, 2
Grallaria andicola	stripe-headed antpitta	tororoi de cabeza listada	lc, 2
Grallaria nuchalis	chestnut-naped antpitta	tororoi de nuca castaña	lc, 2
Grallaria carrikeri	pale-billed antpitta	tororoi de pico pálido	rr, nt?, 1
Grallaria przewalskii	rusty-tinged antpitta	tororoi teñido de rufo	rr, lc, 2
Grallaria capitalis	bay antpitta	tororoi bayo	rr, lc, 1
Grallaria erythroleuca	red-and-white antpitta	tororoi rojo y blanco	rr, lc, 2
Grallaria rufula	rufous antpitta	tororoi rufo	lc, 2
Grallaria quitensis	tawny antpitta	tororoi leonado	lc, 2
Grallaricula ferrugineipectus	rusty-breasted antpitta	tororoi de pecho castaño	lc, 1
Grallaricula nana	slate-crowned antpitta	tororoi de corona pizarroso	lc, 1
Rhinocryptidae	tapaculos	tapaculos	
Myornis senilis	ash-colored tapaculo	tapaculo cenizo	lc, 2
Scytalopus unicolor	unicolored tapaculo	tapaculo unicolor	lc, 2
Scytalopus parvirostris	trilling tapaculo	tapaculo trinador	lc, 2
Scytalopus macropus	large-footed tapaculo	tapaculo de patas grandes	rr, lc, 2
Scytalopus parkeri	chusquea tapaculo	tapaculo de chusquea	rr, lc, 2
Scytalopus simonsi	puna tapaculo	tapaculo de la puna	lc, 2
Scytalopus urubambae	Vilcabamba tapaculo	tapaculo de vilcabamba	rr, lc, 2
Scytalopus altirostris	neblina tapaculo	tapaculo de neblina	rr, lc, 1
Scytalopus canus	paramo tapaculo	tapaculo paramero	lc, 2
Scytalopus acutirostris	Tschudi´s tapaculo	tapaculo de pico filudo	rr, lc, 2
Scytalopus schulenbergi	diademed tapaculo	tapaculo con diadema	rr, lc, 2
Acropternis orthonyx	ocellated tapaculo	tapaculo ocelado	lc, 2
Tyrannidae	tyrant flycatchers	tiranos & mosqueros	
Phyllomyias nigrocapillus	black-capped tyrannulet	moscareta de gorro negro	lc, 2
Phyllomyias uropygialis	tawny-rumped tyrannulet	moscareta de rabadilla leonada	lc, 2
Elaenia albiceps	white-crested elaenia	elainia de cresta blanca	lc, 2
Elaenia pallatangae	sierran elaenia	elainia serrana	lc, 2
Mecocerculus leucophrys	white-throated tyrannulet	tiranillo de garganta blanca	lc, 2
Mecocerculus poecilocercus	white-tailed tyrannulet	tiranillo de cola blanca	lc, 2
Mecocerculus hellmayri	buff-banded tyrannulet	tiranillo de banda anteada	lc, 2
Mecocerculus minor	sulphur-bellied tyrannulet	tiranillo de vientre azufrado	lc, 2
Mecocerculus stictopterus	white-banded tyrannulet	tiranillo de ala con bandas	lc, 2
Serpophaga cinerea	torrent tyrannulet	moscareta de los torrentes	lc, 2
Anairetes alpinus	ash-breasted tit-tyrant	torito de pecho ceniza	rr, e, 1
Anairetes agraphia	unstreaked tit-tyrant	torito llano	lc, 2
Anairetes parulus	tufted tit-tyrant	torito copetón	lc, 2
Mionectes striaticollis	streak-necked flycatcher	mosquerito de cuello listado	lc, 2
Pseudotriccus ruficeps	rufous-headed pygmy-tyrant	tirano-pigmeo de cabeza rufa	lc, 2
Poecilotriccus ruficeps	rufous-crowned tody-tyrant	pico-chato de corona rufa	lc, 2
Hemitriccus granadensis	black-throated tody-tyrant	tirano-todi de garganta negra	lc, 2
Myiophobus lintoni	orange-banded flycatcher	mosquerito con franja naranja	rr, nt, 2
Myiophobus ochraceiventris	ochraceous-breasted flycatcher	mosquerito de pecho ocráceo	lc, 2
Pyrrhomyias cinnamomea	cinnamon flycatcher	mosquerito canela	lc, 2
Contopus fumigatus	smoke-colore pewee	pibí ahumado	lc, 2
Sayornis nigricans	black phoebe	mosquero de agua	lc, 2
Silvicultrix frontalis	crowned chat-tyrant	pitajo coronado	lc, 2
Silvicultrix diadema	yellow-bellied chat-tyrant	pitajo de vientre amarillo	lc, 2
Silvicultrix pulchella	golden-browed chat-tyrant	pitajo de ceja dorada	lc, 2
Ochthoeca cinnamomeiventris	slaty-backed chat-tyrant	pitajo de dorso pizarroso	lc, 2
Ochthoeca rufipectoralis	rufous-breasted chat-tyrant	pitajo de pecho rufo	lc, 2
Ochthoeca fumicolor	brown-backed chat-tyrant	pitajo de dorso pardo	lc, 2
Myiotheretes fumigatus	smoky bush-tyrant	ala-rufa ahumada	lc, 2
Myiotheretes fuscorufus	rufous-bellied bush-tyrant	ala-rufa de vientre rufo	rr, nt, 2

Knipolegus signatus	plumbeous tyrant	viudita andina	lc, 2
Knipolegus poecilurus	rufous-tailed tyrant	viudita de cola rufa	lc, 2
Myiarchus tuberculifer	dusky-capped flycatcher	copetón de cresta oscura	lc, 2
Incertae sedis	species of uncertain position	especies de posición incierto	
Lipaugus fuscocinereus	dusky piha	piha oscura	lc, 2
Lipaugus uropygialis	scimitar-winged piha	piha ala-de-cimatarra	rr, lc, 2
Pachyramphus versicolor	barred becard	cabezón barreteado	lc, 2
Pachyramphus validus	crested becard	cabezón crestudo	lc, 2
Cotingidae	cotingas & fruiteaters	cotingas	
Doliornis remseni	chestnut-bellied cotinga	cotinga de vientre castaño	rr, r, v, 2
Doliornis sclateri	bay-vented cotinga	cotinga de subcaudales rojizos	rr, lc, 2
Ampelion rubrocristatus	red-crested cotinga	cotinga de cresta roja	lc, 2
Pipreola riefferii	green-and-black fruiteater	frutero verde y negro	lc, 2
Pipreola intermedia	band-tailed fruiteater	frutero de cola con banda	lc, 2
Pipreola arcuata	barred fruiteater	frutero barreteado	lc, 2
Vireonidae	vireos & allies	vireos	
Vireo leucophrys	brown-capped vireo	vireo de gorro marrón	lc, 2
Cyclarhis gujanensis	rufous-browed peppershrike	vireón de ceja rufa	lc, 2
Corvidae	crows & jays	urraquitas	
Cyanocorax yncas	green jay	urraca verde	lc, 2
Cyanolyca turcosa	turquoise jay	urraca turquesa	lc, 2
Cyanolyca viridicyana	white-collared jay	urraca de collar blanco	lc, 2
Hirundinidae	swallows & martins	golondrinas	
Pygochelidon cyanoleuca	blue-and-white swallow	golondrina azul y blanca	lc, 2
Notiochelidon murina	brown-bellied swallow	golondrina de vientre marrón	lc, 2
Notiochelidon flavipes	pale-footed swallow	golondrina de patas pálidas	lc, 2
Troglodytidae	wrens	chochines	
Cinnycerthia unirufa	rufous wren	cucarachero rufo	lc, 2
Cinnycerthia olivacens	sharpe´s wren	cucarachero de sharpe	lc, 2
Cinnycerthia peruana	Peruvian wren	cucarachero peruano	lc, 2
Cinnycerthia fulva	superciliated wren	cucarachero fulvo	lc, 2
Thryothorus euophrys	plain-tailed wren	cucarachero de cola llana	lc, 2
Thryothorus eisenmanni	Inca wren	cucarachero inca	rr, lc, 2
Troglodytes aedon	house wren	cucarachero común	lc, 2
Troglodytes solstitialis	mountain wren	cucarachero montañez	lc, 2
Henicorhina leucophrys	gray-breasted wood-wren	cucarachero-montés de pecho gris	lc, 2
Cinclidae	dippers	mirlos de agua	
Cinclus leucocephalus	white-capped dipper	mirlo acuático de gorro blanco	lc, 2
Turdidae	thrushes & solitaires	mirlos & tordos	
Myadestes ralloides	Andean solitaire	solitario andino	lc, 2
Entomodestes leucotis	white-eared solitaire	solitario de orejas blancas	lc, 2
Catharus fuscater	slaty-backed nightingale-thrush	zorzal sombrío	lc, 2
Catharus ustulatus	Swainson´s thrush	zorzal de Swainson	lc, 2
Turdus fuscater	great thrush	mirlo grande	lc, 2
Turdus serranus	glossy-black thrush	mirlo negro-brilloso	lc, 2
Turdus fulviventris	chestnut-bellied thrush	mirlo de vientre castaño	lc, 2
Parulidae	wood-warblers	reinitas	
Dendroica fusca	black-burnian warbler	reinita de garganta naranja	lc, 2
Setophaga ruticilla	American redstart	candelita americana	lc, 2
Wilsonia canadensis	Canada warbler	reinita de collar	lc, 2
Myioborus miniatus	slate-throated whitestart	candelita de garganta plomiza	lc, 2
Myioborus melanocephalus	spectacled whitestart	candelita de anteojos	lc, 2
Basileuterus signatus	pale-legged warbler	reinita de patas pálidas	lc, 2

Basileuterus luteoviridis	citrine warbler	reinita citrina	lc, 2
Basileuterus nigrocristatus	black-crested warbler	reinita de cresta negra	lc, 2
Basileuterus coronatus	russet-crowned warbler	reinita de corona rojiza	lc, 2
Basileuterus tristriatus	three-striped warbler	reinita de cabeza listada	lc, 2
Thraupidae	tanagers	tangaras	
Conirostrum cinereum	cinereous conebill	mielerito cinéreo	lc, 2
Conirostrum ferrugineiventre	white-browed conebill	mielerito de ceja blanca	rr
Conirostrum sitticolor	blue-backed conebill	mielerito de dorso azul	lc, 2
Conirostrum albifrons	capped conebill	mielerito con gorro	lc, 2
Oreomanes fraseri	giant conebill	pico de cono gigante	rr, nt, 2
Chlorornis riefferii	grass-green tanager	tangara verde esmeralda	lc, 2
Sericossypha albocristata	white-capped tanagar	tangara de gorro blanco	r, 2
Chlorospingus ophthalmicus	common bush-tanager	tangara de monte común	lc, 2
Cnemoscopus rubrirostris	gray-hooded bush-tanager	hemispingo de capucho gris	lc, 2
Hemispingus atropileus	black-capped hemispingus	hemispingo de gorro negro	lc, 2
Hemispingus calophrys	orange-browed hemispingus	hemispingo de ceja naranja	rr, lc, 2
Hemispingus parodii	Parodi´s hemispingus	hemispingo de parodi	rr, lc, 2
Hemispingus superciliaris	superciliaried hemispingus	hemispingo superciliado	lc, 2
Hemispingus frontalis	oleaginous hemispingus	hemispingo oleaginoso	lc, 2
Hemispingus melanotis	black-eared hemispingus	hemispingo de oreja negra	lc, 2
Hemispingus rufosuperciliaris	rufous-browed hemispingus	hemispingo de ceja rufa	rr, r, nt, 1
Hemispingus verticalis	black-headed hemispingus	hemispingo de cabeza negra	lc, 2
Hemispingus xanthophthalmus	drab hemispingus	hemispingo simple	lc, 2
Hemispingus trifasciatus	three-striped hemispingus	hemispingo de tres rayas	lc, 2
Thlypopsis ornata	rufous-chested tanager	tangara de pecho rufo	lc, 2
Thlypopsis pectoralis	brown-flanked tanager	tangara de flancos marrones	rr, lc, 2
Thlypopsis ruficeps	rust-and-yellow tanager	tangara rojizo y amarillo	lc, 2
Creurgops verticalis	rufous-crested tanager	tangara de cresta rufa	lc, 2
Piranga flava	hepatic tanager	piranga bermeja	lc, 2
Piranga rubra	summer tanager	piranga roja	lc, 2
Piranga rubriceps	red-hooded tanager	piranga de capucha roja	lc, 2
Thraupis cyanocephala	blue-capped tanager	azulejo de gorra azul	lc, 2
Buthraupis montana	hooded mountain-tanager	tangara-de-montaña encapuchada	lc, 2
Buthraupis eximia	black-chested mountain-tanager	tangara-de-montaña de pecho negro	lc, 2
Buthraupis aureodorsalis	golden-backed mountain-tanager	tangara-de-montaña de d. dorado	rr, v, 1
Buthraupis wetmorei	masked mountain-tanager	tangara-de-montaña enmascarada	rr, v, 2
Anisognathus lacrymosus	lacrymose mountain-tanager	tangara-de-montaña lacrimosa	lc, 2
Anisognathus igniventris	scarlet-bellied mountain-tanager	tangara-de-mt. de vientre escarlata	lc, 2
Anisognathus somptuosus	blue-winged mountain-tanager	tangara-de-montaña de ala azul	lc, 2
Iridosornis jelskii	golden-collared tanager	tangara de cuello dorado	lc, 2
Iridosornis rufivertex	golden-crowned tanager	tangara de corona dorada	lc, 2
Iridosornis reinhardti	yellow-scarfed tanager	tangara de bufanda amarilla	lc, 2
Dubusia taeniata	buff-breasted mountain-tanager	tangara de pecho anteado	lc, 2
Delothraupis castaneoventris	chestnut-bellied mountain-tanager	tangara-de-mt. de vientre castaño	lc, 2
Pipraeidea melanonota	fawn-breasted tanager	tangara-de-mt. de pecho anteado	lc, 2
Euphonia cyanocephala	golden-rumped euphonia	eufonia de rabadilla dorada	lc, 2
Euphonia xanthogaster	orange-bellied euphonia	eufonia de vientre naranja	lc, 2
Chlorophonia pyrrhophrys	chestnut-breasted chlorophonia	clorofonia de pecho castaño	lc, 2
Tangara xanthocephala	saffron-crowned tanager	tangara de corona azafrán	lc, 2
Tangara parzudakii	flame-faced tanager	tangara cara de fuego	lc, 2
Tangara ruficervix	golden-naped tanager	tangara de nuca dorada	lc, 2
Tangara labradorides	metallic-green tanager	tangara verde metalico	lc, 2
Tangara nigroviridis	beryl-spangled tanager	tangara con lentejuelas de berilo	lc, 2
Tangara vassorii	blue-and-black tanager	tangara azul y negro	lc, 2
Tangara viridicollis	silvery tanager	tangara de espalda plateada	lc, 2
Xenodacnis parina	tit-like dacnis	xenodacnis	rr, nt, 2
Catamblyrhynchus diadema	plush-capped finch	gorro afelpado	lc, 2
Nephelornis oneilli	O´neill´s pardusco	pardusco	rr, lc, 2
Emberizidae	buntings, cardinals etc.	pipines	
Atlapetes pallidinucha	pale-naped brush-finch	matorralero de nuca pálida	lc, 2

Atlapetes latinuchus	n. rufous-naped brush-finch	matorralero de nuca rufa	lc, 2
Atlapetes tricolor	tricolored brush-finch	matorralero tricolor	lc, 2
Atlapetes schistaceus	slaty brush-finch	matorralero pizarroso	lc, 2
Atlapetes melanops	black-spectacled brush-finch		rr, cd, 1
Atlapetes terborghi	Vilcabamba brush-finch		rr, lc, 1
Atlapetes canigenis	gray brush-finch		rr, lc, 2
Atlapetes melanolaemus	black-faced brush-finch		rr, lc, 2
Buarremon brunneinuchus	chestnut-capped brush-finch	matorralero de gorro castaño	lc, 2
Buarremonn torquatus	stripe-headed brush-finch	matorralero de cabeza listada	lc, 2
Diglossa albilatera	white-sided flowerpiercer	pincha-flor de flancos blancos	lc, 2
Diglossa humeralis	black flowerpiercer	pincha-flor negro	lc, 2
Diglossa brunneiventris	black-throated flowerpiercer	pincha-flor de garganta negra	lc, 2
Diglossa lafresnayii	glossy flowerpiercer	pincha-flor satinado	lc, 2
Diglossa mystacalis	moustached flowerpiercer	pincha-flor mostachoso	lc, 2
Diglossa caerulescens	bluish flowerpiercer	pincha-flor azulado	lc, 2
Diglossa cyanea	masked flowerpiercer	pincha-flor enmascarado	lc, 2
Catamenia homochroa	paramo seedeater	semillero paramero	lc, 2
Haplospiza rustica	slaty finch	fringilo pizarroso	lc, 2
Zonotrichia capensis	rufous-collared sparrow	gorrión de collar rufo	lc, 2
Cardinalidae	cardinals, grosbeaks & saltators		
Pheucticus chrysogaster	southern yellow grosbeak	picogrueso de vientre dorado	lc, 2
Pheucticus aureoventris	black-backed grosbeak	picogrueso de dorso negro	lc, 2
Saltator aurantiirostris	golden-billed saltator	saltador de pico dorado	lc, 2
Saltator cinctus	masked saltator	saltador enmascarado	r, nt, 2
Icteridae	caciques & allies	boyeros & oropendolas	
Amblycercus holosericeus	yellow-billed cacique	cacique de pico amarillo	lc, 2
Cacicus leucoramphus	mountain cacique	cacique de hombros dorados	lc, 2
Fringillidae	finches	jilgueros & pinzones	
Carduelis crassirostris	thick-billed siskin	jilguero de pico grueso	lc, 2
Carduelis magellanica	hooded siskin	jilguero de cabeza negra	lc, 2

Appendix 7. Reptiles and amphibians

Appendix 7 lists reptiles and amphibians of the montane and premontane forests of the eastern slopes of the Peruvian Andes. Note that the sources used give composition for 600 to 3500 m elevation, so not only montane species were considered. Derived from Carrillo de Espinoza & Icochea (1995) and Rodríguez and others (1993).

Lizards (Sauria)

Amphisbaenidae	Amphisbaena spp.
Gekkonidae	Gonatodes atricucullaris, Hemidactylus mabouia, Phyllodactylus spp.
Gymnophtalmidae	Alopoglossus andeanus, Bachia barbouri, Euspondylus spp., Opipeuter xestus, Pholidobolus anomalus, Prionodactylus manicatus, Proctoporus spp.
Polychrotidae	Anolis spp., Polychrus peruvianus
Teiidae	Ameiva bifrontata, Kentropyx altamazonica
Tropiduridae	Microlophus stolzmanni, Stenocercus spp.

Snakes (Serpentes)

Colubridae	Atractus spp., Chironius spp., Dipsas spp., Drymoluber dichrous, Leptophis ahaetulla, Liophis spp., Mastigodryas boddaerti, Oxybelis aeneus, Osyrhopus spp., Pseudoboa neuwiedii, Spilotes pullatus, Tachymenis tarmensis, Xenodon severus
Elapidae	Leptomicrurus spp., Micrurus spp.
Leptotyphlopidae	Leptotyphlops peruvianus
Typhlopidae	Typhlops reticulatus
Viperidae	Bothriopsis spp., Bothrops spp., Crotalus durissus, Lachesis muta

Frogs (Anura)

Bufonidae	Atelopus spp., Bufo spp.
Centrolenidae	Centrolene spp., Cochranella spp., Hyalinobatrachium spp.
Dendrobatidae	Colostethus spp., Dendrobates spp., Epipedobates spp.
Hylidae	Gastrotheca spp., Hemiphractus johnsoni, Hyla spp., Osteocephalus spp., Phyllomedusa spp., Scinax spp.
Leptodactylidae	Adenomera hylaedactyla, Edalorhina nasuta, Eleutherodactylus spp., Ischnocnema spp., Leptodactylus spp., Lithodytes lineatus, Phrynopus spp., Phyllonastes lynchi, Telmatobius brevirostris

Salamanders (Caudata)

Plethodontidae	Bolitoglossa spp.

Caecilains (Gymnophiona)

Rhinatrematidae	Epicrionops spp.

Appendix 8. Population census data

Population census data for selected provinces found in or adjacent to the study area, extracted from the national censuses. See Figure 6 (page 13) for locations of the departments and provinces used for this purpose.

Department, Province	Census year / Population					
	1876	1940	1961	1972	1981	1993
Amazonas						
Bongará	2564	5723	6808	10456	14235	20459
Chachapoyas	12372	20753	28354	34898	37082	45058
Rodríguez de Mendoza	4522	8294	12529	15758	18174	21389
San Martín						
Huallaga	3863	11768	21873	26767	31580	22236
Mariscal Cáceres	1765	8882	20712	36605	54231	49798
Huánuco						
Huánuco	23657	65085	88647	115029	133315	223339
Pasco						
Oxapampa	1265	5881	25783	39794	49857	60298
Junín						
Chanchamayo	2468	14145	34576	61482	98508	114045
Ayacucho						
Huanta	15322	50983	58353	67417	76060	64503
La Mar	24144	38590	49356	62739	74269	70018
Cusco						
La Convención	10189	27243	61901	84161	106967	157240
Urubamba	16681	29558	32532	34623	38500	48254
Calca	14086	33778	39320	46191	50210	56007
Puno						
Carabaya	11221	21149	28179	29948	32896	46777
Sandia	12721	25171	38550	43853	47559	50042
Eastern slope provinces	156840	367003	547473	709721	863443	1049463
Peru	2651619	6207967	9906746	13538208	17031221	22639443

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