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A non-profit organization dedicated to providing the scientific basis for effective conservation action, NatureServe is a leading provider of scientific information, expertise, and information technology tools that connect science with conservation. The NatureServe network is a public-private partnership that includes 80 independent member programs.

In Latin America, NatureServe works to protect biological diversity by promoting the development and use of scientific information and technologies that can help meet the region's pressing conservation needs. We carry out this work in partnership with a network of 18 conservation data centers (CDCs) in 11 countries, as well as many other partners in the government, conservation, and academic sectors.



The Gordon and Betty Moore Foundation was established in September 2000 to create positive outcomes for future generations. The Foundation funds outcome-based grants and initiatives to achieve significant and measurable results. The mission of the Moore Foundation's Andes-Amazon initiative is to maintain the ecological function, representative biodiversity, and climatologic function of the Amazon Basin and protect the region's long-term ecological viability. www.moore.org

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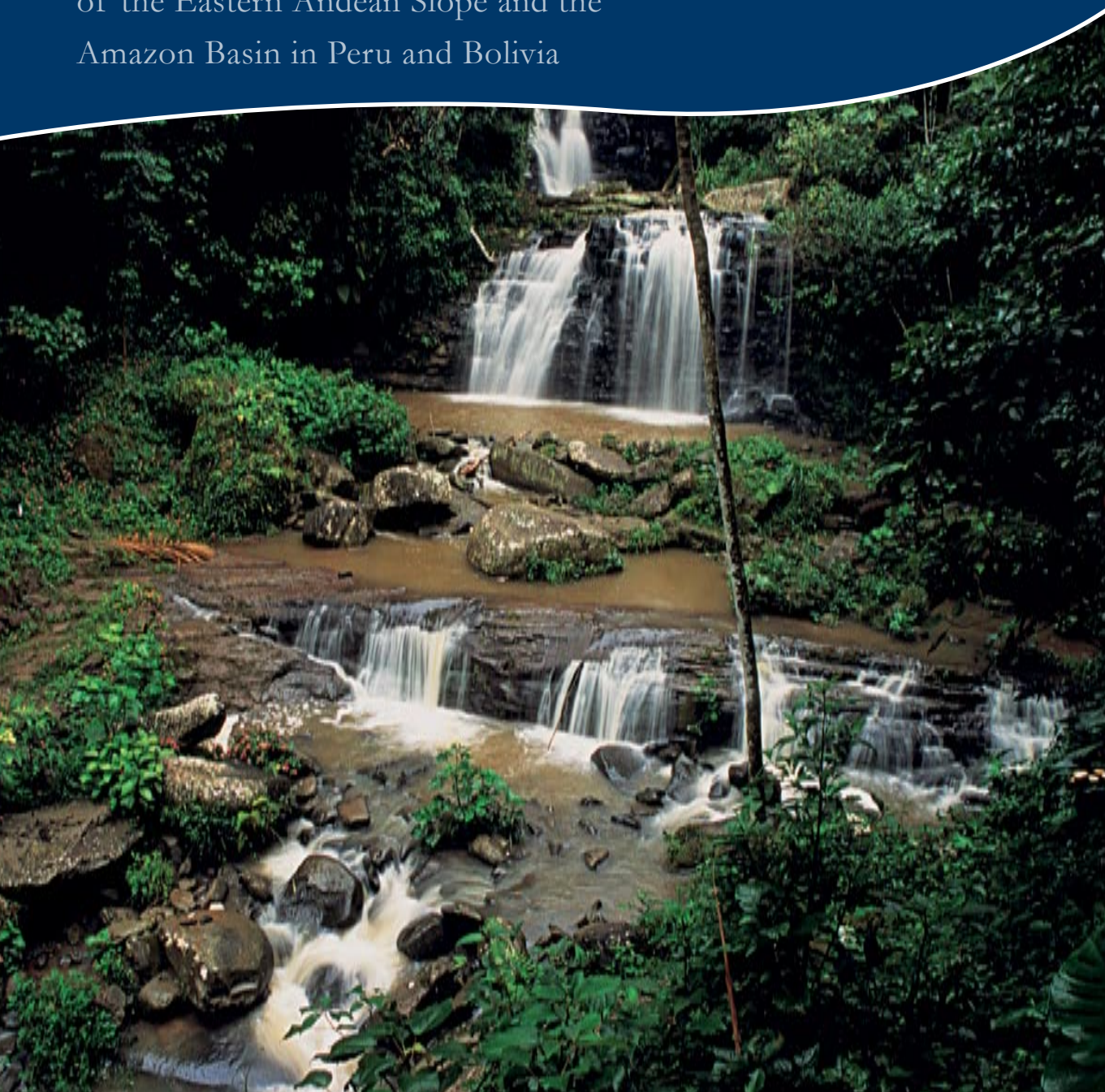
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Endemic Species and Ecological Systems

of the Eastern Andean Slope and the Amazon Basin in Peru and Bolivia



NatureServe

Introduction

With a major grant from the Gordon and Betty Moore Foundation, in 2004 NatureServe launched a project to advance the understanding of biodiversity and patterns of endemic species and ecological systems across the upper Amazon watershed of Peru and Bolivia. Carried out in collaboration with a dozen local and regional institutions, the project was completed in March 2007.

Complete project results and downloadable data can be found at: www.natureserve.org/AndesAmazon.



Peruvian Yungas

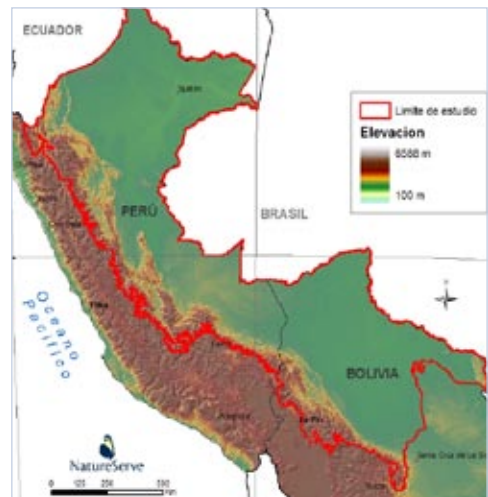
The Yungas represent a belt of humid tropical montane forest that occurs at mid elevations along most of the eastern slope of the Andes from Peru to Argentina.

About the Region

The eastern slope of the Andes is a land of biological superlatives. The complex geologic and evolutionary history of the Andes, the world's longest mountain range, has produced an exceptionally rich landscape in terms of diversity of ecosystems and species. Both this region and the adjacent Amazonian forests, are home to the world's highest diversity of birds, one-third of all freshwater fish species, and more than 60,000 plant species, half of which are found nowhere else.

Our study covered a project area of approximately 1.25 million square kilometers (485,000 square miles) in Peru and Bolivia, extending across all or portions of seven ecoregions: the Peruvian Yungas, Bolivian Yungas, Napo Moist Forests, Ucayali Moist Forests, Southwest Amazon Moist Forests, Beni Savanna, and Iquitos Várzea.

This project focuses on the Yungas and associated ecosystems including the Amazonian lowlands on the eastern slope of the central Andes of Peru and northern Bolivia. The northern and eastern limits of the project area are delimited by the national boundaries of these countries. The southern limit is the division between the northern and more temperate southern Yungas.



Significance for Conservation

By almost any measure, the project area harbors some of the most important biodiversity found anywhere on Earth:

- The project area includes three of the World Wildlife Fund's "Global 200" ecoregions identified as having the most important representative examples of the Earth's biodiversity.
- The Yungas portion of the project area lies within the Tropical Andes hotspot, one of the 34 highest-priority regions proposed by Conservation International for global biodiversity conservation. This same area is believed to have the highest level of terrestrial vertebrate endemism on Earth.



Blue-throated Macaw

- The Tropical Andes, which include the Yungas portion of the project area, are one of only five areas of the world that attain a species richness of more than 5,000 vascular plant species per 10,000 square kilometers (3,860 square miles).
- The upper Amazonian forests of the project area contain the greatest diversity of amphibians in the Western Hemisphere.
- A recent global analysis of bird distributions highlighted the area as one of the richest in the world for diversity and endemism.
- The Peruvian portion of the study area also ranks among the highest in the world for mammal diversity.



Tropical mountain cloud forests on the eastern Andean slope.

Biodiversity in Peril

Today, this extraordinary wilderness is under threat. Both the increase of human populations and economic activity intensifies the pressure on natural resources. Across the slopes of the Andes and the Amazon basin, the loss of forests and other wild lands to logging, cattle ranching, mining, agriculture, and infrastructure, continues at rates of up to 23,300 square kilometers (9,000 square miles) per year. Balancing the conservation of these irreplaceable landscapes with the needs of local peoples to earn their livelihoods, is a shared global responsibility.

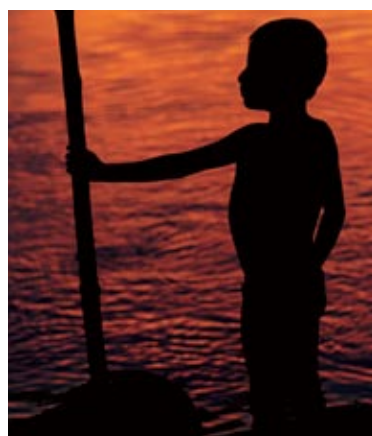
Significant portions of the region remain relatively undisturbed and some are legally protected in large national parks. Nevertheless, extensive areas have already been deforested and others are being threatened by a number of factors. The expansion of the agricultural frontiers for cash crops, –such as citrus, coffee, and soybeans– and for cattle ranching, continue to degrade habitats. Major international infrastructure projects, such as gas pipelines and transportation networks, are proposed to cross the region.

In Peru, 38% of the Yungas in the San Martin and Amazonas Departments, 25% of the Yungas in the Pasco and Junin Departments, and 15% of the Cusco Department have already been deforested. Similar deforestation is occurring in eastern Bolivia. These threats underscore the urgency of regional conservation planning and implementing effective strategies to preserve this tremendous wealth of biodiversity for the future.

Project Summary

Major Project Objectives

- Create conservation baseline maps for the Andes-Amazon regions of Peru and Bolivia to inform planning and effective conservation action at regional and local scales.
- Build capacity for developing and using biodiversity information among key institutions in Peru and Bolivia.
- Assist the Gordon and Betty Moore Foundation, a major supporter of conservation activities in the region, to recognize opportunities for strategic conservation investment.



The project consisted of three interrelated scientific initiatives:

1) Modeling and Mapping Distributions of Endemic Species

Using the latest scientific research, tools, and innovative methods, we modeled and mapped the ranges of 782 endemic species of birds, mammals, amphibians and plants. The results identified areas of high conservation value as well as previously undetected centers of endemism.

2) Classifying and Mapping Ecological Systems

We developed a detailed vegetation map of upland and wetland ecological systems across the project area. Eighty-four different ecological systems were identified and mapped using the classification of Latin American ecological systems developed by NatureServe in collaboration with numerous experts. We characterized and assessed the cartographic accuracy of these different systems using satellite image interpretation, geographic information systems (GIS) modeling, existing maps, extensive field surveys, and aerial overflights.

3) Conservation Planning for San Martín, Peru

We worked in collaboration with local governments and citizens to assist them on their ongoing plans for land use, natural resource protection, and economic development in the San Martín region, Peru. Using NatureServe Vista, a GIS-based decision-support software tool, the analysis identified gaps in the current protected area network and examined the effects on biodiversity of various proposed scenarios for road building and land use. This planning effort in San Martín is intended to serve as a pilot to demonstrate the practicality of applying this process to other jurisdictions in Peru and Bolivia.

PROJECT PARTNERS

Asociación Armonía

Santa Cruz, Bolivia
www.armonia-bo.org/

Centro de Datos para la Conservación

Universidad Nacional Agraria La Molina
Lima, Peru
<http://cdc.lamolina.edu.pe/>

Centro de Biodiversidad y Genética

Universidad Mayor de San Simón
Cochabamba, Bolivia
www.fcyt.umss.edu.bo/investigacion/biodiversidad/index.php

Museo Nacional de Historia Natural Colección Boliviana de Fauna

La Paz, Bolivia
Mywebpage.netscape.com/inseco/cbf.htm

Fundación Amigos de la Naturaleza

Santa Cruz, Bolivia
www.fan-bo.org/

Herbario Nacional de Bolivia

La Paz, Bolivia
www.insteco-bol.org

Instituto de Investigaciones de la Amazonía Peruana

Iquitos, Peru
www.iiap.org.pe/

Missouri Botanical Garden

St. Louis, Missouri, USA
www.mobot.org/plantscience/ccsd/frontpage.shtml

Museo de Historia Natural

Universidad Nacional Mayor de San Marcos
Lima, Peru
museohn.unmsm.edu.pe/divisiones/zoologia/zoologia.htm

Museo de Historia Natural Noel Kempff Mercado

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More than 60 herbaria and related institutions from 20 nations provided botanical data and information used in the project. We thank them for their assistance. Similarly, 19 institutions and dozens of individual experts provided their expertise and data related to the animals studied. A complete list of these institutions is provided on our website.

We thank Jennifer Swenson, who served as project manager for the first two-thirds of the project, and Denny Grossman, former Vice-President of Science for NatureServe, for helping to conceive and lead the project.

We are deeply indebted to the Gordon and Betty Moore Foundation for financial support and technical guidance. In particular, we thank Dr. Jaime Cavelier for his advice and support throughout this project.

Nowhere Else on Earth: Endemic Species Analysis

Goals

- To produce accurate distribution maps, in a digital format, of the birds, mammals, amphibians, and plants that are endemic to the eastern slope of the central Andes to use in conservation planning.
- Identify concentrations of endemic species in the study area.
- Make the maps and distribution data accessible to academic scientists, conservationists, and government planners.

Conserving species first requires knowing where they live. For hundreds of years biologists have conducted field inventories to map the distribution of plants and animals. Yet our understanding of the distribution of most species, especially in remote regions, is still incomplete. Field work can be time-consuming, costly, and even hazardous. Good inventories tell us where particular species have been found, but not where else they are likely to occur.

By combining reliable locational data with technological and analytical tools, we can learn more about species distributions. Nowadays, the development of high-speed computers and geographic mapping software allows us to model the distribution of a particular species by analyzing the environmental characteristics of its known localities. These mathematically defined models can then be combined with known constraints based on the species' life history to predict where else on the landscape the species might occur. The models incorporate a variety of environmental data, including digital terrain models (depicting elevation and slope), current land cover, and digital data layers for precipitation, temperature, and other climatic factors.

Through the use of these models, we have greatly contributed to the knowledge of the distributions of endemic plant and animal species on the eastern slope of the Andes in Peru and Bolivia. The models yielded maps of species distribution that are much more precise than previous range maps. Analysis of this data has pinpointed important, previously unknown centers of endemism and identified concentrations of endemic species that occur outside of the existing protected areas system.



Golden-collared Tanager

Endemic species: a species that is restricted to a particular geographic area. In this report, we treat species restricted to our study area on the east slope of the Andes in Peru and Bolivia as endemic species.



Yellow-browed Toucanet

© Anneke Delanycker



Rio Mayo Titi monkey

Project Results

The project produced maps of the predicted distributions of 782 endemic species. We identified important new areas of high endemic species concentrations, and predicted the locations of previously unknown and undiscovered areas of endemism.

The species mapped included all the members of 15 vascular plant families or genera and all amphibians, mammals, and birds endemic to the study area. The results show distinct areas of endemism for each of the 18 taxonomic groups studied.

- **Plants (435 species):** Four plant groups (Anacardiaceae, Chrysobalanaceae, Inga, and Malpighiaceae) showed endemism in the lowlands. The Acanthaceae showed peaks of endemism at mid elevations, and nine plant groups (Aquifoliaceae, Brunelliaceae, Campanulaceae, Ericaceae, Mimosa, Loasaceae, Marcgraviaceae, Fuchsia, and Passifloraceae) had endemism peaks at elevations above 2,000 meters.
- **Amphibians (177 species):** Amphibians showed a major diversity peak in central Cochabamba Department, Bolivia. Further analysis revealed the existence of equally important areas in the Amazonas and San Martin Departments in northern Peru, where large numbers of microendemic species occurred.
- **Mammals (55 species):** Richness of endemic species of mammals was highest in a long band at high-elevations in the Andes from Cusco, Peru, to Cochabamba, Bolivia. The region of the La Libertad-San Martin departmental border in the Cordillera Central was also important for narrow-ranging endemics.
- **Birds (115 species):** Bird endemism peaked in six areas ranging from the Carpish Hills region of Huanuco Department, Peru, to the Cordillera de Cocapata-Tiraque in Cochabamba, Bolivia. Although birds have been the subject of numerous previous analysis of endemism in the Andes, our predictive modeling methods identified two previously unrecognized areas, both in Peru –the western Cordillera de Vilcabamba and the region along the Rio Mapacho-Yavero east of Cusco.

PROSPECTS FOR CONSERVATION

How well does the existing system of protected areas in Peru and Bolivia overlaps with the areas of endemism identified in this project? Existing national protected areas do cover at least portions of nine of the 12 areas of endemism we identified. Yet, often the area covered is minimal, and large segments of the identified areas of endemism in our analysis are currently unprotected. The greatest overlap of areas of endemism in the entire project area occurs in the Cordilleras near La Paz, where only one small national park (Carrasco) protects the upper slopes of this extensive region. On the other hand, the Cocha Cashu area of endemism is entirely protected by Peru's Manu National Park and the Cordillera de Apolobamba (an area of avian endemism) is largely contained within Bolivia's Madidi National Park. Conservationists have achieved important accomplishments in protecting some key areas for endemism, but significant additional work remains to be done before endemism in the region is well-protected.

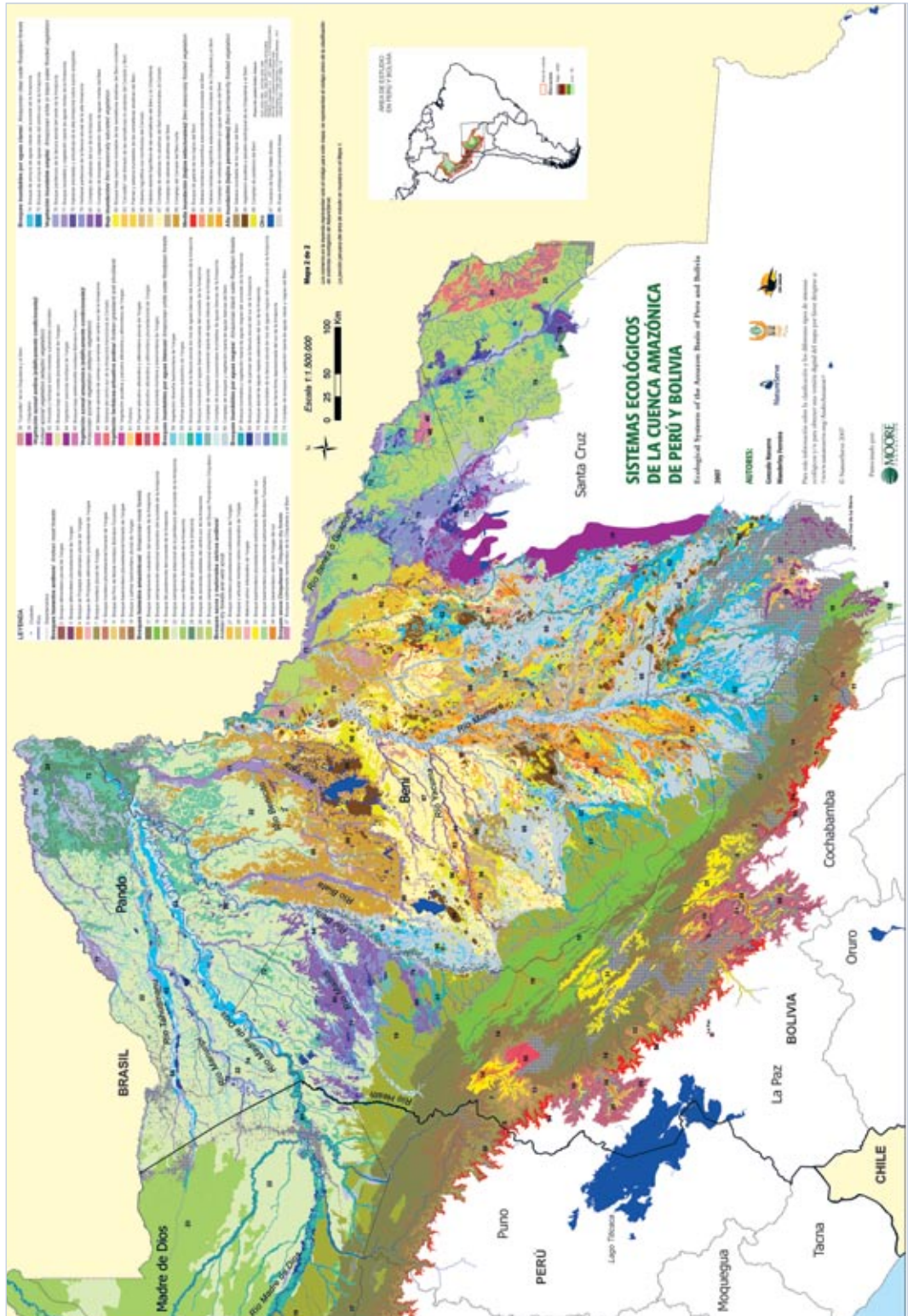


Peruvian Recurvebill

Finally, our results highlight the importance of combining the distributions of species from different taxonomic groups when performing conservation priority-setting exercises. Areas of endemism for amphibians usually occur far from, and at a lower elevations than, areas of endemism for vertebrate groups such as birds or mammals. No single group can serve as a surrogate for all biodiversity.

Amazon Basin of Peru and Bolivia

Systems in the Project Study Area



Mapping Habitats: Ecological Systems Analysis

Goals

- Produce a unified ecological systems classification map of the binational study area.
- Identify rare or vulnerable ecological systems based on spatial analysis.
- Promote the use of ecological systems information in regional planning processes.



In collaboration with numerous experts from across Latin America, over the past five years NatureServe has developed a classification of the terrestrial *ecological systems* of Latin America and the Caribbean. This classification analyzes the landscape in detail, based on both the dominant vegetation, and the ecological processes, and physical environment that shape these systems. Currently, our classification includes more than 750 ecological systems for all of Latin America and the Caribbean. In comparison, ecoregions cover much coarser scales, with 189 terrestrial ecoregions (as defined by the World Wildlife Fund) in Latin America.

When the project began, several vegetation maps already existed for portions of the Andes-Amazon region. However, each was developed using a different classification with varying detail and quality. This uneven coverage precluded consistent analysis across jurisdictions. A major outcome of our work is the production of a single, unified classification and a detailed vegetation map covering the entire project area.

Contributing Partners

- NatureServe
- Centro de Datos para la Conservación, Universidad Nacional Agraria La Molina, Peru
- Instituto de Investigaciones de la Amazonía Peruana (IIAP), Peru
- Gonzalo Navarro and Wanderley Ferreira, Bolivia

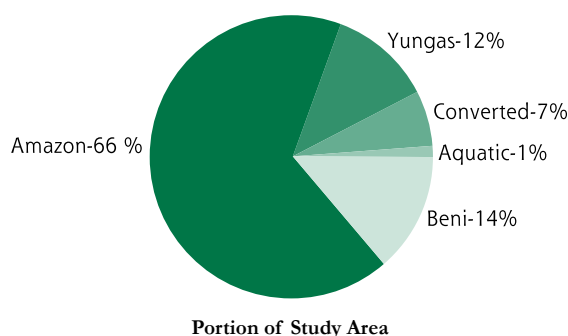
Results

The map covers upland and wetland ecological systems across most of the Amazon watershed in Peru and Bolivia. We identified and mapped a total of 84 distinct ecological systems using the NatureServe classification system. Twenty technicians from three institutions participated in field surveys and map production. They sampled 1,940 field plots and collected 15,000 herbarium specimens.

Although the Yungas only represents 12% of the study area, 37 ecological systems were identified there. In the Amazon region, 66% of the study area, 32 ecological systems were found. In the Beni region, 13 ecological systems representative of the area were identified, as well as Amazonian systems such as floodplain and riparian systems.

Country	% of national territory	Region	Area (km ²)
Peru	62	Yungas	127,112
		Amazon	667,600
Bolivia	42	Yungas	51,237
		Amazon	214,041
		Beni	189,292

Regions of Bolivia and Peru covered by the study area.



What is an Ecological System?

Ecological system: *A group of plant communities that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients.*

The plant communities are based on existing vegetation, and therefore we classify existing ecosystems, not potential systems. Ecological processes include natural disturbances such as fire and flooding. Substrates may include a variety of soil surface and bedrock features, such as soil depth, makeup, and acidity. Finally, environmental gradients include local climates, hydrologically defined patterns in flood plains and savannas or desert areas, or life zones in mountainous areas.

Ecological systems classification and mapping is useful for:

- Evaluating ecosystem conditions and trends over time.
- Mapping ecosystem services, such as carbon storage and watershed conditions.
- Effective, multi-site conservation planning and action across large regions.

Local and Regional Collaboration: Land Use Planning in San Martin, Peru

Goals

- Work with a local government to incorporate biodiversity values into local planning processes.
- Build local capacity through conservation planning assistance and training in NatureServe Vista decision-support software.
- In cooperation with local officials, develop analytical methods and tools that include existing ecological and economic zoning data to recommend land use solutions that balance protection of the environment with sustaining local communities in San Martin.
- Demonstrate the feasibility of this approach through a pilot project that can serve as a model for other parts of the Andes-Amazon basin.



Scenes from San Martin, Peru.

The regional government in the department of San Martin, Peru, is developing a land use master plan to guide economic development and resource conservation. This department, located in the Andean foothill transition to the Amazon, harbors rich biodiversity and includes important protected areas, such as Rio Abiseo and Cordillera Azul. In recent decades, San Martin has experienced significant growth in population and agricultural activity. Because of this, there is increasing pressure on existing



Market in Moyobamba, Peru.

protected areas, and growing interest in identifying effective options for conserving the region's natural values.

Several key local partners collaborated with NatureServe on the project. The Instituto de Investigaciones de la Amazonía Peruana (IIAP) provided technical assistance in land use planning to San Martin and other Peruvian departments in the Amazon Basin. The Proyecto Especial del Alto Mayo (PEAM), a local public/private partnership, focused on land use issues in the northernmost Alto Mayo River watershed in the department. The San Martin regional government has taken the lead in regional land use planning just as the national process of decentralization is placing more responsibility for managing natural resources on local governments.

Using the decision-support software NatureServe Vista, we combined conservation information, such as terrestrial ecosystem types and plant and animal species of concern, and compared those with current data and projected land use for agriculture, highways, electric lines, forestry and fishing. This way, we created new regional scenarios with different levels of biodiversity and land use representation that helped identify a sustainable and efficient land planning strategy.



Left: San Martin. Road from Moyobamba to Rioja. Right: NatureServe and IIAP scientists in white-sand forests in Iquitos, Peru.

Specific analyses to support the regional master planning process include:

- A gap analysis documenting how well existing protected lands represent the region's biodiversity features, and the most significant conservation gaps in the current protected area network.
- An impact analysis that identified potential impacts to biodiversity along planned highway corridors and intensive agricultural zones, with analysis of potential mitigation scenarios.
- An analysis of various regional land use scenarios, with six options analyzed, each with differing levels of emphasis on conservation and economic development.

These analyses were completed and demonstrated for regional officials in March 2007. We continue to work with key partners in San Martin and other local governments to advance the application of these methods and data.



Where are the Gaps?

Analysis of Protected Areas

Our study has demonstrated that the eastern slope of the Andes and the adjacent Amazon basin support exceptional numbers of endemic species and an impressive array of ecological systems. How well are these species and habitat types currently protected, and what are their prospects for the future?

To answer these questions, we began by mapping existing and proposed national-level protected areas in these portions of Peru and Bolivia. The project area includes 42 distinct protected areas (designated or proposed), which collectively cover about 12% of the entire region. National parks comprise 7.5% of the total; managed natural habitats are 3%, and proposed conservation areas are 1.5%.

Endemic Species in Protected Areas

Next, we compared how well the locations of these protected areas overlap with the areas of greatest endemism, based on the predicted distributions of the 782 endemic species. Some existing protected areas, such as Bolivia's Madidi National Park, do encompass substantial areas that are critical to endemic species. However, important concentrations of endemism still fall completely outside of protected areas. These are the places that represent the best opportunities for biodiversity conservation.

Only 7% of the 115 endemic bird species analyzed seem fairly secure, meaning that at least half of their predicted distribution overlaps with protected areas. Eight unfortunate endemic birds have no formally protected habitat at all. The distributions of endemic mammals show a similar pattern.

The story is significantly worse for amphibians and plants. Of the 177 endemic amphibians, a fair number (18%) have at least half of their predicted distribution within protected areas, but a sobering 41% have zero protected habitat. Among the 435 endemic plants, only 8% meet the half-of-distribution threshold, while 35% have no protected habitat at all. In all, 238 out of the 782 endemic species analyzed have no protected habitat at the national level.

Ecological Systems in Protected Areas

We continued by analyzing the representation of terrestrial ecological systems within protected areas. We grouped the 84 ecological systems found in the project area into 14 major habitats, such as Amazonian Moist Forests and Andean Grassland and Shrubland. Representation of these habitats within the protected areas varies widely (see table). For the typical habitat, about 16% of its area lies within protected areas. The Andean Azonal Vegetation, Andean Moist Forests, and Amazonian Moist Forests are all well-represented.

At the other extreme, Beni Seasonally Saturated Vegetation appears to be virtually unrepresented within existing protected areas. In general, the savannas of the Beni district in northeastern Bolivia occur almost entirely outside of national protected areas, suggesting that wildlife dependent on these wetlands are also vulnerable to land use changes. Considering the uniqueness of the region, with its intricate blend of forest and grassland systems, this result highlights an important future focus for conservationists.

Two types of dry forest, Chiquitano Dry Forests and Andean Dry Forests, also lack adequate protection, with several ecological systems within this group completely unrepresented from existing protected areas. Chiquitano Dry Forests might be protected elsewhere, but Andean dry forest system is known for harboring several endemic plant species, including many microendemic cacti. During the field work performed for map validation, researchers collected specimens of two undescribed tree species from dry valleys included in this complex.

Ecological System Group	Portion (in the study area) located within protected areas
Andean moist forests	30%
Amazonian moist forests	25%
Andean dry forests and xeric scrub	12%
Chiquitano dry forests	0%
Andean azonal vegetation	54%
Amazonian azonal vegetation	20%
Andean grassland and shrubland	19%
Amazonian white water floodplain forests	12%
Amazonian black water floodplain forests	16%
Amazonian clear water floodplain forests	20%
Amazonian black or white water flooded vegetation	7%
Beni seasonally saturated vegetation	0.1%
Beni seasonally flooded vegetation	5%
Beni permanently flooded vegetation	5%

Threats to Protected Areas

The final piece of the analysis considered threats to protected areas due to land conversion and resource exploitation. We developed a model depicting current land uses and potential future land uses in the region, along with the zones where these uses are likely to impact biodiversity. The results were somewhat welcoming news: half of the protected areas face relatively low or very low levels of threat from land use change or resource exploitation, and these parks comprise about 85% of the total protected areas coverage. However, some 14 protected areas were documented as being highly or very highly threatened.

Capacity Building

An important outcome of the project was effective capacity-building among local partners. We held a total of 24 workshops, meetings, and symposia in Peru and Bolivia, with more than 1200 participants representing over 50 institutions. Extensive training was carried out for scientists, technicians, and officials from local and regional governments, non-governmental organizations, and universities. Training was conducted in specialties including field surveys, modeling of species distributions and patterns of endemism, biodiversity analyses, data management, ecological systems classification, conservation planning, and use of conservation planning software tools.

We installed and provided training in Biotics software, a biodiversity data management system, at the Centro de Biodiversidad y Genética at the Universidad Mayor de San Simón in Cochabamba, Bolivia. This software will be used by the staff to manage the institution's data on species and habitats, and will facilitate sharing of knowledge with dozens of North American institutions that use the same system. We also installed NatureServe Vista software at the San Martin regional government and provided training in its use. We provided training in digitizing and georeferencing specimen locality data and provided computers and support for staff time at six local herbaria and natural history collections.



Representatives of IIAP, San Martin Regional Government, Proyecto Especial Alto Mayo, GTZ, CIMA, and NatureServe at a workshop held in Moyobamba, San Martin, Peru, in July, 2006.

We presented the results of the project in two technical publications: *Endemic Species Distributions on the Eastern Slope of the Andes in Peru and Bolivia* and *Ecological Systems of the Amazon Basin of Peru and Bolivia: Classification and Mapping*. We distributed these reports to over 400 partners and attendees of four symposiums held in Lima and Cusco, Peru, and La Paz and Santa Cruz, Bolivia, in March 2007. For more information about the results and available online data, visit our website at www.natureserve.org/AndesAmazon.

