Urubamba: The Biodiversity of a Peruvian Rainforest

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Preface

As the world's human population rapidly grows, we continue to explore for new energy sources, habitable space, agricultural lands and fresh water. Few areas of the planet remain unexplored and intact, untouched by human activity and with their full complement of biodiversity.

This book is about such a place — the remote Lower Urubamba River Valley of southeastern Peru. Set deep in the Amazon rainforest, this region is one of the most species rich and biologically diverse enclaves on Earth. Lush tropical plants, an amazing variety of beetles, brightly colored tree frogs, raucous macaws, chattering spider monkeys and stalking jaguars are among the thousands of species that call this rainforest their home.

They share living space with a few thousand Native people, primarily Machiguenga — most of whom reside in small communities scattered throughout the region. For millennia, these people and their ancestors have lived in harmony with their environment, and they know many of the rainforest's secrets.

In 1996, a team of scientists from the Smithsonian Institution was offered a chance to investigate the wonders of the Lower Urubamba River Valley. Shell Prospecting and Development (Peru) B.V. had initiated a project for potential development of a large natural gas reservoir in the region. The company requested our help to develop the gas and condensate resources in the most environmentally sound manner possible.

We accepted the challenge together with our national and international counterparts and thus began a remarkable partnership — remarkable because it is not often that developers and conservation biologists work side by side, integrating biological science with resource development. We saw an opportunity to do it right.

In this book, we present the findings of our research. The book is meant for readers who are interested in learning more about life forms in the Lower Urubamba region and how they interact. We have also published a children's book based on our experiences and findings and a series of three reports that contain more detailed descriptions of the methodologies we used to document the amazing variety of life in this part of the world. All are available from the Smithsonian Institution/ Monitoring and Assessment of Biodiversity Program.

We thank the Royal Dutch/Shell Group of Companies for underwriting this book and especially Phil Watts, Chairman of the Committee of Managing Directors, and Mark Moody-Stuart, former Chairman, for their support of the overall project. We are grateful to our many colleagues at the Smithsonian and collaborators from the Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos, Universidad Nacional San Antonio Abad del Cusco and the Universidad Nacional de Trujillo. Without their dedication and hard work, the project would not have been possible. We also express special thanks to Alan Dabbs, Victor Grande, Lupe Guinand, Alan Hunt, Murray Jones, Sachin Kapila, Mary Malca, Miguel Ruiz, Jose Santisteban, Richard Sikes, Shana Udvardy, Gert VanderHorst, Patricia Zavala, the anonymous reviewers and many others who made this project a success.

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The Lower Urubamba Region, Peru

Alfonso Alonso, Francisco Dallmeier, Patrick Campbell and Ruth Nogueron

1 Introduction

During the nineteenth and early twentieth centuries, adventuresome naturalists such as Charles Darwin and Alfred Russel Wallace traveled the globe to describe this planet's diverse ecosystems, its flora and its fauna. Every day brought the discovery of new species, new peoples and greater understanding.

While today's biologists long for the journeys of the past, few frontiers remain. Humans have penetrated the most remote places on Earth, cities exist even in the most arid deserts and entrepreneurs exploit resources in the deepest jungles. Still until only a short time ago, the Lower Urubamba Region (LUR) in southeastern Peru remained hidden and unknown — an undisturbed treasure chest of potential surprises.

We first set out to explore the forests of the LUR in 1996 — a team of modern-day explorers under the auspices of the Smithsonian Institution seeking to unlock the secrets of the region. No information describing the LUR's biodiversity existed, and our anticipation was high. The forests of Amazonian Peru in places like Manu National Park and Iquitos had revealed such amazing biodiversity that researchers concluded those forests are among the most biologically rich areas on Earth. There was no reason to expect less from the LUR.

Despite the region's isolation, southeastern Peru faced many threats, including deforestation, expansion of the agrarian frontier, overgrazing and soil erosion, unsustainable timber extraction and pollution of water, air and soils (World Resources Institute 2000). In the LUR during the 1970s and 1980s, exploration for energy sources uncovered a huge reservoir of natural gas and condensates (Brack and Yáñez 1997). In 1996, Shell Prospecting and Development Peru (SPDP) signed an agreement with Perupetro S.A. to evaluate the potential of the natural gas deposits in the LUR (Zarzar 1998). It became imperative to assess the biodiversity of this wilderness before development was fully under way.

The Smithsonian Institution joined SPDP in a cooperative effort to achieve environmentally sensitive development of the gas and condensate resources in the LUR (Dallmeier and Alonso 1997). This initiative involved scientists and personnel from the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB), the Museo de Historia Natural of the Universidad Nacional Mayor de San Marcos, the Universidad San Antonio Abad del Cusco, the Universidad Nacional de la Libertad in Trujillo, the Universidad Nacional Agraria "La Molina," the Universidad Peruana Cayetano Heredia and the Universidad San Agustin in Arequipa (Dallmeier and Alonso 1997; Alonso and Dallmeier 1998, 1999).

2 Study area

The forests of the LUR rise from the floor of the Amazon Basin to the foothills of the Andes Mountains. These "transitional forests" — as Prance (1989) called them because of their affinities with forests of the Amazon Basin, the Andes and the savannas to the south — are among the most biologically diverse forests in the world (Gentry 1988, 1990).

The LUR is located in the Department of Cusco, east of the Andes Mountains at 12º south latitude and 72º west longitude. The area derives its name from the Lower Urubamba River, which is the primary drainage

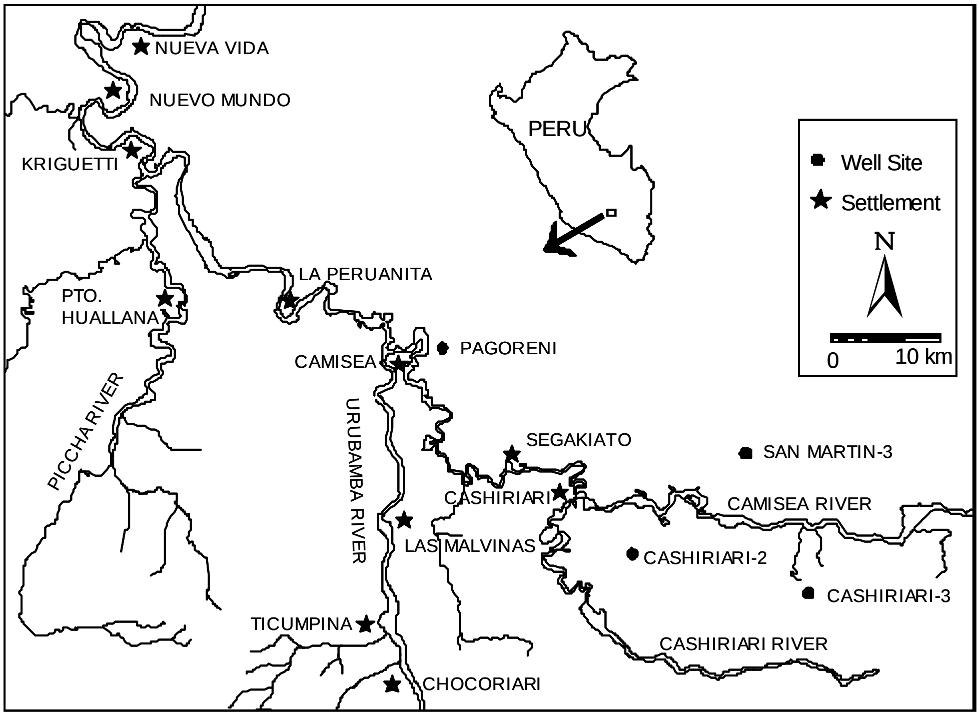

Figure 1. Map of the Lower Urubamba Region, Peru, showing the locations of the well-sites, sampling sites and local communities.

in the region. The Urubamba begins high in the Andes near the town of Cuzco, where locals refer to it as the Upper Urubamba River, and flows north past the vistas and ruins of Machu Picchu before plunging down the Andes towards the Amazon Basin in a series of spectacular and perilous waterfalls. In the Andean foothills, the river adopts a more leisurely pace in its meanderings through the Urubamba River Valley, where it is known as the Lower Urubamba River. The Camisea and Cashiriari rivers soon converge with the Lower Urubamba, which continues north into the Ucayali River, a major tributary of the Amazon River.

The Vilcabamba Mountains to the west and the Urubamba Mountains to the east form the borders of the LUR. The river valley is nestled between Manu National Park, a Global Biosphere Reserve, and the Apurimac Reserve Zone (Alonso *et al.* 2001). The rugged terrain, steep hills and tangled mass of vegetation make access difficult and travel slow, and it is likely that the precipitous landscape affects the characteristics of the forest by promoting landslides and tree falls, which create diverse vertical stratification. Elevation gradients, ranging from 500 meters (m) to 1,000 m, also impact the region's biodiversity by attracting both lowland and highland species to the valley.

The LUR covers approximately 600 square kilometers, or 60,000 hectares, of forested land. In our study, we focused on sites in the forests surrounding four natural gas well sites — San Martin-3 (Sanm-3), Cashiriari-2 (Cash-2), Cashiriari-3 (Cash-3) and Pagoreni (Pag) — and six sites along the rivers — Segakiato-1 (Sega-1), Segakiato-2 (Sega-2), Shivankoreni-1 (Shiv-1), Shivankoreni-2 (Shiv-2), Las Malvinas (Lasm) and La Peruanita (Perua). Centers of logistical operations were located at Nuevo Mundo (Figure 1).

2.1 Geomorphology

The LUR includes three distinctive landscapes, or physiographic units. The alluvial landscape originated from deposition of sediments from the erosive actions of the Camisea and Cashiriari rivers and their tributaries.

It occurs only along the three main rivers; abrupt escarpments bordering the rivers typically limit its extent. The hill landscape dominates the region, stretching across 70% of the study area. Sandy sediments, luthite and clay from the Tertiary form the basis of this landscape. The steep sloping hills originated from tectonic and orogenic events and were shaped by erosive processes. The mountainous landscape, which is concentrated in the southern portion of the LUR and was formed by tectonic process dating from the Jurassic and Cretaceous periods, comprises about 20% of the total study area.

2.2 Geology

The LUR contains one of the largest natural gas reservoirs discovered in South America. They are located within a Cretaceous, gas-bearing vertical sequence of folded and compressed, elongated, steep anticlines. The steepness is associated with major thrust faults. The Sanm-3 and Cash-2 well sites are both located in anticlines separated by the Camisea syncline. From seismic data, it is apparent that substantial horizontal movements are associated with the main thrust fronts. There is also evidence of minor thrust faulting in a parallel direction to the main thrust trends, but no conclusive evidence of cross faulting. Dip and thrust fault closure allowed for the accumulation of the gas reserves.

2.3 Soil

Two primary soil types — the Entisols (recent) and Ultisols (ultimate) — are found in the study area. Entisols, the minor group, occur only on the alluvial benches. They are typically young, sandy and yellowish with minimal epipedon development. Ultisols dominate the remainder of the area. They are usually deep red or yellow, with low native fertility and poor physical properties. Accumulations of humified organic matter in the surface layer are always present, but minimally so, throughout the study area (Table 1).

2.4 Water

An intricate web of small streams crisscrosses the LUR. These streams flow quickly down the steep slopes, and pools of standing water are uncommon. The larger rivers are of the white-water variety. They are rich in silt, sediment and minerals, but low in nutrients and organic matter. These rivers form depositional areas and may be straight, meandering or braided depending on the topography. The Urubamba River has a distinct flood plain, and flooding is common at the height of the rainy season although the water recedes within several days, unlike the black waters of the Amazon when they flood. The Camisea and Cashiriari rivers have poorly developed floodplains.

Local peoples tap the water table for household use, and therefore pollution is a concern. Researchers sampled water quality at various sites in the study area during work on the Environmental Impact Assessment for the gas wells (Environmental Resource Management 1996). The results showed that river temperatures averaged 21.2º C (standard deviation of 0.3º C) at depths ranging from about 0.3 m to 2.0 m. The pH of the creeks, wells and rivers averaged 7.7, and the waters were free of petroleum

Table 1. Lithostatigraphy of the Study Area.

Formation	Constituent rock
Lower red bed	Cap rock/clay stone/shale
Upper and Lower Vivian	Sandstone (gas bearing; Cashiriari only)
Upper Chonta	Clay stone/shale/some limestone
Lower Chonta	Sandstone/intercalated clay stone/shale (gas bearing)
Basal Lower Chonga	Mainly sandstone
Upper and Lower Agua Caliente	Sandstone (gas bearing)
Esperanza	Clay stone/shale/some limestone
Upper and Lower Cushabatay	Sandstone (gas bearing)
Ene and Copacabana	Limestone (gas bearing)

hydrocarbon and detectable levels of trace minerals such as barium, cadmium, chromium, mercury and lead. Overall, the sampling indicated excellent water-quality conditions in the study area, based on national and international water-quality standards.

2.5 Climate and temperature

Below 1000 m, the climate is typically warm and humid with a distinct seasonality. The LUR experiences a wet season from October through April and a dry season from May through September. Annual rainfall ranges between 3,000 and 3,500 millimeters (mm). January is the wettest month, with rainfall typically exceeding one m. Monthly rainfall totals then decline to a low point — typically less than 100 mm — in June. Mean temperature remains constant throughout the year at about 27º C. Relative humidity is high, typically exceeding 80% all year.

2.6 Flora and fauna

Prior to this project, there were no formal biological surveys in the LUR. Biologists knew that the forests of western Amazonia were among the most species rich in the world, and we soon discovered that the LUR was no exception. Over a two-year period, we assessed the biodiversity of the vegetation, aquatic systems, invertebrates, amphibians, reptiles, birds and mammals. We recorded 747 species of trees from 78 families in 11 one-ha plots, more than 150 species of mammals, 75 species of amphibians, 83 species of reptiles, 156 species of fish and 420 species of birds in addition to hundreds of species of invertebrate, including a record 121 species of ants. The biologists who contributed to the project discuss this fabulous wealth of biodiversity throughout this volume.

What makes this region so diverse? Haffer (1969) believed that during the Pleistocene, climatic conditions in the Amazon Basin changed and caused the forest to retreat into isolated remnants surrounded by savannas. These forest refuges served as incubators for pockets of endemism, accounting for some of the observed biodiversity in the Amazon. Additional evidence shows that Pleistocene climate changes did influence the flora (Prance 1987) and fauna (Haffer 1987) of western Amazonia. However, there are many factors — geographic, evolutionary and geologic — as well as climate that produced this diversity. Fine-scale habitat heterogeneity and intermediate levels of natural disturbance, like that seen in the LUR, created many niches, which in turn led to higher diversity of organisms (Connell 1978, Fox 1979, August 1983, Brown 1987). The temporal stability of primary production and asynchronous peaks of fruiting and masting provided a year-round food supply for frugivorous species (Janson and Emmons 1990, Voss and Emmons 1996). In addition, the location of the LUR in southwestern Amazonia allowed for influence from the flora and fauna of the Amazon Basin, the Andes Mountains and the savannas of Bolivia. Ultimately, some combination of these factors created the amazingly rich forests we see in the Lower Urubamba Region today.

Comiskey *et al.* (this volume) describe the forests of the LUR as primary, lowland, non-flooded, tropical rainforest. The forest canopy is low, typically less than 30 m, and nearly impenetrable thickets of bamboo dominate the understory in areas. Although the area is considered primary forest, some disturbance (mainly natural) plays a large role in the structure and composition of the communities. Tree-fall gaps caused by landslides are common and create a somewhat broken canopy. Human disturbance, mainly from small-scale agriculture and selective tree harvesting, is minimal except in locations along the rivers. The fauna of the area has great ecological value and is of economic and subsistence importance to indigenous communities that depend on aquatic and terrestrial wildlife for food, clothing and ornamentation. There is also a substantial cash value for the pelts of many animals. Hunting has placed game species in danger of extinction in parts of Peruvian Amazonia (Redford 1993, Bodmer *et al.* 1997), but this does not yet appear to be an issue in the LUR.

3 Settlements and culture

The LUR is home to 44 indigenous communities — including Nuevo Mundo, Kirigueti, Camisea, Shivankoreni, Segakiato and Cashiriari — and several colonial settlements along the Urubamba River. Camisea, Shivankoreni, Segakiato and Cashiriari are nearest to the well sites. These four villages were established after 1958, and their combined population is just under 1,000 inhabitants. Semi-nomadic groups, consisting of approximately 270 people, also inhabit the area (Zarzar 1998).

Most of the people in the settled communities belong to the Machiguenga ethnic group, while the semi-nomadic families are of Nahua, Yora or Kugapakori descent (Zarzar 1998). The modern Machiguenga, from the Arahuaca linguistic family (Brack and Yáñez 1997), claim an ancestry in the central and southern Peruvian Amazon that dates back 5,000 years (Zarzar 1998).

During the peak of the Inca Empire, the Machiguenga were widely recognized as the “middlemen” between the Amazon and Andean people because of their role in the trade of goods. With the arrival of the Spaniards, some Arahuaca forest communities learned to forge iron and became more independent from western markets. By the end of the seventeenth century and after several wars, the Arahuacas closed their borders to outsiders for 30 years (Zarzar 1998).

In 1742, the most important multi-ethnic, messianic uprising in the history of Peruvian Amazonia closed off all contact with the Spaniards for 100 years. But by the middle of the nineteenth century, increased colonization and a boom in demand for sarsaparilla, quinine bark and rubber forced an end to isolationist policies. Soon, control of the Ucayali-Urubamba region fell into the hands of a rubber baron and explorer, who established a monopoly for a short period until 1896. Between 1880 and 1920, in what has been called the rubber boom period, the native peoples of the Urubamba region suffered many abuses. Europeans exploited natural resources in the region beyond sustainable capacities and introduced a number of diseases such as malaria and chicken pox that brought about the death of many natives (Brack and Yáñez 1997).

In 1918, Dominican missionaries founded the mission of Timpia in the LUR and later started a program of formal school education for native people. After 1940, Andean peasants began to settle in the Upper Urubamba and soon descended the mountains to the Lower Urubamba. In 1950, the Summer Institute of Linguistics began evangelization and school education in the LUR (Zarzar 1998).

Today, the Peruvian Laws of Native Communities (N. 22175 of 1974 and 1978) organize the Machiguenga communities into two legal entities. The General Assembly is a democratic entity, formed by all members of each community. The Directive Board, which is responsible for the government and administration of the community, is an elected body consisting of several officials. This type of organization has become a very effective decision-making tool for it seeks approval by all members of the community on important decisions. It also promotes inter-community relations (Zarzar 1998).

Beyond the locally based community organizations, Machiguenga communities are aggregated into two federations (CECONAMA and COMARU) to represent their broader interests (Zarzar 1998). These institutions allow the Machiguenga to govern events that occur on their lands.

3.1 Machiguenga and their environment

The Machiguenga depend on the forest for their livelihood and subsistence. Subsistence and commerce both rely on a combination of agriculture, gathering, hunting, fishing and extraction of forest products, but for the Machiguenga, these activities are primarily limited to subsistence because the communities have not yet developed a regular system of commerce (Zarzar 1998). What income the families derive from the forests stems from the sale of agricultural products to occasional traders, the periodic sale of wood (a communal activity in which the proceeds are normally divided among the community on an equal basis) and temporary labor to estates and petroleum companies.

The Machiguenga practice agriculture on small farms along the rivers and streams and close to permanent dwellings, and each family is likely to have multiple plots. Slash-and-burn is the most common form of clearing the land for agriculture. Cultivated crops include plantains, pineapple, peanuts, sugar cane, legumes, maize and root vegetables as well as some market crops such as cocoa, spices, achiote, rice, beans and coffee (Zarzar 1998). The villagers also practice selective logging, primarily for local building materials and canoes.

Hunting and fishing supplement the agricultural crops. Traditionally, men hunt with bows and arrows, although the use of shotguns is increasing. Game species include wild pigs, tapir, armadillo, deer, monkeys, wild fowl and fish. Surplus fish are salted, dried and exchanged with other households or traded with outsiders (Zarzar 1998). The Machiguenga also gather many non-timber forest products such as palm fronds for roofing, vines for ropes and several kinds of leaves and canes for handcrafts (Zarzar 1998). In addition, the Machiguenga use more than 300 species for medicinal and other health-related purposes (Shepard 1997).

The Machiguenga communities inside the study area have legal rights to their land, except for the Montetoni located in the Nahua-Kugapakori Reserve. The land titles specify information on different land uses and capabilities (crop cultivation, cattle raising, forestry and forest protection). Communal ownership is only applicable to lands suitable for agriculture and raising cattle. Ownership is nontransferable except that forestlands and forested edges are subject to free transit via existing bridges, railways or forest paths. Also, the areas are subject to free passage of oil pipelines, gas pipelines and other installations for the exploration and exploitation of minerals and petroleum.

4 Conclusion

The Lower Urubamba Region is important not only for its proven richness in wildlife and culture, but also in the natural resources and ecosystem services it provides. While many neotropical forests experience negative impacts from agriculture, logging, hunting and development for petroleum products, to date the LUR remains an intact wilderness with abundant biodiversity and an excellent chance for survival if economic development proceeds in an appropriate, informed manner.

The results of the study, described in the following chapters, provided much needed information on the biodiversity of the Lower Urubamba Region and led to important decisions regarding development in sensitive areas. These decisions ensured that the biological integrity of the region would remain intact and that indigenous concerns would be met while assuring the economic viability of the project.

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The Vegetation Communities of the Lower Urubamba Region, Peru

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1 Introduction

The Amazonian forests, extending from southern Peru to northern Bolivia along the foothills of the eastern Andes, are among the most species-rich areas in the world (Gentry 1988, 1990; Foster 1990; Gentry and Terborgh 1990; Foster *et al*. 1994; Wilson and Sandoval 1996). Prance (1989) describes these forests as "transitional" because of their affinities with the flora and fauna of the Amazon Basin to the east, the Andes Mountains to the west and the great South American savannas to the south.

The Lower Urubamba Region (LUR) in southeastern Peru, part of the larger extent of Amazonian forests, is a tropical wilderness with little evidence of human impacts, primarily because of its inaccessibility. Nevertheless, like many other relatively untouched regions, resource development is becoming an issue in the LUR. Therefore, assessing the biodiversity of this region, where very few studies of species have been conducted, is of utmost importance to prevent loss of species and increase understanding of how these forests function and the effects of human encroachment on them.

In 1996, Shell Prospecting and Development Peru (SPDP) reestablished a natural gas exploration project in the LUR. SPDP planned to drill four well sites and construct flow lines, a gas plant and a pipeline. The Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) entered into a cooperative venture with SPDP to integrate science and conservation with exploration and development of natural gas resources. Together, SI/MAB and SPDP conducted the first ever biodiversity assessment of the Lower Urubamba forests and created a plan for wise development (Alonso and Dallmeier 1999).

We focused on vegetation in the LUR with the following objectives: (1) describe the structure and composition of vegetation in selected habitat types, (2) determine the important tree species in each habitat type and (3) compare the structure and composition of the flora among habitat types.

2 Study area

The study area (approximately 20 x 30 kilometers in size) is located east of the Andes Mountains between Manu National Park and the Apurimac Reserve Zone in the Lower Urubamba River Valley of the Ucayali watershed, southeastern Peru (Figure 1).

Temperatures are quite stable across the study region, varying annually from about 23.5°C to 24.5°C. Relative humidity typically exceeds 80%. Rainfall averages between 3,000 and 3,500 millimeters per year and occurs mostly in the wet season, October through April; December is the rainiest month (Dallmeier and Alonso 1997).

Topographic variation is extreme, with hills rising sharply from the lower river valleys and slopes reaching 75 degrees. The rugged terrain makes access difficult and affects the vegetation by promoting landslides and tree falls.

Indigenous groups, mostly Machiguenga, live in small communities throughout the region, and there are

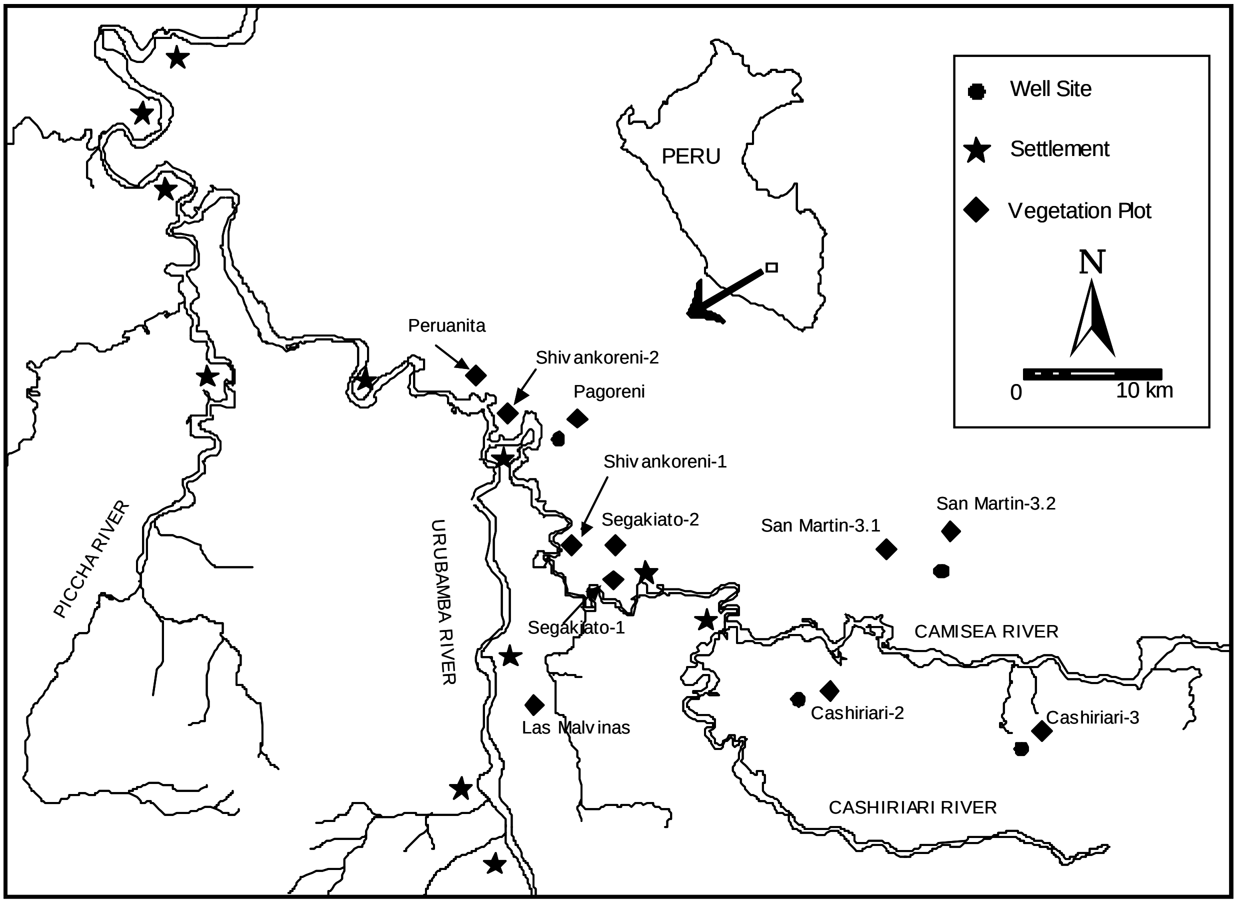

Figure 1. Location of the biodiversity plots in the Lower Urubamba Region, Peru.

a few colonist settlements along the Urubamba River. The four communities closest to the survey sites were established after 1958 and have a combined population of about 1,000 people (Dallmeier and Alonso 1997).

3 Methods

We established 11 one-hectare (ha) biodiversity monitoring plots following SI/MAB protocols (Dallmeier 1992, Dallmeier and Comiskey 1996) to provide species accounts and descriptions of forest structure and to act as a reference for assessments of other taxa. Because a primary objective of the study was to monitor the effects of the gas drilling operation on biodiversity, we established five of the study sites in the forest habitats surrounding each of the well sites. We established six other study sites along the Camisea and Urubamba rivers because SPDP planned to construct a gas processing plant and pipelines along those rivers.

Table 1 summarizes the locations and characteristics of each assessment site (see Dallmeier and Alonso 1997 and Alonso and Dallmeier 1998, 1999). The site names are Cashiriari-2 (Cash-2), Cashiriari-3 (Cash-3), San Martin-3.1 (Sanm-3.1), San Martin-3.2 (Sanm-3.2), Las Malvinas (Lasm), Segakiato-1 (Sega-1), Segakiato-2 (Sega-2), Shivankoreni-1 (Shiv-1), Shivankoreni-2 (Shiv-2), Peruanita (Perua) and Pagoreni (Pag).

All of the study sites are located in non-flooded forest with minimal to no human disturbance. Small-scale agriculture is apparent around some of the riverine sites, and there is evidence of small-scale selective tree harvesting in others.

3.1 Establishing the plots

SI/MAB’s protocols for establishing biodiversity plots are currently being used at more than 300 plots in 23 countries. The protocols allow for consistent documentation and publication of field results and monitoring procedures. The methodology is comparable to other permanent plot studies (for example, Balslev *et al.* 1987, Alder and Synnott 1992).

We selected the monitoring sites based on the following criteria: (1) the area should contain species representative of the habitat type, (2) the common or dominant species should be represented and (3) the plot must be located within one habitat type to give a true representation of the area’s diversity. Botanists selected sites using cartographic information, remote sensing photographs and field verification to identify different habitat types. At each site, survey teams delineated a one-ha plot (100 meters [m] x 100 m in a horizontal plane) and divided it into 25 quadrats, each 20 m by 20 m (400 m^2).

3.2 Field measurements

After we delineated the quadrats, we located, measured, marked and mapped all trees with a diameter at breast height (dbh) ≥ centimeters (cm) at the five study sites near the wells (Sanm-3.1, Sanm-3.2, Cash-2, Cash-3 and Pag) and ≥ 10 cm dbh at the six remaining sites (Lasm, Sega-1, Sega-2, Shiv-1, Shiv-2 and Perua).

For the sites where bamboo was common, we treated each bamboo culm as one individual because in many cases we could not distinguish which culms belonged to which plants. The large abundance of bamboo culms also made it difficult to measure the dbh of all individuals. Instead, we measured the dbh of individuals from a randomly selected sample of 30 culms and assigned the resulting mean dbh of 0.07 m to all bamboo culms. We used clinometers to measure tree heights, recording to the nearest 0.5 m.

Species were identified following the *Catalogue of the Flowering Plants* and *Gymnosperms of Peru* (Brako and Zarucchi 1993). Botanists identified morphospecies in the field and gathered samples for each morphospecies for further verification in the herbarium. To date, 70% of the 747 species encountered in the study have been identified to species that represents 85% of all trees in our data set.

3.3 Data analysis

We used species abundance data in a detrended correspondence analysis (Hill and Gauch 1980) to group sites based on similarity of species composition.

Table 1. Locations and descriptions for the biodiversity monitoring plots in the Lower Urubamba Region, Peru.

Site	Site Code	Location Latitude/Longitude degrees / minutes / seconds	Elevation (m)	Terrain	Type of Human Disturbance
Cashirirari-3	Cash-3	11/51/51/S, 72/46/45/W	579	steep sloping hills	none
Cashiriari-2	Cash-2	11/51/51/S, 72/46/45/W	469	steep sloping hills	none
Las Malvinas	Lasm	11/52/55/S, 72/55/84/W	480	flat plateau	agriculture
Pagoreni	Pag	11/47/09/S, 72/42/05/W	465	steep sloping hills	none
Peruanita	Perua	11/40/32/S, 72/59/32/W	350	flat plateau	none
San Martin-3.1	Sanm-3.1	11/47/09/S, 72/42/05/W	487	steep sloping hills	none
San Martin-3.2	Sanm-3.2	11/47/09/S, 72/42/05/W	487	steep sloping hills	none
Segakiato-1	Sega-1	11/48/18/S, 72/52/30/W	450	steep sloping hills	tree harvesting
Segakiato-2	Sega-2	11/47/09/S, 72/52/32/W	400	steep sloping hills	tree harvesting
Shivankoreni-1	Shiv-1	11/47/20/S, 72/55/07/W	400	steep sloping hills	agriculture
Shivankoreni-2	Shiv-2	11/41/28/S, 72/58/41/W	350	flat plateau	none

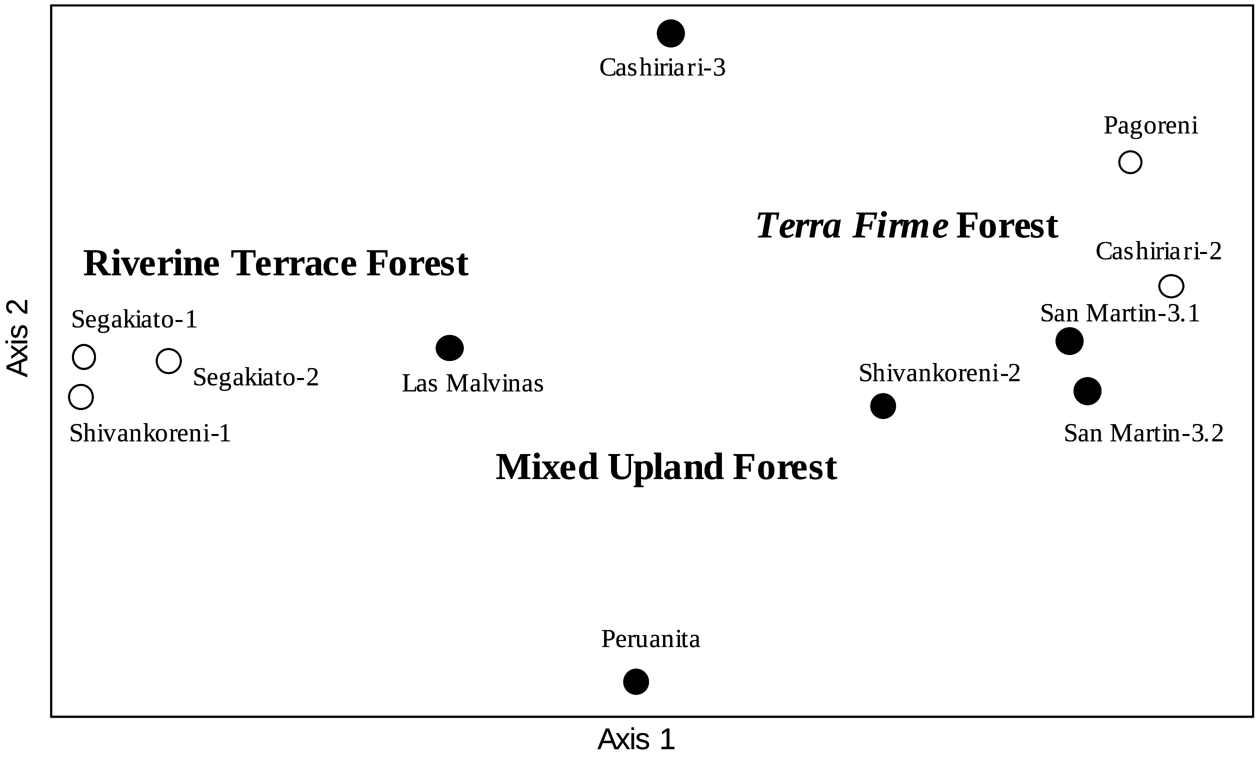

Figure 2. Results of the detrended correspondence analysis for trees ≥ 10 cm dbh in one-ha plots in the Lower Urubamba Region, Peru (Eigen values: axis 1 = 0.66, axis 2 = 0.22; filled circles represent sites with bamboo [*Guadua sarcocarpa*]).

Sites were described based on species importance values (SIV), calculated by adding the relative density (total individuals of a species/total number of individuals of all species) and relative basal area (total basal area of a species/total basal area of all species) of each species within each site. Species with the highest SIV were referred to as the most "important" at the site (Curtis and McIntosh 1951).

We calculated species diversity using Shannon's Index (Magurran 1988), including a measure of evenness (E) and Fisher's Alpha Index (Fisher *et al.* 1943). Both of these indexes provide more accurate estimates of diversity with a sample size of 2000 or fewer trees (Condit *et al.* 1998).

4 Results

4.1 Forest structure and composition

All results refer to trees ≥ 10 cm dbh unless otherwise stated. Table 2, Appendix 1and Appendix 2 summarize the structure and composition of the 11 biodiversity assessment sites in the LUR. Overall, we recorded 603 species representing 74 families and 272 genera among trees ≥ 10 cm dbh. There were 747 species in 78 families and 318 genera when trees ≥ 4 cm dbh were included.

The detrended correspondence analysis (Figure 2) suggests that the 11 assessment sites, all of which are non-flooded *terra firme* forest, can be classified as three habitat types that, for the purposes of this study, we have named as follows: *terra firme* forest, riverine terrace forest and mixed upland forest.

Typically, the top three most important species at each site represent a large proportion of the total number of individuals (10% to 54%) and the total basal area (16% to 59%), while most species are uncommon or rare. In fact, rarity is the norm throughout the study area where 252 species (42% of those recorded) occurred at only one site, just 70 species (12%) occurred in more than five sites and 171 species (28%) were represented by one individual. *Iriartea deltoidea* was the only species recorded at all 11 sites. Common to all sites was the prevalence of the family Leguminosae, the most speciose family. We recorded 90 species ≥ 10 cm dbh of this family among all sites, with a mean of 21.1 species per site.

4.2 Riverine terrace forest: Lasm, Sega-1, Sega-2 and Shiv-1

The most defining feature of this habitat was the overwhelming dominance of the Euphorb *Senefeldera inclinata*, which occurred only along riverine terrace forests and represented between 30% and 48% of the individuals counted in Sega-1, Sega-2 and Shiv-1. It was the most important species in terms of abundance and basal area at those three sites (Appendix 1), but it was less important at Lasm. No other species at any of the sites was as dominant.

Abundance of trees ≥ 10 cm dbh was greatest in the riverine terrace forests, and the total basal area was also generally high (Table 2). The number of species varied from 100 to 173, while family richness was low (Table 2). We recorded 319 species across all four sites, and 99 (31%) were unique to this habitat. Few tall trees were recorded; less than 5% of the trees stood taller than 30 m (Table 2). Other important species in the riverine terrace forests included *Cedrelinga catenaeformis*, *Pourouma minor* and *Tocoyena* sp. (Appendix 1).

Leguminosae was the most speciose family at all four riverine terrace forest sites. It was represented by a total of 48 species that ranged from 16 to 22 species per site. Euphorbiaceae had the highest relative abundance

Table 2. Summary results for 1-ha biodiversity monitoring plots in the Lower Urubamba Region Peru (results divided into two categories based on dbh ≥ 10 cm and ≥ 4 cm).

Site #	Habitat[a]	Number of individuals			# Species		# Families		Basal Area (m^2/ha)			% of individuals > 30 m tall
		>=10	>= 4	Bamboo	>=10	>=4	>=10	>=4	>=10	>= 4[b]	>= 4[c]	
San Martin-3.1	tf	481	1479	1325	138	258	42	65	22.16	30.46	25.35	17.9
San Martin-3.2	tf	412	1124	1512	126	227	44	58	19.06	27.39	21.57	13.8
Cashiriari-2	tf	592	1585	0	155	272	53	65	34.94	38.25	-	7.3
Pagoreni	tf	575	1399	0	185	307	48	59	27.77	30.53	-	5.7
Las Malvinas	rt	564	-	374	173	-	39	-	30.2	-	-	4.6
Segakiato-1	rt	715	-	0	111	-	32	-	28.04	-	-	4.8
Segakiato-2	rt	813	-	0	171	-	39	-	30.26	-	-	2
Shivankoreni-1	rt	640	-	0	100	-	28	-	33.96	-	-	1.9
Shivankoreni-2	mu	599	-	71	177	-	47	-	27.51	-	-	0.2
Peruanita	mu	616	-	418	168	-	44	-	21.4	-	-	0.3
Cashiriari-3	mu	564	1503	822	159	255	49	62	28.58	34.91	-	0.4

[a] tf = *terra firme*; rt = riverine terrace forest; mu = mixed upland forest

[b] includes bamboo

[c] does not include bamboo

(38% to 49%) at Sega-1, Sega-2 and Shiv-1, while Arecaceae accounted for 14% of the abundance at Lasm. Other relatively abundant families included Sapotaceae, Moraceae and Cecropiaceae.

Diversity varied among the four sites but was relatively low compared to the other habitats. Sega-1, Sega-2 and Shiv-1 had the lowest Shannon Index values of all sites, while Lasm had the second highest value (Table 3).

4.3 *Terra firme* forest habitat: Sanm-3.1, Sanm-3.2, Cash-2, Pag

The most definitive feature of the *terra firme* forests was the presence of the tall, arborescent palm *Iriartea deltoidea*, which dominated all four sites in both number of individuals and total basal area (Appendix 1). *Matisia cordata* was also important at all sites. Abundance of trees ≥ 10 cm dbh was lowest in the *terra firme* habitat, and total basal area ranged from the lowest recorded — Sanm-3.2 (19.02 m^2) — to the highest recorded at Cash-2 (34.94 m^2; Table 2).

Pag, with 185 species, had the largest number of species recorded at any of the sites. We found 370 species across all four sites, 152 (41%) of which were unique to the *terra firme* forests. Trees in the *terra firme* forests were taller than elsewhere. Sanm-3.1, where nearly 18% of all individuals were 30 m or taller, had the highest proportion of tall trees. Other important *terra firme* forest species included *Chimarrhis* sp. and *Pentagonia parvifolia* (Appendix 1).

Trees ≥ 4 cm dbh were also recorded at these sites. The results are listed in Table 2. On average there were between 100 and 120 additional species among this smaller size class.

Leguminosae was the most speciose family in all sites (18 to 21 species), except at Pag where Moraceae was the most speciose (22 species). The family Arecaceae accounted for the highest relative abundance (13% to 15%) at Sanm-3.1, Sanm-3.2 and Pag, while Leguminosae were the most abundant (12%) at Cash-2. Other families with high relative abundance were Moraceae, Bombacaceae, Rubiaceae and Meliaceae.

Diversity was higher than at the riverine terrace forests, but lower than at the mixed upland habitat (Table 3).

Table 3. Shannon Diversity Index and Fischer's alpha index for trees ≥ 10 cm dbh at 11 biodiversity monitoring plots, Lower Urubamba Region, Peru.

Site	Habitat type	Shannon's Index		Fischer's Index
		H`	E	
Cashiriari-2	*terra firme*	4.36	0.86	68.3
Pagoreni		4.51	0.86	94.5
San Martin-3.1		4.13	0.84	64.7
San Martin-3.2		4.11	0.85	61.9
Las Malvinas	riverine terrace forest	4.56	0.88	85.2
Segakiato-1		3.01	0.64	36.8
Segakiato-2		3.84	0.75	66.1
Shivankoreni-1		2.78	0.6	33.2
Cashiriari-3	mixed upland forest	4.48	0.88	73.7
Peruanita		4.65	0.91	76.1
Shivankoreni-2		4.65	0.9	84.8

4.4 Mixed upland forest habitat: Shiv-2, Perua, Cash-3

The mixed upland forests shared many species in common with the other habitat types. Of the 318 total species recorded at these sites, only 60 (19%) were unique to this habitat. The total number of trees, species, families and basal area were similar among the three sites (Table 2). The mixed upland forests had the lowest stature of all the sites. Individuals > 30 m tall represented less than 0.5% of the trees recorded (Table 2).

Unlike the other habitats, there was little overlap among the most important species at the three sites (Appendix 1). Important species in Shiv-2 included *Ficus amazonica* (only one individual was counted at the site, but its 3.8-m dbh resulted in the highest SIV for the plot), *Pourouma guianensis* and *I. deltoidea*. Important species at Perua were *Himatanthus sucuuba*, *Guatteria guentheri* and *Inga thibaudiana*. At Cash-3, the important species included *I. deltoidea* (although it was less important than at *terra firme* forest sites), *Miconia triplinervis* and *Pseudolmedia laevis*. Except for *I. deltoidea*, none of the above species were among the top five most important species at any of the other sites.

Leguminosae was the most speciose family at all three sites, where it ranged from 18 to 27 species per site. The families with the highest relative abundances were Meliaceae (12%) at Shiv-2, Leguminosae (14%) at Perua and Moraceae (16%) at Cash-3. Other relatively abundant families were Cecropiaceae at Shiv-2 and Perua, Apocynaceae at Perua and Arecaceae at Cash-3.

Diversity in the mixed upland forest habitat was higher than in other habitat types, with Shiv-2 and Perua the most diverse of all the sites (Table 3).

4.5 Bamboo

Bamboo (*Guadua sarcocarpa*) occurred in all three habitat types. We recorded it at Sanm-3.1, Sanm-3.2, Lasm, Shiv-2, Perua and Cash-3 (Table 2). At Sanm-3.1, Sanm-3.2 and Cash-3, bamboo was included in the category of trees ≥ 4 cm dbh. At Lasm, Shiv-2 and Perua, although we sampled only trees ≥10 cm dbh, we did include bamboo in the sample. The number of individual culms of *G. sarcocarpa* ranged from 71 at Shiv-2 to 1512 at Sanm-3.2 (Table 2).

5 Discussion

5.1 Comparison to other sites

The values for abundance and basal area that we recorded in the LUR are similar to those recorded in species-rich lowland forests elsewhere in the neotropics, including Rio Xingu, Brazil (Campbell *et al.* 1986); Manaus, Brazil (Rankin-de-Mérona *et al.* 1992); Rio Jurua, western Brazil (Campbell *et al.* 1992); Choco Region, Colombia (Faber-Langendoen and Gentry 1991 and Galeano *et al.* 1998); Manu National Park, Peru (Dallmeier and Comiskey 1996); various other sites in Peru (Gentry 1988); Laguna Grande, Ecuador (Balslev *et al.* 1987, Valencia *et al.* 1994); and Yasuni National Park, Ecuador (Korning *et al.* 1991).

Species richness of trees ≥ 10 cm dbh in the LUR was generally higher than in the Brazilian sites, but richness appears to be at or below typical values for sites in western Amazonia. In Manu National Park in southern Peru, Gentry and Terborgh (1990) recorded 200 species per ha, Gentry (1988) recorded 300 species at one-ha in Yanamono, Peru and Valencia *et al.* (1994) recorded 307 species per ha near Laguna Grande, Ecuador — the most species-rich site yet recorded anywhere in the world.

Family richness of the *terra firme* forests in the LUR, up to 53 families per ha in Pag, is among the highest recorded. Gentry (1988) found 58 families at a one-ha plot in Yanamono, Peru, while the site described by Valencia *et al.* (1994) in Ecuador, despite containing 307 species, had only 46 families. Rankin-de-Merona *et al.* (1992) recorded 53 families across 70 ha in central Brazil. Note that when we include trees ≥ 4 cm dbh in our sample, five LUR sites recorded more than 58 families (Sanm-3.1 and Cash-2 each had 65 families). The Ecuadorian site studied by Valencia *et al*. (1994) contained 54 families of trees ≥ 5 cm dbh.

5.2 Riverine terrace forest

The riverine forest sites (Lasm, Sega-1, Sega-2 and Shiv-1), all of which are located along the Camisea River, lie on terraces at least 60 m above the river and are not affected by seasonal flooding. These sites are dominated by *S. inclinata*, an early to mid-successional species common at disturbed sites (Brako and Zarucchi 1993, H. Beltran pers. comm.). Notes from botanical collections at the Missouri Botanical Garden describe this species as occurring from 100 m to 1000 m or more in elevation — from floodplains to the "highest hilltops." One collection note from nearby Manu National Park in Peru (R. Foster and T. Wachter) mentions that it is "super-abundant," a claim that is substantiated by additional field observations in Peru (H. Beltran pers. comm.). Aymard (1997) and Aymard *et al.* (1998) describe 0.1-ha plots in upland, hilly forest on sandy soils in Venezuela that contain a high abundance of *S. inclinata*. However, at the Venezuela sites, relative density of this species attained a maximum of 12.3%, while relative dominance reached a maximum of 3.1%. In the LUR, *S. inclinata* attained a maximum relative density of 47.7% in Shiv-1 and relative dominance of 20.6% at Sega-1. *S. inclinata* was an understory species in the Venezuelan site, but a canopy species in the LUR.

Other common species in the riverine terrace plots suggest that these sites may have experienced some form of disturbance. *Pourouma minor* is a major component at all four sites and is considered a pioneer species (H. Beltran pers. comm.), and *Jacaranda copaia*, also at the riverine sites, has been described as a common pioneer species throughout the Amazon (James *et al.* 1998, Thompson *et al.* 1998). In fact, many of the 20 most important species from the LUR sites are common members of *varzea* forests in Manaus, Brazil (Worbes *et al.* 1992), Rio Jurua in western Brazil (Campbell *et al.* 1992) and Manu National Park to the east of the LUR (Gentry and Terborgh 1990). Though the current site does not exhibit seasonal flooding, the species composition and affinities to *varzea* forests are most likely due to the sandy substrate. A similar species composition was also recorded on a high floodplain forest at Pakitza, Manu National Park (Dallmeier *et al.* 1996), although *S. inclinata* was not present.

The riverine forest sites are strikingly similar in structure and composition, particularly Sega-1, Sega-2 and Shiv-1. Species richness is low, and the abundance of *S. inclinata* is high. Such an oligarchic forest type (forests dominated by one or few species) is not uncommon even in highly diverse areas of the Amazon (Campbell 1994). Peters *et al.* (1989) state that oligarchic forests are the result of severe or frequent disturbance, which suggests that the LUR riverine forests may have experienced some type of large-scale disturbance. The close proximity of the river makes these sites more accessible to local people. As a result, the sites have experienced the effects of human disturbance, such as observable small-scale clearing of forest for both active and abandoned agricultural plots. Local people also use trees as material for building houses and boats.

Lasm, which is similar to *terra firme* forests while retaining affinities to the other riverine forest sites, is clearly a transitional site where *S. inclinata* is an important component, but *I. deltoidea* is also common. Lasm is characterized by high species richness, lower abundance of trees and tall trees — all traits that are associated with the more mature *terra firme* forests in the region. This may mean that Lasm represents a transitional stage from riverine terrace to *terra firme* forest.

5.3 *Terra firme* forests

The *terra firme* forests (Sanm-3.1, Sanm-3.2, Cash-2 and Pag) are structurally similar to *terra firme* sites elsewhere in Amazonia. They are characterized by high alpha diversity, high species richness and a large proportion of tall trees (Campbell *et al.* 1986, Gentry 1988, Korning *et al.* 1991, Valencia *et al.* 1994). Where bamboo is present, species diversity is lower among trees ≥ 10 cm dbh, probably because of the great amount of disturbance caused by bamboo culms.

The four *terra firme* sites are dominated by the canopy palm *I. deltoidea* and the economically significant fruit tree *Matisia cordata*. The plots share many species, but as expected in a lowland tropical forest, there are compositional differences. A primary difference among these plots is the presence of the highly abundant, arborescent bamboo *G. sarcocarpa* at Sanm-3.1 and

Sanm-3.2, which probably represents a form of natural disturbance, and its absence at Cash-2 and Pag.

5.4 Mixed upland forests

The mixed upland forests appear to be transitional. They are compositionally related to the other two habitat types, but each contains its own unique characteristics. Long-term monitoring should help determine whether or not these sites represent successional stages between riverine terrace forest and *terra firme* forests.

Shiv-2 and Perua, like the riverine terrace forests, are located on old, non-flooded river terraces. But there is no apparent human disturbance in the area. In addition, there are no clear dominant species at either site. At Shiv-2, the most abundant species, *Pourouma guianensis*, reaches a relative abundance of only 6%. At Perua, the most abundant tree, *Himatanthus sucuuba*, represents only 4.5% of the relative abundance. *I. deltoidea* is present in both plots, but it is not abundant. Overall density, basal area and species richness are similar to the *terra firme* sites, but the stature of the trees is much lower than the surrounding forests. Only one individual at Shiv-2 and two individuals in Perua exceed 30 m in height. *G. sarcocarpa* is present in both plots and may be a response to natural disturbance.

Cash-3 is structurally similar to the *terra firme* forests, but compositionally it is more similar to the riverine forest sites. There is no evidence of human disturbance at Cash-3, and its remote location and difficult access suggest that past human disturbance is unlikely. Bamboo at the plot likely represents a natural disturbance.

Only 13 (8%) of the species at Cash-3 are unique to the plot, while 88% of the species are found in either riverine or *terra firme* habitats. Except for *I. deltoidea*, most of the important species in Cash-3 are not important at any other site. For example, the second most important species is *Miconia triplinervis*, a tree not common at any of the other sites.

Notable points about the understory trees (≥ 4 cm dbh) include the abundance of the tree fern *Alsophila cuspidate*, which occurs nowhere else. Another unique characteristic is the high abundance of the two understory palms *Socratea salazarii* and *Wettinia augusta*. *S. salazarii* is found elsewhere only at Pag, and *W. augusta* is found in no other plot. *W. augusta* is considered to be a submontane species from the Andean piedmont (Kahn and de Granville 1992, Moraes *et al.* 1995).

Cash-3 is most likely a transitional forest, showing affinities to both *terra firme* forests and submontane forests.

5.5 Dominance of palms and bamboo

The LUR study sites are notable for the extensive distributions of two monocots — the tall, canopy palm *I. deltoidea* and the arborescent bamboo *G. sarcocarpa*. The palm family (Arecaceae) is represented by more than 180 species in the Amazon (Kahn and de Granville 1992). Palm diversity reaches its peak in the forests of southwestern Amazonia, with 150 species occurring in Peru (Kahn *et al.* 1988, Kahn and de Granville 1992). Arborescent bamboos (*Guadua* sp.) are also prevalent over extensive areas of southwestern Amazonia, especially near the intersection of the borders of Brazil, Peru and Bolivia where at least 180,000 km^2 of forest are dominated by bamboo (Judziewicz *et al.* 1999).

I. deltoidea is common throughout the LUR and is found in most habitat types, but it reaches its highest abundance and basal area in *terra firme* forests, a trait that is characteristic of palms (Kahn and Mejia 1991, Kahn and de Castro 1985). *I. deltoidea* is found in a wide variety of habitat types. Clark *et al.* (1995) found no association of this tree with topography and only a slight preference for alluvial soils. Typically, palm-dominated forests contain small, understory species, and large arborescent palms are less common.

Kahn and Mejia (1991) examined the palm community in two *terra firme* sites in the Ucayali River Valley of Peru, just north of our study site. They recorded 29 species and more than 7000 individuals in a 0.71-ha plot and 34 species and nearly 4000 individuals in a 0.5-ha site. At both sites, more than 99% of the individuals were < 10 m in height. Furthermore, the genera *Bactris* and *Geonoma*, both understory palms, were always among the most diverse and abundant palms, while *I. deltoidea*, typically a common species, was almost always a low to mid-understory palm. Other studies have reported similar findings (Kahn and de Castro 1985, Kahn 1987, Clark *et al.* 1995).

In addition to *I. deltoidea*, there are few arborescent palm species at the LUR plots, and abundance of palms in the understory appears to be lower than elsewhere. Additional data collected on the understory vegetation around these plots (Campbell *et al.* In press) show that the most common understory palms are *Geonoma deversa*, a palm common throughout Amazonia, and *I. deltoidea*. These data indicate that the widespread and abundant genus *Bactris* is not represented in the area.

Forests dominated by canopy palms are not unusual, although Kahn and Mejia (1990) reported high densities of canopy-level palms (>10 m tall) in some wetland areas of the Ucayali River Valley. But *I. deltoidea* was never the dominant species, and in all cases the understory palm community was species rich and highly abundant. Gentry and Terborgh (1990) describe a community dominated by canopy-level palms from Manu National Park where overall palm density for individuals ≥ 10cm dbh was 103/ha. That value consisted of nearly equivalent numbers of the three palms *Astrocaryum murumuru*, *Scheelea cephalotes* and *I. deltoidea*. *A. murumuru* and *S. cephalotes* were rare in our plots. Gentry and Terborgh too only gathered data on trees ≥ 10 cm dbh and made note of the open quality of the understory due to the lack of trees in the 2.5 to 10 cm dbh class. This suggests that the understory palm community was not well developed. Galeano *et al.* (1998) describe a forest dominated by the palm *Welfia regia* in the Choco Region of Colombia. They report total palm density for individuals ≥ 10 cm dbh in a one-ha plot as 119 and *W. regia* having 75 individuals. Sanm-3.1 in the LUR contained 73 individuals of *I. deltoidea*. Although, Galeano *et al.* (1998) recorded no data on trees < 10 cm dbh, they describe the understory as having "seedlings and juveniles [of *W. regia*] everywhere." Faber-Langendoen and Gentry (1991) also describe high densities of canopy-level palms from Choco and again the stands have a rich and abundant understory palm community. Some of the highest palm densities were recorded in the Beni Biosphere Reserve, Bolivia, where *terra firme* forests were dominated by *Astrocaryum murumuru* and *Socratea exorrhiza*, while riverine forests and forest islands in the transitional savanna habitats were dominated by *Attalea phalerata* (Comiskey *et al.* 2000). Densities reached as high as 306 palms per hectare (Comiskey 1999).

The prevalence of a single canopy-level palm species and the paucity of members of the genera *Bactris* set the LUR palm community apart from other forests in the region. This may be related to the steep slopes in the LUR and natural disturbances. *I. deltoidea* is a member of the small group of palms exhibiting stilt roots, which may be an adaptation that allows the palms to anchor themselves on steep slopes (Kahn and de Granville 1992). And in addition to *I. deltoidea*, the common palms recorded in the LUR, including the abundant understory palms *S. salazarii* and *W. augusta* at Cash-3, all have stilt roots. The prevalence of this group of palms again suggests that the forests in the LUR are driven by natural forms of disturbance such as wind falls, and landslides that create a broken canopy mosaic. Coupled with the steeply sloping hillsides of the area, natural disturbances may promote the palm community that we observed.

Bamboo, particularly the canopy-level bamboo *G. sarcocarpa*, is the other obvious component of our LUR forest plots. Satellite images of the larger study area reveal that the distribution of bamboo is not patchy. Rather, it covers extensive areas but is completely absent from other areas (ERM 1996). The transition from bamboo forest to non-bamboo forest is strikingly abrupt.

Little is known of the ecology of *Guadua* and its effects on the forest dynamics of the LUR, but *Guadua* has potentially tremendous impacts on forest structure. This is especially true of *G. sarcocarpa,* which was first described in 1991 (Londoño and Peterson 1991) and is known only from the Cuzco and Madre de Dios regions of southwestern Peru, except for one record at a semi-deciduous forest in Santa Cruz, Bolivia. Judziewicz *et al.* (1999) state that *Guadua* is typical of non-inundated forests, its distribution does not correlate with any apparent environmental factors, it seems independent of topographic features and it does not correlate with any generalized soil maps of the region.

The LUR *terra firme* sites present an opportunity to examine some of the potential effects of bamboo on forest structure and composition. Oliveira-Filho *et al.* (1994) describe a forest dominated by the bamboo *Merostachys neesii* in Madre de Deus de Minas in southeastern Brazil, where they counted 7,776 individual culms in a 1.6-ha plot. They contend that bamboo impeded the establishment of other species, resulting in a much lower tree density and basal area than in adjacent stands where bamboo was absent. They reported that these differences were even greater for smaller trees and concluded that bamboo, through shade and displacement, eliminates smaller trees and reduces recruitment into the canopy class. This ultimately leads to lower density and total basal area in larger trees.

In the LUR, we counted fewer trees and measured a lower basal area in the two stands where bamboo was present. However, additional data from these sites (Campbell *et al.* In press) that allow for statistical comparisons show that there are no significant differences (ANOVA, $p > 0.05$) in the number of trees or total basal area of trees ≥ 10cm dbh in *terra firme* sites with and without bamboo. In addition, when we examined the LUR stands by comparing trees ≥ 4cm dbh, our data also appear to contradict those of Oliveira-Filho *et al.* (1994). Overall, density of non-bamboo trees among the four plots is very similar. We did not find a reduction in the abundance of understory trees in the presence of bamboo.

Young (1991) examined the effects of bamboo (*Chusquea* sp.) in a timberline forest in Peru and found that bamboo did not increase the mortality of young trees or affect regeneration. The only difference between bamboo-present and bamboo-absent forests was an increased number of small-stemmed woody plants and a smaller basal area where bamboo was present. Young concluded that bamboo has no effect on the mortality, composition or regeneration of arboreal species. Similarly, bamboo in the LUR sites appears to have little effect on the structure of the forest.

Unlike Young, our data suggest that there may be compositional differences among bamboo and non-bamboo sites in the LUR. The species richness is much higher in the sites without bamboo. Our additional studies (Campbell *et al.* In press) show that the number of species is higher in the two sites without bamboo (ANOVA $p < 0.01$).

Two studies that have examined the effects of bamboo on forest dynamics (Oliveira-Filho *et al.* 1994, P. Nunez and J. Terborgh, unpub. data cited in Judziewicz *et al.* 1999) show that the species composition among bamboo and non-bamboo stands was quite similar, but that there were differences in the relative abundances. In both the bamboo-present and bamboo-absent sites, canopy gaps caused by tree falls were common. Canopy gaps allow for invasion by earlier successional species, which increases the species richness in a particular site. Although tree fall gaps are common at the LUR sites, in the bamboo sites bamboo may be rapidly colonizing the gaps through vegetative reproduction. This prevents the establishment of sun-loving pioneer species that invade the gaps at the sites without bamboo and increase the richness of species.

6 Conclusion

Broadly speaking, the forests of the LUR are rich, diverse and dynamic — qualities that are enhanced by the confluence of several ecoregions in the study area. In addition, richness and diversity are influenced by the highly dynamic nature of the forests, which appear to be driven by disturbance, both natural (windfalls, landslides, flooding, river meanderings) and human caused (clearing for agriculture and logging for wood products). Together, these forces retain the forests in a constant state of flux that results in a mosaic of different successional stages. Each stage nurtures its own representative suite of species. Continued monitoring and research will begin to reveal the mechanisms that drive this system and contribute to efforts to maintain natural processes in the forests.

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Appendix 1. Ten most important species, based on species importance value, ranked in descending order of importance at each of the assessment sites grouped by habitat type (relative density [RD] and relative basal area [RBA] also shown).

Terra Firme Forests			Riverine Terrace Forests			Mixed Upland Forest		
Species	RD	RBA	Species	RD	RBA	Species	RD	RBA
Cashiriari-2			Las Malvinas			Cashiriari-3		
Iriartea deltoidea	0.095	0.090	*Cedrelinga cateniformis*	0.012	0.178	*Iriartea deltoidea*	0.092	0.079
Matisia cordata	0.044	0.060	*Iriartea deltoidea*	0.078	0.070	*Miconia triplinervis*	0.037	0.075
Calatola venezuelana	0.061	0.024	*Senefeldera inclinata*	0.046	0.029	*Pseudolmedia laevis*	0.059	0.052
Chimarrhis sp	0.019	0.054	*Tocoyena* sp	0.039	0.014	*Psychotria* sp	0.039	0.062
Rinorea guianensis	0.037	0.026	*Hevea brasiliensis*	0.028	0.024	*Copaifera reticulata*	0.002	0.052
Copaifera reticulata	0.005	0.057	*Inga alba*	0.005	0.045	*Inga edulis*	0.020	0.033
Sapium marmieri	0.017	0.032	*Pseudolmedia laevigata*	0.021	0.029	*Pourouma minor*	0.027	0.026
Pentagonia parvifolia	0.037	0.011	*Pterygota amazonica*	0.012	0.037	*Socratea salazarii*	0.034	0.008
Grias peruviana	0.035	0.011	*Socratea salazarii*	0.039	0.008	*Sloanea guianensis*	0.016	0.022
Guarea macrophylla	0.029	0.014	*Protium tenuifolium*	0.027	0.017	*Neea* sp	0.016	0.021
Pagoreni			Segakiato-1			Peruanita		
Iriartea deltoidea	0.085	0.093	*Senefeldera inclinata*	0.424	0.206	*Himatanthus sucuuba*	0.045	0.055
Pentagonia parvifolia	0.064	0.026	*Cedrelinga cateniformis*	0.007	0.097	*Guatteria guentheri*	0.019	0.071
Sapium marmieri	0.024	0.064	*Pourouma minor*	0.035	0.067	*Inga thibaudiana*	0.036	0.031
Matisia cordata	0.028	0.055	*Mabea maynensis*	0.060	0.017	*Pseudobombax* sp	0.034	0.031
Guarea macrophylla	0.042	0.031	*Cariniana* sp	0.004	0.057	*Dipteryx micrantha*	0.005	0.060
Calatola venezuelana	0.042	0.021	*Pouteria* sp	0.021	0.034	*Iriartea deltoidea*	0.023	0.041
Otoba parvifolia	0.026	0.032	*Tocoyena* sp	0.034	0.018	*Pourouma guianensis*	0.031	0.023
Bauhinia tarapotensis	0.007	0.040	*Virola surinamensis*	0.029	0.020	*Tabernaemontana psychotriifolia*	0.018	0.025
Guarea kunthiana	0.023	0.021	*Protium neglectum*	0.014	0.032	*Inga alba*	0.011	0.031
Chimarrhis glabriflora	0.010	0.027	*Virola sebifera*	0.020	0.022	*Socratea exorrhiza*	0.023	0.018
San Martin-3.1			Segakiato-2			Shivankoreni-2		
Iriartea deltoidea	0.152	0.174	*Senefeldera inclinata*	0.305	0.172	*Ficus amazonica*	0.002	0.139
Matisia cordata	0.114	0.106	*Jacaranda copaia*	0.025	0.072	*Pourouma guianensis*	0.058	0.057
Poulsenia armata	0.008	0.046	*Protium neglectum*	0.039	0.050	*Iriartea deltoidea*	0.048	0.057
Guapira sp	0.031	0.014	*Pourouma minor*	0.023	0.060	*Guarea kunthiana* ssp	0.042	0.049
Spondias mombin	0.008	0.034	*Tocoyena* sp	0.023	0.019	*Pseudolmedia laevis*	0.020	0.035
Ceiba pentandra	0.002	0.037	*Laetia procera*	0.017	0.024	*Inga edulis*	0.020	0.029
Cabralea canjerana	0.010	0.028	*Hevea brasiliensis*	0.012	0.022	*Protium puncticulatum*	0.032	0.014
Pentagonia parvifolia	0.029	0.009	*Protium tenuifolium*	0.014	0.019	*Brosimum alicastrum*	0.005	0.040
Chimarrhis sp	0.008	0.028	*Pouteria juruana*	0.006	0.020	*Matisia cordata*	0.020	0.019
Tabebuia ochracea	0.002	0.031	*Mabea nitida*	0.020	0.006	*Calatola venezuelana*	0.027	0.009
San Martin 3.2			Shivankoreni-1					
Iriartea deltoidea	0.133	0.156	*Senefeldera inclinata*	0.477	0.187			
Matisia cordata	0.121	0.140	*Cedrelinga cateniformis*	0.019	0.337			
Chimarrhis sp	0.019	0.047	*Pourouma minor*	0.041	0.061			
Otoba parvifolia	0.032	0.032	*Tocoyena* sp	0.058	0.021			
Lonchocarpus sp	0.019	0.043	*Virola mollissima*	0.025	0.027			
Cabralea canjerana	0.019	0.030	*Pourouma guianensis*	0.023	0.022			
Inga edulis	0.012	0.037	*Swartzia* sp	0.005	0.034			
Huertea glandulosa	0.007	0.038	*Pouteria procera*	0.011	0.025			
Erythrina ulei	0.017	0.027	*Helicostylis tomentosa*	0.020	0.012			
Lonchocarpus spiciflorus	0.019	0.020	*Pourouma mollis*	0.008	0.022			

Appendix 2. List of species encountered in the biodiversity plots and additional plots (Campbell *et al.* In press) of the Lower Urubamba Region, Peru.

Anacardiaceae
Astronium graveolens
Spondias mombin
Tapirira guianensis
Tapirira peckoltiana
Thyrsodium sp1
Annonaceae
Annona ambotay
Annona montana
Annona sp1
Annonaceae sp
Annonaceae sp1
Cremastosperma sp1
Cymbopetalum sp1
Duguetia quitarensis
Ephedranthus guianensis
Guatteria acutissima
Guatteria alutacea
Guatteria dielsiana
Guatteria guentheri
Guatteria scytophylla
Guatteria sp1
Klarobelia candida
Malmea diclina
Malmea sp1
Oxandra acuminata
Oxandra espintana
Oxandra mediocris
Oxandra sp1
Oxandra xylopioides
Porcelia nitidifolia
Rollinia edulis
Rollinia pittieri
Rollinia sp1
Ruizodendron ovale
Trigynaea sp1
Unonopsis floribunda
Unonopsis matthewsii
Unonopsis sp1
Unonopsis veneficiorum
Xylopia benthamii
Xylopia cuspidata
Xylopia ligustrifolia
Xylopia sp1
Apocynaceae
Aspidosperma marcgravianum
Aspidosperma megaphyllum
Aspidosperma nitidum
Aspidosperma sp1
Aspidosperma vargasii
Forsteronia sp1
Himatanthus sucuuba
Tabernaemontana psychotriifolia
Tabernaemontana sananho
Araliaceae
Dendropanax sp1
Schefflera morototoni
Arecaceae
Aiphanes aculeata
Aiphanes sp1
Astrocaryum chonta
Astrocaryum murumuru
Attalea butyracea
Chamaedorea sp1
Euterpe precatoria
Geonoma sp1
Iriartea deltoidea
Oenocarpus balickii
Oenocarpus bataua
Oenocarpus mapora
Scheelea sp1
Socratea exorrhiza
Socratea salazarii
Socratea sp1
Wettinia augusta
Wettinia maynensis
Asteraceae
Vernonia sp1
Bignoniaceae
Jacaranda copaia
Tabebuia incana
Tabebuia ochracea
Tabebuia serratifolia
Bixaceae
Bixa platycarpa
Bombacaceae
Bombacopsis sp1
Ceiba pentandra
Chorisia insignis
Eriotheca globosa
Huberodendron swietenioides
Matisia cordata

Appendix 2. Continued

Pseudobombax septenatum
Pseudobombax sp1
Quararibea ochrocalyx
Quararibea sp1
Quararibea wittii
Boraginaceae
Cordia alliodora
Cordia lomatoloba
Cordia nodosa
Cordia sp1
Cordia toqueve
Cordia ucayaliensis
Burseraceae
Protium aracouchini
Protium neglectum
Protium puncticulatum
Protium sp1
Protium sp2
Protium tenuifolium
Tetragastris panamensis
Tetragastris sp1
Trattinnickia aspera
Trattinnickia peruviana
Trattinnickia sp1
Capparaceae
Capparis macrophylla
Capparis sp1
Caricaceae
Carica sp1
Jacaratia digitata
Jacaratia spinosa
Caryocaraceae
Anthodiscus klugii
Caryocar amygdaliforme
Caryocar pallidum
Cecropiaceae
Cecropia engleriana
Cecropia peltata
Cecropia polystachya
Cecropia sciadophylla
Cecropia sp1
Cecropia tessmannii
Coussapoa villosa
Coussarea sp1
Pourouma cecropiifolia
Pourouma cucura
Pourouma guianensis
Pourouma minor
Pourouma mollis
Pourouma palmata
Pourouma sp1
Pourouma tomentosa
Celastraceae
Maytenus ebenifolia
Maytenus magnifolia
Maytenus sp1
Chrysobalanaceae
Couepia latifolia
Couepia sp1
Hirtella bullata
Hirtella excelsa
Hirtella lightioides
Hirtella racemosa
Hirtella sp1
Hirtella triandra
Licania britteniana
Licania sp1
Parinari parilis
Clusiaceae
Caraipa myrcioides
Caraipa sp1
Chrysochlamys membranacea
Chrysochlamys sp1
Chrysochlamys ulei
Garcinia acuminata
Garcinia macrophylla
Marila laxiflora
Rheedia acuminata
Symphonia globulifera
Symphonia sp1
Combretaceae
Bucida sp1
Terminalia amazonia
Terminalia argentea
Terminalia oblonga
Terminalia sp1
Connaraceae
Connarus sp1
Rourea sp1
Cyatheaceae
Alsophila cuspidata
Dichapetalaceae
Tapura juruana
Tapura peruviana

Appendix 2. Continued

Dilleniaceae
Doliocarpus dentatus
Tetracera parviflora
Ebenaceae
Diospyros ebenifolia
Diospyros poeppigiana
Diospyros pubescens
Diospyros sp1
Diospyros subrotata
Elaeocarpaceae
Sloanea fragrans
Sloanea guianensis
Sloanea laurifolia
Sloanea picapica
Sloanea pubescens
Sloanea sinemariensis
Sloanea sp1
Sloanea spathulata
Sloanea terniflora
Erythroxylaceae
Erythroxylum macrophyllum
Erythroxylum sp1
Euphorbiaceae
Acalypha cuneata
Acalypha mapirensis
Alchornea glandulosa
Alchornea sp1
Alchornea triplinervia
Caryodendron orinocense
Conceveiba guianensis
Croton sp1
Croton tessmannii
Drypetes amazonica
Drypetes gentryi
Drypetes sp1
Euphorbiaceae sp1
Glycydendron amazonicum
Glycydendron sp1
Hevea brasiliensis
Hevea guianensis
Hura crepitans
Hyeronima alchorneoides
Hyeronima laxiflora
Hyeronima oblonga
Mabea maynensis
Mabea nitida
Mabea sp1
Margaritaria nobilis
Pausandra trianae
Richeria sp1
Sagotia racemosa
Sapium eglandulosum
Sapium glandulosum
Sapium marmieri
Sapium sp1
Senefeldera inclinata
Senefeldera sp1
Unknown sp1
Flacourtiaceae
Carpotroche longifolia
Casearia aculeata
Casearia decandra
Casearia megacarpa
Casearia obovalis
Casearia sp1
Casearia ulmifolia
Flacourtiaceae sp
Hasseltia floribunda
Laetia procera
Lindackeria paludosa
Lunania parviflora
Myroxylon balsamum
Pleuranthodendron lindenii
Pleuranthodendron sp1
Prockia crucis
Tetrathylacium macrophyllum
Xylosma benthamii
Xylosma intermedium
Hippocrateaceae
Anthodon sp1
Cheiloclinium cognatum
Cheiloclinium sp1
Peritassa sp1
Salacia gigantea
Salacia macrantha
Salacia macrophylla
Salacia sp1
Humiriaceae
Humiriastrum excelsum
Icacinaceae
Calatola microcarpa
Calatola venezuelana
Casimirella sp1
Citronella incarum

Appendix 2. Continued

Citronella sp1
Icacinaceae sp
Poraqueiba sp1
Lacistemataceae
Lacistema aggregatum
Lauraceae
Aniba guianensis
Aniba sp1
Aniba taubertiana
Aniba terminalis
Beilschmiedia sp1
Caryodaphnopsis fosteri
Endlicheria dysodantha
Endlicheria formosa
Endlicheria sericea
Endlicheria sp1
Endlicheria williamsii
Lauraceae sp
Licaria triandra
Nectandra cuneatocordata
Nectandra cuspidata
Nectandra longifolia
Nectandra pulverulenta
Nectandra reticulata
Nectandra rubriflora
Nectandra sp1
Nectandra sp2
Nectandra tessmannii
Ocotea aurea
Ocotea camphoromoea
Ocotea cernua
Ocotea javitensis
Ocotea longifolia
Ocotea oblonga
Ocotea sp1
Ocotea tessmannii
Persea sp1
Pleurothyrium parviflorum
Pleurothyrium poeppigii
Pleurothyrium sp1
Pleurothyrium vasquezii
Pleurothyrium williamsii
Rhodostemonodaphne kunthiana
Rhodostemonodaphne sp1
Lecythidaceae
Cariniana sp1
Couratari guianensis
Eschweilera coriacea
Eschweilera sp1
Grias peruviana
Leguminosae
Acacia loretensis
Acacia sp1
Amburana sp1
Andira inermis
Andira sp1
Andira surinamensis
Apuleia leiocarpa
Bauhinia brachycalyx
Bauhinia sp1
Bauhinia tarapotensis
Bocoa alterna
Browneopsis sp1
Calliandra amazonica
Cassia silvestris
Cassia sp1
Cedrelinga cateniformis
Cedrelinga sp1
Copaifera reticulata
Copaifera sp1
Dalbergia sp1
Dioclea arborea
Dioclea argentea
Dioclea sp1
Dioclea virgata
Dipteryx micrantha
Dipteryx odorata
Dussia tessmannii
Erythrina poeppigiana
Erythrina sp1
Erythrina ulei
Harleyodendron sp1
Hymenolobium sp1
Inga acreana
Inga acrocephala
Inga alba
Inga auristellae
Inga chartacea
Inga cinnamomea
Inga coruscans
Inga dumosa
Inga edulis
Inga ferruginea
Inga fosteriana

Appendix 2. Continued

Inga gracilior
Inga latifolia
Inga laurifolia
Inga laurina
Inga macrophylla
Inga megalobotrys
Inga nobilis
Inga oerstediana
Inga pavoniana
Inga pezizifera
Inga ptariana
Inga punctata
Inga quaternata
Inga ruiziana
Inga semialata
Inga sertulifera
Inga setosa
Inga sp1
Inga sp2
Inga sp3
Inga spuria
Inga stipularis
Inga thibaudiana
Inga tomentosa
Inga umbellifera
Inga vismiifolia
Lecointea amazonica
Lecointea peruviana
Leguminosae sp
Leguminosae sp1
Lonchocarpus glabrescens
Lonchocarpus sp1
Lonchocarpus spiciflorus
Machaerium sp1
Ormosia amazonica
Ormosia bopiensis
Ormosia sp1
Parkia nitida
Parkia velutina
Piptadenia adiantoides
Piptadenia communis
Piptadenia sp1
Piscidia sp1
Pithecellobium corymbosum
Pithecellobium latifolium
Pithecellobium macrophyllum
Platymiscium sp1
Platymiscium sp2
Platymiscium ulei
Platypodium viride
Pterocarpus rohrii
Pterocarpus sp1
Sclerolobium bracteosum
Senna herzogii
Stryphnodendron guianense
Stryphnodendron sp1
Swartzia arborescens
Swartzia myrtifolia
Swartzia sp1
Tachigali polyphylla
Tachigali sp1
Vatairea peruviana
Zygia latifolia
Zygia longifolia
Zygia macrophylla
Zygia sp
Zygia sp1

Loganiaceae
Strychnos darienensis

Lythraceae
Lafoensia punicifolia

Magnoliaceae
Talauma amazonica

Malpighiaceae
Bunchosia sp1
Malpighiaceae sp
Mascagnia sp1

Melastomataceae
Bellucia pentamera
Bellucia sp1
Miconia bubalina
Miconia sp1
Miconia triplinervis
Mouriri grandiflora
Mouriri longifolia
Mouriri sp1

Meliaceae
Cabralea canjerana
Cedrela fissilis
Guarea ecuadoriensis
Guarea glabra
Guarea gomma
Guarea kunthiana
Guarea kunthiana sp1

Appendix 2. Continued

Guarea kunthiana sp2
Guarea kunthiana sp3
Guarea macrophylla
Guarea pterorhachis
Guarea sp1
Meliaceae sp1
Trichilia pallida
Trichilia pleeana
Trichilia poeppigii
Trichilia quadrijuga
Trichilia rubra
Trichilia septentrionalis
Trichilia solitudinis
Trichilia sp1

Menispermaceae
Abuta sp1

Monimiaceae
Mollinedia cuspidata
Mollinedia killipii
Mollinedia latifolia
Mollinedia sp1
Siparuna cuspidata
Siparuna decipiens
Siparuna guianensis
Siparuna sp1
Siparuna tabacifolia

Moraceae
Batocarpus amazonicus
Batocarpus sp1
Brosimum acutifolium
Brosimum alicastrum
Brosimum lactescens
Brosimum parinarioides
Brosimum rubescens
Brosimum utile
Castilla ulei
Clarisia biflora
Clarisia racemosa
Clarisia sp1
Ficus amazonica
Ficus gomelleira
Ficus guianensis
Ficus mathewsii
Ficus maxima
Ficus paraensis
Ficus perez-arbelaezii
Ficus schultesii
Ficus spathulata
Ficus sphenophylla
Ficus trigonata
Helicostylis tomentosa
Maquira calophylla
Maquira coriacea
Maquira costaricana
Maquira guianensis
Maquira sp1
moraceae sp1
Naucleopsis glabra
Naucleopsis krukovii
Naucleopsis pseudonaga
Naucleopsis sp1
Naucleopsis ternstroemiiflora
Naucleopsis ulei
Perebea angustifolia
Perebea guianensis
Perebea humilis
Perebea sp1
Perebea tessmannii
Perebea xanthochyma
Poulsenia armata
Pseudolmedia laevigata
Pseudolmedia laevis
Pseudolmedia macrophylla
Pseudolmedia murure
Pseudolmedia rigida
Pseudolmedia sp1
Sorocea briquetii
Sorocea guilleminiana
Sorocea pileata
Sorocea sp1
Sorocea steinbachii
Trophis caucana

Myristicaceae
Iryanthera juruensis
Iryanthera laevis
Iryanthera olacoides
Iryanthera sp1
Otoba glycicarpa
Otoba parvifolia
Virola calophylla
Virola duckei
Virola flexuosa
Virola mollissima
Virola multinervia

Appendix 2. Continued

- *Virola sebifera*
- *Virola* sp1
- *Virola surinamensis*

Myrsinaceae

- *Cybianthus* sp1
- *Stylogyne ambigua*
- *Stylogyne cauliflora*
- *Stylogyne* sp1

Myrtaceae

- *Calyptranthes longifolia*
- *Calyptranthes oblongifolia*
- *Calyptranthes* sp1
- *Campomanesia* sp1
- *Eugenia coriacea*
- *Eugenia florida*
- *Eugenia* sp1
- *Eugenia* sp2
- *Eugenia* sp3
- *Eugenia* sp
- *Eugenia uniflora*
- *Myrcia* sp1
- *Myrcia* sp
- *Myrciaria floribunda*
- *Myrciaria* sp1
- Myrtaceae sp
- Myrtaceae sp1
- Myrtaceae sp2
- *Psidium acutangulum*
- *Psidium* sp1

Nyctaginaceae

- *Guapira* sp.nov.
- *Guapira* sp1
- *Neea chlorantha*
- *Neea hirsuta*
- *Neea macrophylla*
- *Neea* sp1
- *Neea* sp2

Olacaceae

- *Heisteria acuminata*
- *Heisteria ovata*
- *Heisteria* sp1
- *Minquartia guianensis*

Opiliaceae

- *Agonandra brasiliensis*
- *Agonandra* sp1

Piperaceae

- *Piper cordifolium*
- *Piper crassifolium*
- *Piper pseudoarboreum*
- *Piper reticulatum*
- *Piper* sp1

Poaceae

- *Guadua sarcocarpa*

Polygonaceae

- *Coccoloba mollis*
- *Coccoloba peruviana*
- *Coccoloba* sp1
- *Coccoloba warmingii*
- *Coccoloba williamsii*
- *Triplaris americana*
- *Triplaris poeppigiana*
- *Triplaris setosa*

Proteaceae

- *Roupala montana*

Pteridophyta

- *Cyathea boliviana*
- *Cyathea* sp
- *Cyathea* sp1
- *Cyathea* sp2

Quiinaceae

- *Lacunaria* sp1
- *Quiina macrophylla*
- *Quiina peruviana*

Rhamnaceae

- *Ampelozizyphus* sp
- *Rhamnidium* sp1
- *Ziziphus cinnamomum*

Rosaceae

- *Licania parinarioides*
- *Prunus vana*

Rubiaceae

- *Alibertia* sp
- *Alibertia* sp1
- *Alseis* sp1
- *Bathysa obovata*
- *Borojoa* sp1
- *Calycophyllum acreanum*
- *Capirona decorticans*
- *Cephaelis flaviflora*
- *Chimarrhis glabriflora*
- *Chimarrhis* sp1
- *Cinchona* sp1
- *Coutarea hexandra*
- *Faramea* sp1

Appendix 2. Continued

Ferdinandusa sp1
Isertia laevis
Macbrideina peruviana
Macrocnemum roseum
Macrocnemum sp1
Palicourea sp1
Pentagonia parvifolia
Pentagonia sp1
Posoqueria latifolia
Posoqueria sp1
Psychotria carthagenensis
Psychotria flaviflora
Psychotria sp1
Psychotria viridis
Randia armata
Rubiaceae sp1
Rudgea sp1
Tocoyena sp1
Tocoyena sp2
Warszewiczia coccinea

Rutaceae

Galipea trifoliata
Spathelia terminalioides
Toxosiphon sp1
Zanthoxylum culantrillo
Zanthoxylum ekmanii
Zanthoxylum huberi
Zanthoxylum rhoifolium
Zanthoxylum sp1
Zanthoxylum sprucei

Sabiaceae

Meliosma boliviensis
Meliosma herbertii
Meliosma loretoyacuensis
Meliosma sp1
Meliosma sp2
Meliosma vasquezii

Sapindaceae

Allophylus glabratus
Allophylus incanus
Allophylus scrobiculatus
Cupania cinerea
Matayba arborescens
Matayba scrobiculata
Matayba sp1
Pseudima frutescens
Sapindaceae sp
Talisia cerasina
Talisia reticulata
Talisia sp1
Toulicia reticulata

Sapotaceae

Chrysophyllum sp1
Chrysophyllum venezuelanense
Diploon cuspidatum
Ecclinusa guianensis
Ecclinusa longifolia
Ecclinusa sp1
Manilkara bidentata
Manilkara sp1
Manilkara sp2
Micropholis egensis
Micropholis guyanensis
Micropholis melinoniana
Micropholis sp1
Micropholis venulosa
Pouteria bilocularis
Pouteria boliviana
Pouteria caimito
Pouteria ephedrantha
Pouteria gonglyocarpa
Pouteria juruana
Pouteria macrophylla
Pouteria procera
Pouteria reticulata
Pouteria sp
Pouteria sp1
Pouteria sp2
Pouteria sp3
Pouteria sp4
Pouteria tarapotensis
Pouteria torta
Pouteria trilocularis
Sapotaceae sp1

Simaroubaceae

Picramnia latifolia
Picramnia sp1
Simaba sp1
Simarouba amara
Simaroubaceae sp1

Solanaceae

Cestrum arboreum
Cestrum megalophyllum
Cestrum sp1

Appendix 2. Continued

  - *Cyphomandra endopogon*
  - *Cyphomandra* sp
  - *Cyphomandra* sp1
  - *Solanum sessile*
  - *Solanum* sp1
- **Staphyleaceae**
  - *Huertea glandulosa*
  - *Turpinia occidentalis*
- **Sterculiaceae**
  - *Byttneria* sp1
  - *Guazuma ulmifolia*
  - *Pterygota amazonica*
  - *Sterculia apetala*
  - *Sterculia pruriens*
  - *Sterculia* sp
  - *Sterculia* sp1
  - *Theobroma cacao*
- **Styracaceae**
  - *Styrax tessmannii*
- **Theophrastaceae**
  - *Clavija* sp1
  - *Clavija weberbaueri*
- **Thymelaeaceae**
  - *Daphnopsis* sp1
- **Tiliaceae**
  - *Apeiba aspera*
  - *Apeiba membranacea*
  - *Apeiba* sp
  - *Heliocarpus americanus*
  - *Lueheopsis* sp1
- **Ulmaceae**
  - *Ampelocera edentula*
  - *Ampelocera ruizii*
  - *Ampelocera* sp1
  - *Celtis schippii*
  - *Trema integerrima*
  - *Trema micrantha*
- **Urticaceae**
  - *Boehmeria caudata*
  - *Myriocarpa stipitata*
  - *Urera baccifera*
  - *Urera caracasana*
  - *Urera* sp1
- **Verbenaceae**
  - *Aegiphila cordata*
  - *Aegiphila haughtii*
  - *Aegiphila integrifolia*
  - *Aegiphila* sp1
  - *Citharexylum poeppigii*
  - *Vitex cymosa*
- **Violaceae**
  - *Gloeospermum sphaerocarpum*
  - *Leonia crassa*
  - *Leonia glycycarpa*
  - *Rinorea guianensis*
  - *Rinorea lindeniana*
  - *Rinorea viridifolia*
  - *Rinoreocarpus ulei*
- **Vochysiaceae**
  - *Qualea* sp
  - *Vochysia boliviana*
  - *Vochysia* sp1

Orchids of the Lower Urubamba Region, Peru

William Nauray and Lucero Acurio

1 Introduction

Orchids are one of the most diverse families of plants. Taxonomists estimate that up to 25,000 species occur in the family Orchidaceae, or one-tenth of all known flowering plant species.

While orchids are widely distributed, ranging beyond even the polar circles, most are native to the moist tropical regions of the world. This incredibly species-rich family displays a diverse array of vegetative forms. For example, in temperate climates all orchid species are terrestrial, while in the tropics they also grow on rocks or as epiphytes that cling by their roots to the branches and twigs of trees (Van der Pijl and Dodson 1966, Dressler 1981, Ackerman 1992).

From tiny seeds, orchids produce highly specialized plants and flowers to attract, deceive and manipulate pollinators, including bees, moths, wasps, butterflies, flies, beetles, ants and hummingbirds. The diversity and function of the orchids' intricate floral structures clearly illustrate adaptive evolution and the action of selective forces among organisms, and early evolutionary biologists recognized these characteristics and often made orchids the focus of their studies (Darwin 1862).

Orchids have an interesting life cycle. The flowers may develop wonderful colors, shapes and fragrances to attract pollinators for cross-pollination. Then, the wind carries the seed to a suitable substrate. For successful germination and establishment, the dispersed seed must encounter an appropriate fungus. A mutualistic relationship then develops, which enables the orchid to develop structures for photosynthesis and eventually to produce its own carbohydrates (Dressler 1981, Ackerman 1992, Rasmussen 1995).

Humans have a strong attraction to orchids. We cultivate them throughout the world for their beauty and some — such as *Vanilla* spp. — for economic reasons. Unfortunately, this attraction can lead to over-collecting, which is one of the biggest threats to orchids around the world. To help reduce this threat, scientists are conducting studies to improve our knowledge of orchids. Much of this effort is focused on orchids in the tropics where their biology and natural history are poorly known. Scientists realize that increased knowledge and preservation of critical habitats are necessary to conserve orchids. Basic research is underway to understand the factors that control the health and reproduction of orchid populations, including the protection of their pollinators.

The objective of this study was to provide an assessment of orchids in the Lower Urubamba Region (LUR), where Shell Prospecting and Development (Peru) B. V. (SPDP) was exploring the rainforest for natural gas and condensates. The Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) joined the company in an effort to conduct the gas project in the most environmentally sound manner possible. SI/MAB led teams of researchers in assessing various taxa in the LUR and establishing the basis for future monitoring of biodiversity in the region.

2 Methods

The rainforest in the LUR is a dynamic system with mixed forests dominated in places by bamboo (*Guadua sarcocarpa*). The structure and composition of the forests are primarily influenced by topography, climate and biological factors and, increasingly, by human activity (Comiskey *et al*. this volume).

The study area surrounds four natural gas well sites at elevations ranging from 450 to 650 meters (m) above sea level. We selected terrestrial and epiphyte habitats for the study and classified the types of orchids as: (1) terrestrial orchids in forest clearings, (2) terrestrial orchids in the forest understory, (3) epiphyte orchids in the forest understory, (4) epiphyte orchids in the intermediate forest layer, (5) epiphyte orchids in the canopy and (6) vine orchids.

We searched for specimens opportunistically rather than through a systematic approach, recording orchids in the understory of the forest from both standing and fallen trees and from small trees. The orchids in the intermediate and canopy layers were recorded only from fallen trees and from fallen branches because of the difficulties in accessing these layers.

In all cases, we identified orchids to the species level, if possible, or at least to the morphospecies level, placing species with the same morphological characteristics in the same species category.

3 Results and Discussion

We recorded 45 species of orchids in the LUR (Appendix 1). More species were found growing on trees as epiphytes than as terrestrial life forms, which is not surprising because the diversity of epiphytic orchids is greatest in the neotropics (Dressler 1981). The distribution of species observed in the LUR was most likely related to differences in the availability of light and humidity among different forest strata. In a tropical rainforest, the forest floor receives little light and humidity is high. Conversely, the canopy layer receives more light and humidity is relatively low. This continuum of light and humidity from floor to canopy provides a variety of microhabitats for orchids, which typically prefer humid, shady areas, although epiphytic orchids can tolerate more sunlight and lower humidity than other orchid species and thus can inhabit many microhabitats not available to terrestrially rooted life forms. In higher forest strata, orchids presumably enjoy good access to pollinators, good seed dispersion and reduced exposure to herbivory (Dressler 1990). Epiphytic orchids (for example, *Cattleya luteola*) have further adapted to these conditions by developing noticeable pseudo bulbs and fleshy leaves.

Orchids in the LUR occupied a variety of niches. Terrestrial species such as *Chaubardia klugii, Kefersteinia* sp. and *Cochleanthes amazonica* occurred only in the shaded understory, while other terrestrial species such as *Bletia catenulata* occurred only in sunny tree-fall gaps. Among epiphytic species, *Cryptarrhena lunata* had a limited distribution, occurring only in the mid-strata of the forest, while others such as *Dichaea graminoides*, *Myoxanthus trachychlamys* and *Scaphyglottis boliviensis* were recorded in all forest strata. Unusual among all orchids at LUR, *Vanilla* spp. germinate on the forest floor and then climb as a vine to the upper canopy.

We noted that upper layers of the forest in the LUR were not as explored as the lower ones because they were difficult to reach. The canopy in the study area is typically more than 20 m in height**.** Understanding epiphytic orchid development in the rainforest will be greatly enhanced when it is possible to study the canopy without relying on fallen trees and branches.

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Appendix 1. List of orchid species (Orchidaceae) recorded in the Lower Urubamba Region, southeastern Perú. Species are classified by life form (terrestrial or epiphytic) and segregated by forest strata (Cle= clearing, Und = understory, Int = intermediate height, Can = canopy).

	Life Form					
	Terrestrial		Epiphytic			
Species	Cle	Und	Und	Int	Can	Vines
Bletia catenulata	x					
Brassia sp.					x	
Bulbophyllum sp.					x	
Campylocentrum hondurense					x	
Catasetum sp.					x	
Cattleya luteola					x	
Chaubardia klugii			x	x		
Cochleanthes amazonica			x			
Cyclopogon sp.		x				
Cryptarrhena lunata				x		
Dichaea graminoides			x	x	x	
Dichaea muricata			x			
Elleanthus sp.				x	x	
Encyclia sp.					x	
Encyclia vespa				x	x	
Epidendrum prostratum			x			
Epidendrun sp.				x	x	
Erythrodes anchorifera		x				
Gongora sp.				x		
Kefersteinia sp.			x			
Lycaste sp.				x		
Masdevallia sp.					x	
Maxillaria sp.1				x	x	
Maxillaria sp.2					x	
Maxillaria sp.3					x	
Maxillaria sp.4		x				
Maxillaria sp.5			x		x	
Myoxanthus trachychlamys			x	x	x	
Oncidium sp.					x	
Palmorchis aff. *lobulata*		x				
Pleurothallis flexuosa				x	x	
Pleurothallis magnipetala			x		x	
Pleurothallis sp.					x	
Pleurothallis spathulifolia					x	
Psilochilus macrophyllus		x				

Appendix 1. Continued

	Life Form					
	Terrestrial		Epiphytic			
Species	Cle	Und	Und	Int	Can	Vines
Psygmorchis glossomystax				x		
Rodriguezia lanceolata				x		
Scaphyglottis boliviensis			x	x	x	
Sobralia sp.				x		
Stanhopea candida			x	x		
Stelis argentata					x	
Stelis sp.			x		x	
Trizeuxis falcata				x	x	
Vanilla spp.						x
Xylobium sp.				x	x	
TOTAL	1	5	12	18	26	1

Biodiversity Assessment of the Aquatic Systems of the Lower Urubamba Region, Peru

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1 Introduction

With its 60 known freshwater fish families and 5000 freshwater fish species, South America boasts the most diverse freshwater fish communities on Earth. Until the last decade or so, however, biodiversity studies of neotropical icthyofauna in Peru were rare. Since the early 1990s, research related to aquatic systems in that country has increased, with emphasis on species richness in the Amazon watershed (Ortega and Chang 1992).

This is especially important because evaluations of aquatic communities also provide information about water quality. Aquatic organisms quickly respond to perturbations and thus are useful in detecting changes in water quality caused by intermittent or chronic pollution (Tuffery and Verneaux 1968). As well, analysis of community structure and distribution, based on biological diversity indexes, elicit abundant information regarding water bodies. Such analyses can indicate chemical pollution or physical perturbation that reduces the number of organisms in the water, substrates that may obstruct the development of benthic communities and severe organic pollution that prevents the survival of tolerant individuals (Johnscher-Fornasaro and Zagatto 1987).

In 1996, the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) initiated a biodiversity monitoring and assessment project in the Lower Urubamba Region of southeastern Peru. The goal was to provide Shell Prospecting and Development Peru (SPDP) with information concerning the abundance and distribution of species in the area, where the company was engaged in exploration and potential development of natural gas reserves, for use in management decisions.

We studied aquatic systems in the area around Pagoreni, the site of one of SPDP's test wells. Our objective was to evaluate biodiversity in disturbed and undisturbed aquatic systems at the well site in relation to species richness and abundance and test a standardized assessment protocol and methods for future monitoring.

2 Study area

The Pagoreni well site is located between the Urubamba and Camisea rivers. Elevations vary between 350 and 465 meters (m). The hilly topography at Pagoreni favors the formation of steep-sloped watersheds, rocky substrate and rapid drainage. The steepness of the slopes decreases along the waterways, and the substrate changes to a more complex formation that contains particles of various sizes.

We explored the area using four trails (Camisea, Mirador, Chinook and Boddicker) and studied the following small watersheds within the area of influence of the well site (Figure 1):

* Chataro Creek (CHA), which flows to the north and receives soil effluents from well site construction. Two tributaries of Chataro Creek are Chomenta (CHO) and Oshetoato (OSH) creeks.

* Yopuato 1 Creek (YO1), which flows southwest and was dammed to supply water to the well site camp. The mid- to lower course of the creek receives organic effluents from Union Creek (UNI). Cristal (CRI) and Irapitare Kimaro (IRA) are tributaries of Yopuato 1 and Union creeks.

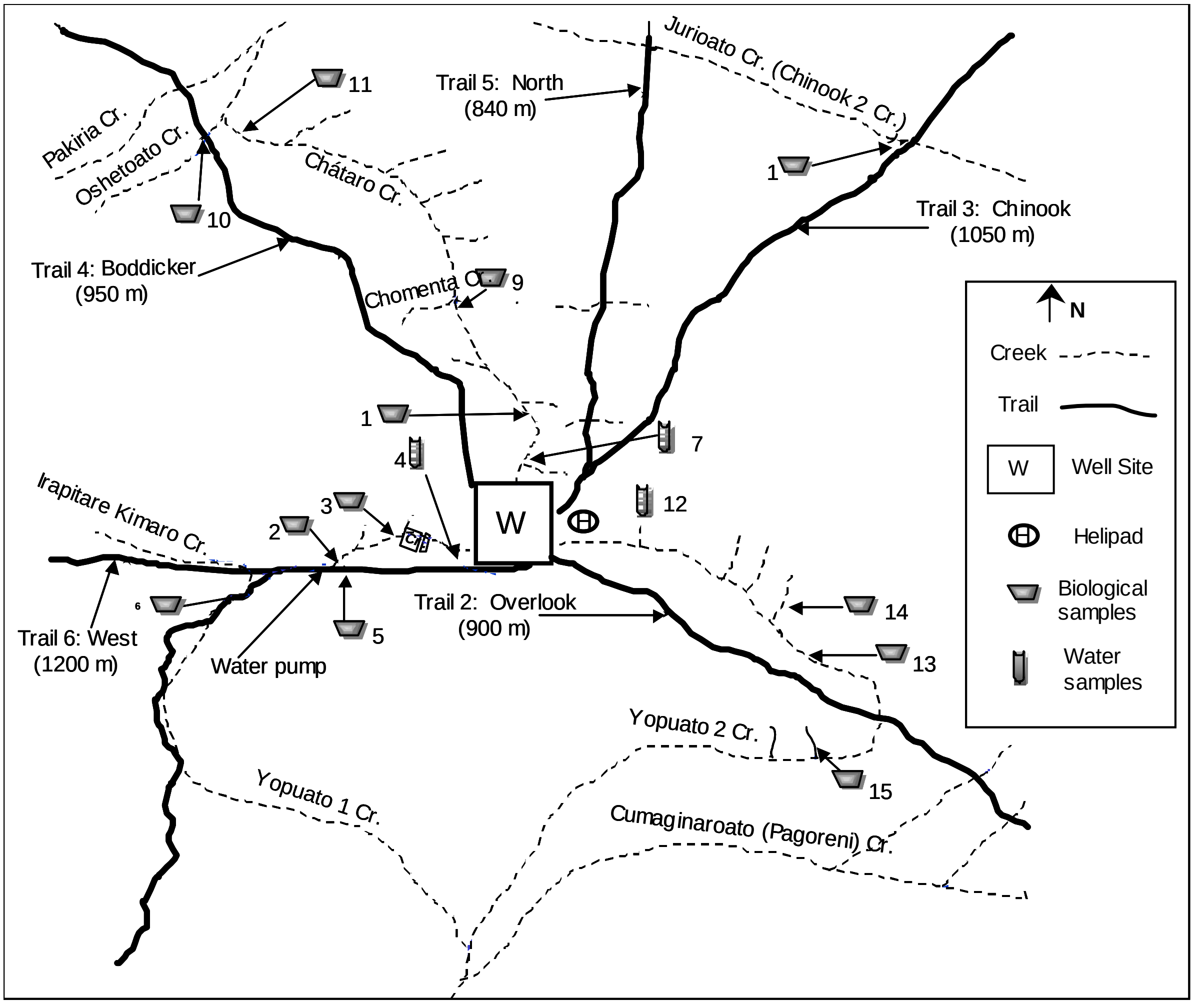

Figure 1. Diagram of Pagoreni well site, Lower Urubamba Region, Peru, and surrounding area, showing biological and water sampling points for this study.

* Yopuato 2 (YO2), which flows southeast and receives the majority of organic effluents from the well site camp. Carachama (CAR) is the major tributary of Yopuato 2, and we sampled along that waterway.

* We also took samples at Jurioato Creek (JUR), which flows northeast over the Chinook Trail and experiences negligible impacts from the well site. We sampled this stream because it represented an undisturbed system.

Members of the Shivankoreni community, who were part of the field team, supplied the names of the creeks.

3 Methods

3.1 Establishing sampling stations

We sampled from April 20 to May 4, 1998. During the first four days, we explored the surroundings of the drilling site and located water bodies for sampling, selecting only permanent creeks. We divided the creeks into treatment creeks and control creeks. Treatment creeks showed evidence of direct impacts from drilling activities at the well site, including organic effluents and sediments that could be seen in the river beds. Control creeks showed no sign of impacts from the well site.

We established 15 sampling stations in Chataro, Jurioato, Union and Yopuato creeks and their tributaries (Table 1) and assigned each station a code name composed of three elements: PA (_ _ _) U/M/L, where PA stands for Pagoreni, (_ _ _) equals the first three letters of the creek name and U/M/L means upper, middle or lower water course of the stream. For example, the code PA(UNI)U represents Pagoreni, Union Creek, upper course.

3.2 Water: physical and chemical evaluation

At each of the sampling stations, we registered the physical features of the creek (depth, width, substrate). We measured water and air temperatures with a mercury thermometer and used a limnological tool to determine chemical parameters — oxygen, pH, carbon dioxide, total alkalinity, nitrates and total hardness.

3.3 Biological qualitative analysis

3.3.1 Plankton

To conduct the plankton sampling, we considered only major creeks forming permanently irradiated pools. These creeks ensured high productivity and therefore good-quality samples. We swept the pools with a standard net tied to a wide-mouth packet used for countercurrent sweeping and fixed the samples in 5% formaldehyde in sealed, labeled vials.

3.3.2 Macroinvertebrates

We sampled macroinvertebrates using hand nets as we stirred the water over the substrates (stones, rocks, litter, etc.) as much as possible. Conspicuous organisms were placed in labeled vials containing 70% ethyl alcohol. To minimize the amount of inorganic material, we sifted the samples and separated macroinvertebrate specimens, which we then identified to the genus level from the following identification keys: Benedetto (1974), Flint (1978), Correa *et al*. (1981), Merrit and Cummins (1984), Dominguez *et. al*. (1992) and Magalhaes and Turkay (1996).

3.3.3 Fishes

We sampled fishes in major creeks with sweep nets in small pools along the creeks and hand nets in running water where the substrate had been disturbed (pebbles

Table 1. Sampling stations at the Pagoreni well site, Lower Urubamba Region, Peru.

Station	Reference	Distance to platform (m)
PA(CHA)U	Upper Chataro Creek	100
PA(CHA)M	Middle Chataro Creek	400
PA(CHO)L	Tributary of Chataro Creek	500
PA(CHA)L	Lower Chataro Creek	850
PA(OSH)L	Lower Oshetoato Creek	850
PA(JUR)L	Lower Jurioato Creek	1000
PA(YO2)U	Upper Yopuato 2 Creek	100
PA(YO2)M	Middle Yopuato 2 Creek	400
PA(CAR)L	Tributary of Yopuato 2 Creek	400
PA(YO2)L	Lower Yopuato 2 Creek	800
PA(CRI)L	Tributary of Union Creek	200
PA(UNI)U	Upper Union Creek	200
PA(UNI)L	Tributary of Yopuato 1 Creek	500
PA(YO1)M	Middle Yopuato 1 Creek	500
PA(IRA)L	Tributary of Yopuato 1 Creek	700

Table 2. Physical and chemical characteristics of the creeks at Pagoreni, Lower Urubamba Region, Peru.

Station	pH	Alkalinity (grains/gallon of $CaCO_3$)	CO_2 (mg/l)	Total Hardness (grains/gallon of $CaCO_3$)	O_2 (mg/l)	Nitrates (mg/l)	Water Temperature (C°)	Air Temperature (C°)
PA(CHA)U	7.2	8	25	8	6	0	24.5	25.0
PA(CHA)M	7.8	7	20	5	8	0	24.7	25.5
PA(CHO)L	7.5	5	15	5	8	0	24.0	24.5
PA(CHA)L	8.0	5	10	5	9	0	22.0	21.5
PA(OSH)L	8.0	4	10	4	9	0	22.0	21.0
PA(JUR)L	8.0	5	10	5	8	0	24.0	24.5
PA(YO2)U	7.0	4	50	8	2	0	24.0	24.0
PA(YO2)M	7.5	7	15	4	8	0	24.0	24.5
PA(CAR)L	8.0	7	10	6	9	0	23.8	25.0
PA(YO2)L	7.5	6	15	6	8	0	24.0	24.5
PA(CRI)L	8.0	4	5	5	10	0	24.0	24.5
PA(UNI)U	7.0	5	25	10	7	7.5	24.5	23.5
PA(UNI)L	7.5	3	10	7	8	0	23.5	24.0
PA(YO1)M	7.5	4	10	4	8	0	24.0	24.5
PA(IRA)L	7.5	6	10	5	4	0	24.5	25.0

and small rocks). We fixed fish samples in 10% formaldehyde for 24 hours, separated the samples by species in the laboratory and preserved the samples in 70% alcohol. Taxonomic identification was completed using keys and descriptions, including Eigenmann (1927), Fowler (1945) and Burgess (1989).

Further processing and identification of plankton, macroinvertebrate and fish samples was conducted at the Museo de Historia Natural of the Universidad Nacional Mayor de San Marcos and at the Universidad Nacional Agraria “La Molina.”

3.4 Quantitative analysis

We conducted a quantitative evaluation only for benthic macroinvertebrates. We established ten points at each sampling station along the creek and took samples with sweeping nets, although it was not possible to sample at some stations because of very steep slopes or pollution. We deposited the sediment in 7-liter containers with water, separated the organisms through decantation and fixed them in 70% ethyl alcohol.

We identified the organisms to the family level and counted them through use of a stereoscopic microscope. We also determined biodiversity indexes, including Shannon diversity (species composition within an ecosystem), EPT (proportion of insects corresponding to the Ephemeroptera, Plecoptera and Trichoptera orders in relation to the total number of insects in the sample) and CA (proportion of organisms corresponding to the groups Chironomidae and Anellida in relation to the total number of organisms in the sample). We also determined species richness (number of families per sampling station), total abundance (number of individuals per station) and density (total number of organisms per area [individuals/m^2]).

4 Results and Discussion

4.1 Water: physical and chemical evaluation

We recorded physical and chemical parameters from one point at each of the 15 sampling stations (Table 2). In general water pH was neutral (7 to 8) and lightly alkaline. Low hardness values indicated soft waters with slight mineral concentration that likely derived from the drainage of acid igneous rocks (Renn 1970). Oxygen, nitrate and carbon dioxide concentrations were average. These conditions varied in the upper part of Yopuato 2 Creek, primarily because of relatively high concentrations of organic discharge from the Pagoreni camp.

4.2 Biological qualitative analysis

4.2.1 Plankton

Samples were taken at Yopuato 2 and Oshetoato creeks. We recorded 13 algae species, all with small numbers of individuals, belonging to the Cyanophyta and Bacillariophyta divisions. We concluded that productivity is low in the sampled aquatic environments, as expected in creeks with fast-running water.

4.2.2 Macroinvertebrates

Our qualitative analysis for Pagoreni aquatic macro-invertebrates showed a total of 89 species distributed in 72 families, 19 orders, and eight taxonomic classes (Appendix 1). The best-represented orders were Coleoptera with 14 families and Diptera with 12 families.

We found a relatively large number of benthic macroinvertebrate families, averaging 30 families per sampling station. The numbers were highest in the creeks that were not affected by discharge from the well site.

4.2.3 Fishes

Of the 193 fish specimens sampled, there were eight species, seven genera, three families and two orders (Super Order Ostariophysi). All specimens were small to medium in size. The Characidae family was best represented, with six species: *Astyanax bimaculatus*, *Ceratobranchia* sp., *Charax* sp., *Knodus* sp. 1, *Knodus* sp. 2, and *Scopaeocharax* sp. These species are typically omnivorous. Their main food items are terrestrial and aquatic arthropods (Goulding 1980), although they also eat algae and aquatic plants. The other families were Loricariidae, with one species (*Ancistrus* sp.), and Astroblepidae, also with one species (*Astroblepus* sp.). These two species are siluriformes, which means they are adapted to very fast running water (Ortega 1996).

The seemingly low fish diversity (eight species) in the waters around Pagoreni might have been a result of the sampling effort, or it could reflect a small number of habitats suitable for fish communities given the geomorphologic features of the area that have contributed to the formation of fast-running water environments with narrow riverbeds, steep slopes and rapid runoff. For additional studies on the fish community in the Lower Urubamba Region, see Ortega *et al*. (this volume).

It is possible that some of the specimens are new records in the region. Taxonomic review is underway for final identification, particularly for species of the genera *Knodus* (Tetragonopterinae) and *Scopaeocharax* (Glandulocaudinae).

4.3 Quantitative analysis

The biological parameters applied to the benthic macroinvertebrate communities were good indicators of the degree of perturbation in the creeks. Through the Shannon diversity index, we were able to differentiate the perturbed creeks Yopuato and Union from the non-perturbed creeks Chomenta, Oshetoato and Jurioato. The EPT index indicated perturbations in the creeks caused by organic residues. However, this index could be improved through the addition of a factor representing the proportion of the pollution-resistant organisms Diptera and Anellida. Table 3 presents data related to the diversity indexes.

High density values for the resistant organisms Diptera-Chironomidae confirmed high levels of organic pollution in Yopuato 2 Creek, where the proportion of Chironomidae varied between 65% and 88% of the total individuals. Densities varied between 153 and 422

Table 3. Physical and biological* parameters of sampling sites at Pagoreni (substrate particle size: BD = >256 mm, PB = 16 to 64 mm, GR = 2 to16 mm, ST = 0.004 to 0.06 mm).

	Physical Parameters			Biological Parameters						
Station	depth (cm)	width (cm)	substrate	# of families	abundance (# of individuals)	density (individuals/ m^2)	EPT	CA	EPT/CA	H’
PA(CHA)M	19.1	211	GR	22	122	136	50.8	18	2.82	3.57
PA(CHO)L	11	95	GR	24	69	77	33.3	15.9	2.09	4.13
PA(CHA)L	10.7	182	BD	15	49	54	38.8	22.5	1.73	3.43
PA(OSH)L	13.9	187	BD	28	174	193	50.6	4.6	10.99	3.99
PA(JUR)L	18.3	246	PB	26	124	138	33.9	10.5	3.23	3.92
PA(YO2)M	12.1	135	ST	15	380	422	0.8	91.8	0.01	0.87
PA(CAR)L	1.1	157	GR	23	101	112	36.6	27.7	1.32	3.91
PA(YO2)L	13.6	231	ST	15	138	153	1.4	67.4	0.02	1.92
PA(UNI)U	6.3	68	PB	12	19	21	15.8	26.3	0.6	3.32
PA(UNI)L	14.9	273	ST	12	32	36	18.8	21.9	0.86	3.14
PA(YO1)M	7.7	148	ST	17	37	41	43.3	10.8	4	3.77

* H’ = Shannon diversity (species composition within an ecosystem); EPT = proportion of insects corresponding to the Ephemeroptera, Plecoptera and Trichoptera orders in relation to the total number of insects in the sample; CA = proportion of organisms corresponding to the groups Chironomidae and Anellida in relation to the total number of organisms in the sample.

individuals/m^2. Both Yopuato 2 and Union, the creeks influenced by domestic organic residues from the Pagoreni well site, showed gradual recuperation of diversity values through water dilution along their courses.

The upper part of Chataro Creek was strongly disturbed by inorganic sediments from activity at the well site, as reflected by the relatively low number of families recorded. Because of the dilution effect of the creeks, however, the biological communities can recover fairly rapidly, and after 200 m, we found normal values of diversity.

We recorded the second highest diversity index and density values (3.99 and 193 individuals/m^2, respectively) at Oshetoato Creek station PA(OSH)L, which was not affected by sediments or organic matter. The physical properties of the creek and its chemical composition represented optimal conditions for the establishment of benthic organisms.

From our findings, we concluded that water bodies with a high diversity index are chemically healthy — well oxygenated with a low degree of organic and inorganic pollution. Water bodies with a low diversity index we generally considered polluted.

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Appendix 1. Macroinvertebrates sampled at Pagoreni, Lower Urubamba Region, Peru (April – May 1998).

	Stations												
	1	2	3	5	6	7	8	9	10	11	13	14	15
Taxa	PA(JUR)L	PA(UNI)L	PA(UNI)U	PA(YO1)M	PA(IRA)L	PA(CHA)M	PA(CHA)U	PA(CHO)L	PA(CHA)L	PA(OSH)L	PA(YO2)M	PA(CAR)L	PA(YO2)L
Class Turbellaria													
Order Tricladida													
Family Planariidae		X		X	X				X			X	
ClassNematoda	X												
Class Oligochaeta													
Order Haplotaxida		X		X		X	X	X	X		X	X	X
Class Hirudinea		X				X							
Class Gastropoda	X	X		X		X				X	X	X	X
Order Bassomatophora													
Family Valvatidae				X							X		X
Family Planorbidae		X											
Order Mesogastropoda													
Family Ampullaridae	X	X		X							X		
Family Hydrobiidae	X												
Class Insecta													
Order Collembola			X			X	X	X	X	X	X		X
Family Sminthuridae	X				X								
Order Ephemeroptera													
Family Caenidae													
Brachyceras sp.				X									
Family Euthyplociidae													
Euthyplocia sp.	X	X		X	X	X		X	X	X		X	
Family Leptohyhidae				X		X			X		X	X	X
Haplohyphes sp.	X				X					X			
Leptohyphes sp.		X											
Trichorythodes sp.									X	X			
Family Leptophlebiibae													
Thraulodes sp.	X	X		X	X	X			X	X	X	X	X
Family Oniscigastidae						X							
Family Baetidae	X	X					X	X	X	X	X	X	
Baetis sp.				X	X	X							
Family Polymitarcidae						X				X		X	
Family Undetermined	X			X	X	X		X	X	X			
Order Odonata													
Family Platystictidae													
Palaemnema sp.						X						X	X
Family Gomphidae	X	X		X	X	X		X	X	X	X	X	X

Appendix 1. Continued

	Stations												
	1	2	3	5	6	7	8	9	10	11	13	14	15
Taxa	PA(JUR)L	PA(UNI)L	PA(UNI)U	PA(YO1)M	PA(IRA)L	PA(CHA)M	PA(CHA)U	PA(CHO)L	PA(CHA)L	PA(OSH)L	PA(YO2)M	PA(CAR)L	PA(YO2)L
Family Libellulidae	X			X	X	X		X	X	X	X	X	X
Brechmorhoga sp.				X	X	X				X	X		
Family Calopterygidae										X			
Mnesarete sp.		X											
Family Polythoridae	X	X		X	X					X	X		X
Family Coenagrionidae		X				X			X	X	X		
Argia sp.		X											
Family Megapodagrionidae										X			
Heteragrion sp.		X			X							X	X
Family Undetermined	X	X		X	X	X		X	X	X	X	X	X
Order Plecoptera													
Family Perlidae													
Anacroneuria sp.	X	X		X	X	X		X	X	X		X	
Order Megaloptera													
Family Corydalidae													
Corydalus sp.	X	X		X	X	X		X	X	X			
Order Hemiptera													
Family Vellidae													
Rhagovelia sp.	X	X			X	X		X	X	X	X	X	
Family Gerridae		X	X			X		X		X			
Family Naucoridae		X		X		X		X	X	X		X	
Ambrysus sp.		X											
Family Saldidae						X							
Family Gelastocoridae				X									X
Order Coleoptera													
Family Elmidae	X		X	X	X	X	X	X	X	X	X	X	X
Neocylloepus sp.					X								
Phanocerus sp.					X								
Neoelmis sp.					X								
Heterelmis sp.		X											
Microcylloepus sp.		X			X								
Macrelmis sp.		X											
Family Psphenidae	X	X	X	X	X			X		X		X	
Family Ptilodactylidae	X	X	X	X	X	X	X	X	X	X		X	
Family Gyrinidae						X							
Family Helodidae				X								X	
Family Hydraenidae								X				X	

Appendix 1. Continued

	Stations												
	1	2	3	5	6	7	8	9	10	11	13	14	15
Taxa	PA(JUR)L	PA(UNI)L	PA(UNI)U	PA(YO1)M	PA(IRA)L	PA(CHA)M	PA(CHA)U	PA(CHO)L	PA(CHA)L	PA(OSH)L	PA(YO2)M	PA(CAR)L	PA(YO2)L
Family Hydrophilidae	X			X				X					X
Family Hydroscaphidae										X			
Hydroscapha sp.		X											
Family Ptiliidae													X
Family Staphylinidae	X										X		
Family Dryopidae	X			X				X					
Family Dytiscidae									X				
Family Heteroceridae		X		X									
Family Undetermined										X			
Order Trichoptera													
Family Hydropsychidae													
Leptonema sp.	X			X	X	X		X	X	X	X	X	
Smicridea sp.	X	X	X	X	X	X		X					
Family Hydroptilidae	X		X	X	X			X		X			
Family Leptoceridae													
Atanatolica sp.	X	X		X	X	X				X			
Family Philopotamidae													
Chimarra sp.	X					X		X		X			
Family Calamoceratidae													
Philloicus sp.	X			X		X			X	X		X	
Banyallarga sp.										X			
Family Polycentropodidae												X	
Family Odontoceridae													
Marilia sp.					X								
Undetermined	X												
Family Undetermined	X	X		X	X	X			X	X	X	X	
Order Lepidoptera													
Family Pyralidae										X			
Family Undetermined											X		
Order Diptera													
Family Athericidae													
Atherix sp.		X											
Family Ceratopogonidae	X	X	X	X	X	X		X	X	X		X	
Family Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X
Family Psychodidae	X	X	X	X		X		X	X		X	X	X
Family Simuliidae	X							X					
Family Tabanidae		X				X		X					X

Appendix 1. Continued

	Stations												
	1	2	3	5	6	7	8	9	10	11	13	14	15
Taxa	PA(JUR)L	PA(UNI)L	PA(UNI)U	PA(YO1)M	PA(IRA)L	PA(CHA)M	PA(CHA)U	PA(CHO)L	PA(CHA)L	PA(OSH)L	PA(YO2)M	PA(CAR)L	PA(YO2)L
Family Tipulidae	X		X	X	X	X		X	X	X	X	X	X
Tipula sp.													X
Hexatoma sp.		X											
Erioptera sp.		X											
Limonia sp.		X											
Family Stratiomyidae		X		X	X							X	
Family Dolichopodidae					X			X					
Aphrosylus sp.		X											
Family Muscidae						X							
Family Culicidae												X	
Family Undetermined	X	X								X		X	X
Class Arachnida													
Order Acarina	X		X						X	X			
Class Crustacea													
Order Amphipoda	X	X	X	X	X						X	X	
Order Decapoda													
Family Pseudothelphusidae		X		X		X							
Family Atyidae	X	X	X	X				X		X		X	X
Families per station	40	47	15	42	35	37	6	33	28	40	23	35	25

Diversity of Land Mollusks in the Bamboo-dominated Forest of the Lower Urubamba Region, Peru

Rina Ramírez, Saida Córdova and Katia Caro

1 Introduction

With over 35,000 species, the phylum Mollusca is more species rich than all known mammals, birds, reptiles and amphibians combined (Solem 1984, Bruggen 1995). In fact, Mollusca is the second most species-rich group in the animal kingdom.

Most mollusks are found in the tropics where they are conspicuous inhabitants of the ecosystem, although large regions of these areas remain unexplored by scientists (Solem 1984). This is certainly the case in Peru's tropical rainforest, which comprises about 41.7% of the country but where life in the forests is not generally well known (Rodríguez 1996a,b). Nevertheless, the 758 species of land mollusks identified in Peru to date (Ramírez 1997) represent a larger number than in neighboring countries such as Argentina (238 species; Fernandez 1973) and Chile (150 species; Stuardo and Vega 1985) where the malacofauna are better known.

In 1996, the Smithsonian Institution/Monitoring and Assessment of Biodiversity Program (SI/MAB) initiated a large-scale study of biodiversity in the Lower Urubamba Region (LUR) of southeastern Peru in conjunction with a natural gas and condensates exploration and development project of Shell Prospecting and Development Peru. The biodiversity study offered an excellent opportunity to add to information about the mollusks in Peru. The findings from our work should also help increase understanding of ecosystem functions because mollusks are highly dependent on the quality of substrates and structure of vegetation, they are important as biogeographic indicators of early tectonic events and they are key to knowledge of morphological evolution. In addition, mollusks digest large amounts of cellulose, accumulate calcium, provide a source of food for many animals (including humans) and are producers of valuable pharmacological products (Emberton 1995a).

Our primary objective was to assess the community composition of terrestrial mollusks in the Lower Urubamba Region.

2 Study area

The LUR is located east of the Andes Mountains in the Urubamba River Valley of the Ucayali watershed. Land mollusks were surveyed at two sites — the San Martin-3 well site (11º51.88'S, 72º46.69'W) approximately five kilometers north of the Camisea River at an elevation of 474 meters (m) and the Cashiriari-3 well site (11º52´S, 72º39´W) south of San Martin-3 and the Camisea River at approximately 690 m in elevation (Comiskey *et al*. this volume). SI/MAB established a series of one-hectare (ha) vegetation monitoring plots in the study area, including two at San Martin-3 and one at Cashiriari-3 (Comiskey *et al*. this volume).

The forests surrounding the two sites are non-flooded, lowland, primary tropical rainforest with a bamboo-dominated understory (*Guadua sarcocarpa*). The canopy at San Martin-3 is high (> 30 m) and dominated by *Iriartea deltoidea* and *Matisia cordata*, while the lower canopy (< 30 m) at Cashiriari-3 is dominated by *I. deltoidea*, *Miconia triplinervis* and *Pseudolmedia laevis* (Comiskey *et al*. this volume). Cashiriari-3 contains many components of montane forests in the region.

The climate of the study area is typical of lowland rainforest (below 500 m in elevation), with wet (October through April) and dry (May through September) seasons. Average annual rainfall ranges from 3000 to 3500 millimeters, and average temperatures vary little — from 23.4º C to 24.5º C.

At San Martin-3, we sampled within the two vegetation plots (SMP01, SMP02) and at two sites near the plots (SMxP1, SMxP2). At Cashiriari-3, we sampled within the vegetation plot (CASHP01), an area dominated by bamboo near the plot (CASHTr), a riparian zone (CASH-F) and within the nearby true montane forest (CASH-MF). CASH-F and CASH-MF were the only two sites where the understory was not dominated by bamboo (Dallmeier and Alonso 1997).

3 Methods

A three-person team conducted the assessment of land mollusks at San Martin-3 from April 1 through April 27, 1997. At Cashiriari-3, a two-person team carried out the assessment from November 23 to December 10, 1997. Both surveys included exhaustive searches at the three one-ha vegetation monitoring plots (each divided into 25 20x20-m subplots) and at subjectively chosen sampling sites along nearby trails and streams. An additional survey was conducted for one day (December 6) in the montane forest (1000 m in elevation) near Cashiriari-3.

Sampling methods included direct observation, examination of foliage, bark and log fragments and sifting through litter and soil. Litter and soil samples (1x1 m^2, two centimeters [cm] deep) were taken, and we used a dissecting microscope to examine the litter and obtain samples of different species of micromollusks and juveniles. The soil samples were screened through several sizes of mesh sifters and checked under a magnifying lens. Snail and veronicellid slug samples were fixed in 10% formaldehyde and preserved in 70% ethanol.

Primary identification of the species was accomplished using the literature and reference material in the collections at the Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos. Higher classification primarily followed Vaugh (1989) and for the genera of the Systrophiidae, Ramírez (1993).

4 Results and Discussion

We recorded 49 species at the two sites (48 land snails and one veronicellid slug), many of them probably undescribed species (Appendix 1). At San Martin-3, we recorded 35 species (including one veronicellid). At Cashiriari-3, we recorded 41 species (including one veronicellid), 34 of which were observed in the bamboo forest (CASHP01 and CASHTr). The remaining seven species were observed in the montane forest (Appendix 1).

Several species at each site were not observed alive. Species recorded only by the presence of shells at San Martin-3 included *Drymaeus* cf. *catenae*, *Subulina* sp., *Guestieria* sp. and *Labyrinthus diminutus*. At Cashiriari-3, the species recorded only by the presence of shells were *Drymaeus* sp. C, *Thaumastus* sp., *Euglandina* cf. *striata*, *Systrophia* sp. C and *Zilchogyra* sp. Twelve families were represented in the study, including Systrophiidae, Bulimulidae and Subulinidae — the most frequently found families (Appendix 1).

Habitat preferences appeared to be similar at both sites. The greatest number of species dwelled in leaf litter (71% at San Martin-3 and 73% at Cashiriari-3), followed by species that live on the ground but are frequently found in understory vegetation (20% and 24%, respectively). At both sites, the arboreal species were least represented (9% and 3%, respectively).

It will not be surprising if, upon further identification, many of the species sampled during our work are new to science, since most tropical species have not yet been described (Emberton 1995a,b; Ramírez 1991, 1993). We do not know the range of the species we sampled, but they may well have restricted distributions. The genera were not endemic to Peru except *Zilchistrophia* and some members of Systrophiidae. The few known species of *Zilchistrophia* have been collected only a few times, including samples from forests at Chanchamayo (Department of Junin), Divisoria (Department of Huanuco) and Contamana (Department of Loreto) — all in Peru.

When comparing our findings in the LUR with the 34 species of land mollusks identified at Cuzco Amazonico (Duellman and Koecklin 1991) to the south of our study region, we found almost no species in common. Exceptions included the edible "congompe" (Ramírez 1991) and *Megalobulimus popelairianus* and *Plecocheilus floccosa* from emerging vegetation in flooded areas of Cuzco Amazonico (Ramírez 1991). Family composition was also very different at the two study areas. Ramírez (1991) recorded 15 families at Cuzco, three more than we found in the LUR, and the dominant family at Cuzco was Bulimulidae.

We corroborated the carnivorous behavior of the family Systrophiidae when we observed a snail of *Drepanostomella* sp. A eating a juvenile of *Leptinaria* at Cashiriari-3. We also verified predation when we saw a female of Lampyridae (Coleoptera) eating a snail of *Leptinaria lamellata*.

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Appendix 1. Species of terrestrial Mollusca recorded in the Lower Urubamba Region, southeastern Peru (species ordered by family according to Vaugh (1989) and listed by site; all sites lowland tropical rainforest with understories except CASH-F and CASH-MF, dominated by the arborescent bamboo *Guadua sarcocarpa*; 49 species recorded in total, 35 among the four sites at San Martin-3 and 41 among the four sites at Cashiriari-3; X = species present, - = species not present).

	San Martin-3				Cashiriari-3			
Species	SMP01	SMxP1	SMP02	SMxP2	CASHP01	CASHTr	CASH-F	CASH-MF
Helicinidae (7 spp.)								
Archecharax aff. *orbignyi*	-	-	-	-	-	X	X	-
Helicina aff. *bourguignatiana*	X	X	X	X	X	X	X	-
Helicina sp. A	X	X	X	X	-	X		-
Helicina sp. B	X	-	X	X	-	-	-	-
Helicina sp. C	-	-	-	-	-	X	-	-
Helicina sp. D	-	-	-	-	-	X	-	-
Helicina sp. E	-	-	-	-	-	-	X	X
Cyclophoridae (1 sp.)								
Aperostoma peruvianum	X	X	X	X	X	X	-	X
Bulimulidae (9 spp.)								
Bulimulus sp. A	X	-	X	X	-	-	-	-
Bulimulus sp. B	-	-	-	-	-	X	X	-
Drymaeus cf. *catenae*	X	-	X	X	-	-	-	-
Drymaeus rustrigatus	X	X	X	X	-	-	-	-
Drymaeus sp. A	X	X	-	-	-	-	-	-
Drymaeus sp. B	-	-	-	-	-	X	X	-
Drymaeus sp. C	-	-	-	-	-	-	-	X
Plecocheilus floccosa	X	X	-	X	X	X	-	-
Thaumastus sp.	-	-	-	-	-	-	-	X
Subulinidae (8 spp.)								
Beckianum beckianum	X	X	X	X	X	X	X	-
Lamellaxis (*Lamellaxis*) sp.	X	-	X	X	X	X	X	-
Lamellaxis (*Leptopeas*) sp.	X	X	X	X	X	X	-	-
Leptinaria lamellata	X	X	X	X	X	X	-	-
Obeliscus (*Ischnocion*) aff. *triptyx*	X	-	X	X	X	X	-	-

Appendix 1. Continued

	San Martin-3				Cashiriari-3			
Species	SMP01	SMxP1	SMP02	SMxP2	CASHP01	CASHTr	CASH-F	CASH-MF
Obeliscus (*Protobeliscus*) sp.	X	-	-	X	-	-	-	-
Opeas pumilum	X	-	X	X	X	X	X	-
Subulina sp.	X	-	X	-	X	X	X	-
Oleacinidae (1 sp.)								
Euglandina cf. *striata*	X	X	-	-	-	-	-	X
Megalobulimidae (2 spp.)								
Megalobulimus aff. *maximus*	-	-	-	-	-	-	X	X
Megalobulimus polepairianus	-	X	X	X	-	X	X	-
Systrophiidae (14 spp.)								
Drepanostomella aff. *ammonoceras*	X	-	X	X	X	X	X	-
Drepanostomella aff. *excisa*	X	X	X	-	-	-	-	-
Drepanostomella sp.	X	X	X	X	X	X	-	-
Guestieria sp.	X	X	-	X	X	X	X	-
Happia sp.	X	X	-	X	X	X	-	-
Miradiscops sp. A	X	X	X	-	X	X	X	-
Miradiscops sp. B	-	X	-	X	X	X	-	-
Systrophia aff. *eatoni*	X	-	X	X	X	X	X	-
Systrophia (*S*.) sp. A	-	-	-	-	X	X	-	-
Systrophia (*S.*) sp. B	-	-	-	-	-	-	-	X
Systrophia (*S.*) sp. C	-	-	-	-	-	X	-	-
Tamayoa sp.	X	X	X	X	X	X	-	-
Wayampia sp.	X	X	X	X	X	X	X	-
Zilchistrophia sp.	X	X	X	X	-	-	-	-
Helicodiscidae (2 spp.)								
Zilchogyra aff. *microhelix*	X	X	X	X	X	X	-	-
Zilchogyra sp.	-	-	-	-	X	X	-	-
Helicarionidae (1 sp.)								
Habroconus cf. *cassiquiensis*	X	X	X	X	X	X	-	-
Camaenidae (2 spp.)								
Labyrinthus diminutus	X	X	X	X	-	-	-	X
Labyrinthus sp.	-	-	-	-	-	X	-	-
Solaropsidae (1 sp.)								
Psadara aff. *monile*	X	X	X	X	X	X	-	-
Veronicellidae								
Unknown species			X			X		
Total Species	32	24	28	29	24	34	16	8

Biodiversity Assessment of the Arthropods of the Lower Urubamba Region, Peru

José Santisteban, Roberto Polo, Saida Córdova, Gorky Valencia, Flor Gómez,
Alicia De La Cruz and Paola Aibar

1 Introduction

Mites, spiders, ants, bees, wasps, beetles, moths, butterflies, grasshoppers — all and many more are part of the arthropods, the most specious group of organisms on Earth. Current estimates place the number of known species of insects alone at nearly 750,000 — more than 10 times the number of all known vertebrate species. In addition to insects, the arthropod group contains crustaceans, arachnids and myriapods.

These creatures, often with secretive life styles, play critical roles in continental ecosystems, and especially in tropical rainforests where they account for the bulk of biodiversity mass. Among their most important functions are their effects on plant dynamics through herbivory, seed dispersal and pollination, population control of other organisms and cycling of decaying matter.

We sampled arthropods as part of the biodiversity assessment and monitoring project conducted by the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) in the Lower Urubamba Region (LUR) of southeastern Peru. The assessment was carried out in partnership with Shell Prospecting and Development Peru (SPDP) in the vicinity of the company's test natural gas well sites. The study area and our sampling methods and findings are described below.

2 Study area

We carried out our work from May 7 through May 28, 1998, (the end of the rainy season) at the Pagoreni well site (11^{0}47'09"S, 72^{0}42'05"W), elevation of 465 meters (m), just east of where the Camisea and Lower Urubamba rivers meet. The terrain is hilly and strongly dissected with numerous streams and ravines. The elevation gradient ranges from about 550 m on hilltops to 360 m on the Camisea River banks about 2.0 kilometers south and southeast of the well site. Formations around the platform at the well correspond to lowland tropical rainforest (20 to 25 m in canopy height), with a low-density understory. Aerial and ground observations indicate a large frequency of landslides because of the steep terrain and landscape features (Comiskey *et al.* this volume).

3 Methods

We used passive methods (traps) to sample five distinct arthropod taxa — Araneae, Orthoptera, Coleoptera, Coleoptera-Scarabeidae and Hymenoptera — at selected sampling plots. Each plot corresponded to modified 0.1-hectare (20 x 50 m) Whittaker vegetation plots. We chose four (#2, #3, #8 and #10) of the 10 vegetation plots previously established by a team of botanists around the Pagoreni well site (Alonso and Dallmeier 1999, Campbell *et al.* In press).

We set pan pitfall traps and bait pitfall traps (discussed below). All traps were placed inside the vegetation plots, following a distinct pattern. We installed the same number of traps at each sampling site and serviced each trap approximately every 48 hours, completing at least three sampling repetitions for each trap to help ensure the highest quality results. All specimens were pooled for site analysis after each specimen was recorded separately on the original data sheets.

3.1 Pan pitfall traps

We placed 10 pan pitfall traps at each plot. These traps consist of round plastic bowls bright yellow in color and measuring 270 millimeters (mm) in diameter and 78 mm in depth. We buried each container in the soil up to its opening, taking care to minimize soil disturbance around the trap edge. We filled bowls with water to one-third of their capacity and then added enough salt to obtain a saturated solution. The salt retards specimen decomposition, which is particularly important for soft-bodied arthropods. We also added a few drops of liquid soap or shampoo to lessen water surface tension and allow arthropods to submerge into the solution. We did not use 70% ethanol because it attracts some insect species.

We distributed the pan traps inside each plot in a straight line from the baseline and at equal distances from both sides of the interior 10 x 5-m subplots. Servicing equipment included 18-ounce whirl packs (one for each trap), an aquarium dip net, a wash bottle, 70% ethanol, labels, alcohol-resistant ink pens and a bucket for carrying water.

We removed specimens with the aquarium net after taking out all leaves, twigs and other animals that may have fallen into the trap. We transferred the specimens to 70% ethanol, labeled each container and took the samples to the field laboratory for careful washing.

3.2 Pitfall bait traps

Bait traps are designed to attract arthropods that specialize in decaying matter, including species with a preference for fermenting fruit (saprophagous), rotting flesh (necrophagous) or the droppings of vertebrate animals (coprophagous). Groups that are commonly found in such traps are Scarabeidae, Staphylinidae, Nitidulidae, Scolytidae (Coleoptera), Sarcophagidae, Calliphoridae (Diptera) and Gryllidae (Orthoptera).

We used traps similar to the necrotrap NTP-80 (Morón and Terrón 1984), which consist of one-liter plastic containers with tight fitting tops. Four 5 x 5-centimeter (cm) openings, or access windows, are cut in the sides of the containers about 5 mm below the lid in a symmetrical distribution. An eight-ounce plastic container (disposable plastic cup) is placed in the larger outer container and suspended just below the lid of the outer container by #16 wire 13.5 cm in length. Since the inside container holds the bait (100 grams [g] per trap), numerous ventilation holes must be punched into its upper third portion to allow the odor to escape.

We poured about 100 milliliters of 70% ethanol (as a killing and preserving agent) into the bottom of the large container. The bottom of the smaller container should never touch the preserving liquid.

These traps were buried in substrate or soil up to the lower level of the small side windows, preferably in level or somewhat raised places within the plots. If the terrain slopes, it is advisable to cut a small drainage chute in case of moderate rain. The carrion traps containing chicken or fish meat must be secured with branches or stakes (40 to 50 cm in length) pushed into the ground to help prevent small carrion-feeding vertebrates from getting to the bait and spoiling the trap. A large leaf should be fixed on top of the trap to provide further protection against rain.

We distributed eight traps in two series of four each about 2 m in from the borders of the plots, indicating their placement with a small red plastic flag. The vegetation plots for this study were all oriented from south to north, so we set the traps on a south line from right to left (traps 1 through 4) and on a north line from left to right (traps 5 through 8).

Baits used were as follows:

- Saprophagous trap (traps 1 and 5) — a fermenting fruit cocktail of two-thirds mashed papaya and one-third chopped bananas, including peels. We added a teaspoon of baking yeast dissolved in water to accelerate the rotting process. This bait was left to decay for 48 hours in a tightly closed container before use.

- Necrotrap (traps 2 and 6) — 100 g of fish meat (pieces of sea fish fillet) left to decay for 48 hours in a tightly closed container.

- Necrotrap (traps 4 and 8) — 100 g of chicken meat, eviscerated and left to decay for 48 hours in tightly closed containers.

- Coprotrap (traps 3 and 7) — human feces kept in a tightly closed container for 72 hours.

3.3 Sample processing and data management

We processed specimens in the field. All specimens were placed in 70% ethanol on site, then stored in whirl pack bags, labeled (using permanent, alcohol-resistant ink) with codes unique to each specimen and transported to the field laboratory for washing and sorting to ordinal level.

All relevant data were entered and stored in a custom-designed database using a commercial database computer program (Microsoft Access). We plan to deposit voucher material in the arthropod collection at the Department of Entomology, Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Lima.

3.4 Data analysis

Data on species richness and species abundance were analyzed in EstimateS 5 version 5.0.1 (Colwell 1997). For each taxon, we computed the ICE (Incidence-based Coverage Estimator) and ACE (Abundance-based Coverage Estimator). These two indexes are based on the concept of "sample coverage," which, as noted by Colwell (1997), takes into account the pattern of relative abundance of species in the samples (see also Colwell and Coddington 1994, Chazdon *et al*. 1998). Traditional abundance-based estimators would usually overestimate species richness when data consist of some very common and some very rare classes. In such cases, all useful information about undiscovered classes would be in the

Table 1. Araneae sampled from pan pitfall and bait pitfall traps, Pagoreni well site.

Family	# Species	# Individuals	# Juveniles
Agelenidae	2	3	0
Anapidae	2	5	1
Anyphaenidae	1	1	5
Araneidae	6	10	5
Caponidae	1	5	0
Clubionidae	2	17	0
Corinnidae	8	22	4
Ctenidae	4	5	14
Hahnidae	2	6	3
Linyphiidae	4	6	0
Lycosidae	5	24	38
Oonopidae	8	32	1
Pholcidae	4	43	5
Pisauridae	0	0	2
Salticidae	12	12	9
Scytodidae	2	2	0
Theridiidae	4	5	0
Theridiosomatidae	4	4	0
Thomisidae	0	0	1
unknown	0	30	0
Total individuals		232	88
Total species	71		

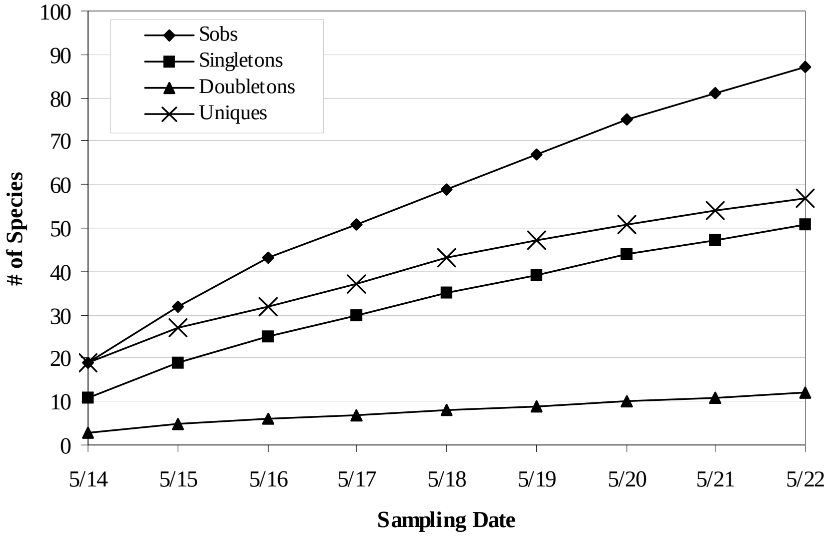

Figure 1. Species accumulation curve for Araneae at all Pagoreni sampling sites (sobs = # of species observed in the pooled *n*-samples [accumulated], singletons = # of singletons [species with only one individual] in the *n*-samples, doubletons = # of doubletons [species with only two individuals] in the *n*-samples, uniques = # of uniques [species that occur in only one sample] among the *n*-samples).

rarer discovered classes. ICE is thus based on species found in 10 or fewer sampling units, while ACE is based on species with 10 or fewer individuals in the sample.

The indexes Chao1 and Chao2 were also computed for comparison. Relevant formulas can be found in documentation and the user manual for EstimateS. Data entered into EstimateS were in Format 1 — species (rows) by samples (columns). Parameters for diversity statistics, kept constant for all trials, were as follows: number of randomizations=100, random seed number=17 and upper limit for rare or infrequent species set to 10 (default). Indexes are illustrated in graphs for each taxonomic group and sampling location.

4 Results and Discussion

4.1 Araneae (Spiders)

We found 320 spiders (including juveniles) from 19 families and 71 species in pan and bait pitfall traps during the sampling period (Table 1). We considered only adults

Table 2. Orthoptera sampled from pan pitfall and bait pitfall traps by date at all sampling units, Pagoreni well site.

Family	# Species	# Individuals
Acrididae	1	2
Gryllidae	11	24
Tetrigidae	4	5
Tettigoniidae	4	5
Total	20	36

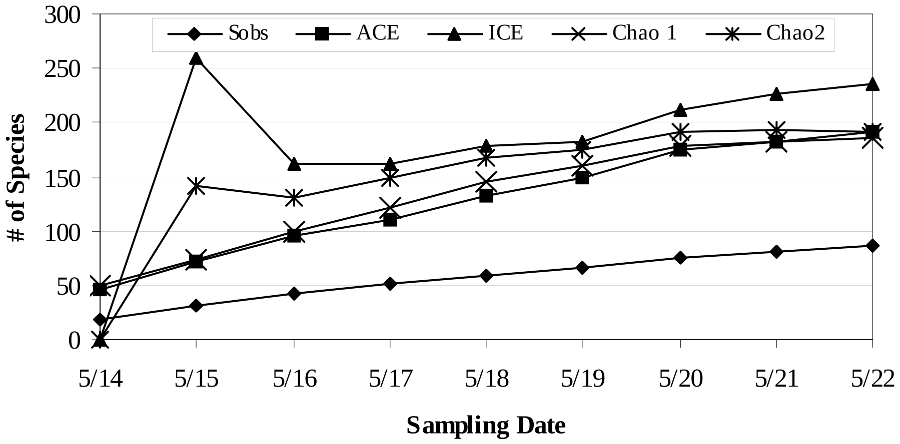

Figure 2. Abundance- and incidence-based species diversity estimators for Araneae at all Pagoreni sampling sites (sobs = # of species observed in the pooled *n*-samples [accumulated], ACE = abundance-based coverage estimator of species richness, ICE = incidence-based coverage estimator of species richness, Chao1 = Chao1 richness estimator, Chao2 = Chao2 richness estimator).

(about 70% of the total) in our data analysis. The family Pholcidae had the most individuals (43) followed by Oonopidae (32) and Lycosidae (24) (Table 1). Juveniles (about 30% of the total) were most abundant in the families Lycosidae (38) and Ctenidae (14), while the Pisauridae and Tomicidae families were represented only by juveniles. Sex ratio as observed in adults was males (58%) and females (42%).

We had limited success in sampling Araneae (the number of specimens per trap was relatively low). The dominant species were those in families (Corinnidae, Salticidae, Lycosidae and Oonopidae) with hunting and cursorial or ambush habits. Species accumulation curves and species diversity estimates for the pooled samples and all sites are presented in Figures 1 and 2. Separate

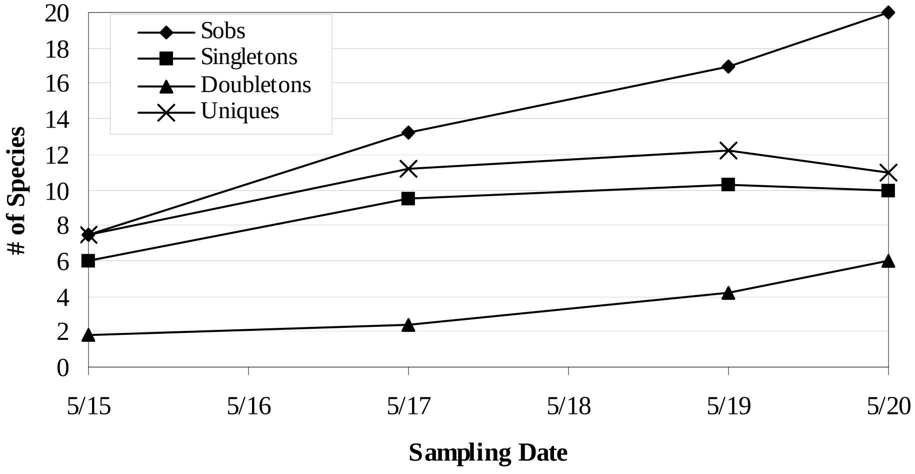

Figure 3. Species accumulation curve for Orthoptera at all Pagoreni sampling sites (sobs = # of species observed in the pooled *n*-samples [accumulated], singletons = # of singletons [species with only one individual] in the *n*-samples, doubletons = # of doubletons [species with only two individuals] in the *n*-samples, uniques = # of uniques [species that occur in only one sample] among the *n*-samples).

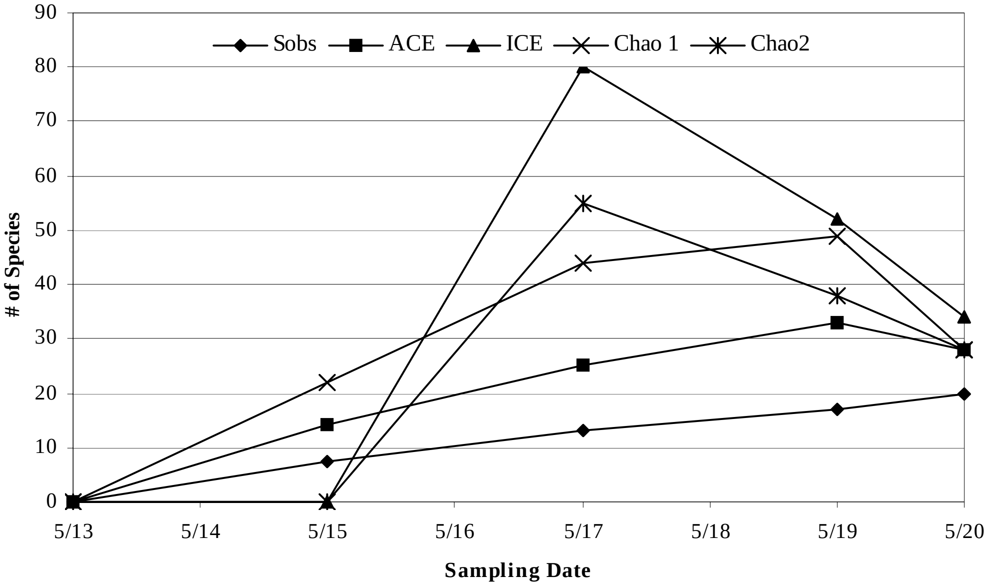

Figure 4. Abundance- and incidence-based species diversity estimators for Orthoptera at all Pagoreni sampling sites (sobs = # of species observed in the pooled *n*-samples [accumulated], ACE = abundance-based coverage estimator of species richness, ICE = incidence-based coverage estimator of species richness, Chao1 = Chao1 richness estimator, Chao2 = Chao2 richness estimator).

Table 3. Coleoptera sampled from pan pitfall and bait pitfall traps by date and sampling site, Pagoreni well site.

Family	# Species	# Individuals
Bruchidae	1	2
Carabidae	16	32
Chrysomelidae	25	45
Curculionidae	10	19
Dytiscidae	1	1
Elateridae	2	3
Erotylidae	1	1
Nitidulidae	2	3
Pselaphidae	8	9
Ptiliidae	1	2
Scarabaeidae	9	38
Scolytidae	6	107
Silphidae	1	1
Staphylinidae	15	29*
undetermined		12
Total	98	304

* 96 individuals of Staphylinidae could not be identified to morphospecies.

analysis by each sampling site did not differ substantially from this pattern.

4.2 Orthoptera

We sampled Orthoptera from four families and 20 species in pan and bait pitfall traps (Table 2). The total number of individuals was 36, excluding nymphs. The most abundant family was Gryllidae with 11 species and 24 individuals. Tetrigidae and Tettigonidae had four species and five individuals each. Gryllidae were the most abundant on the ground, while Tettigonidae were found only occasionally in the soil and primarily in vegetation and tree trunk substrates. Species accumulation curves and species diversity estimators are presented in Figures 3 and 4. The estimators predict that more than 60% of the species were found.

4.3 Coleoptera

We found 98 species of beetles from 14 major families in the pan and bait pitfall traps (Table 3; Figures 5 and 6). The total number of individuals was 304, all adults. The most abundant family was Chrysomelidae (leaf beetles) with 25 species, followed by Carabidae (tiger beetles) and Staphylinidae (rove beetles) with 16 species each.

In relation to individuals, the most abundant families were Scolytidae and Staphylinidae. The high number of Chrysomelidae species may be explained by the large number of Galerucinae and Alticinae present in the samples. These species are primarily vegetation feeders typically found in the understory and are usually sampled in relatively high numbers by more active methods such as beating. Alticinae and Galerucinae are very active on vegetation during the day and are probably visually cued.

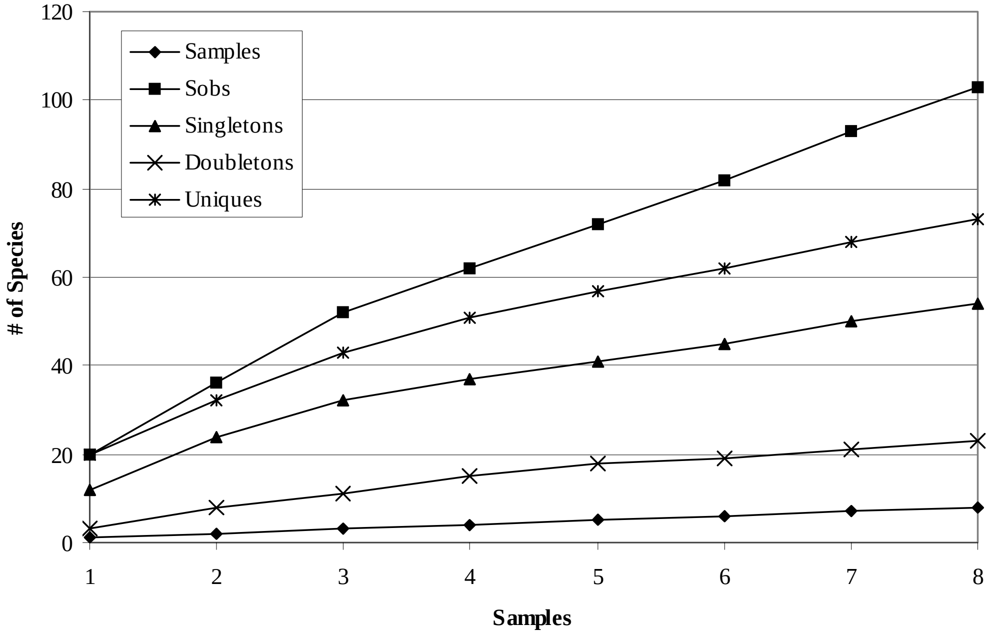

Figure 5. Species accumulation curve for Coleoptera at all Pagoreni sampling sites (sobs = # of species observed in the pooled *n*-samples [accumulated], singletons = # of singletons [species with only one individual] in the *n*-samples, doubletons = # of doubletons [species with only two individuals] in the *n*-samples, uniques = # of uniques [species that occur in only one sample] among the *n*-samples).

The bright coloration of the pan pitfall trap may be the primary reason for our results. Carabidae are mainly hunters and actively seek out their prey. Many are ground or litter dwellers. Curculionidae are also primarily phytophagous but may be associated with fallen fruits.

4.4 Scarabeidae

We separated scarab beetles from the main samples for analytical purposes. We found 898 individual scarabs, mostly from bait pitfall traps, in three subfamilies and 57 species (Table 4). Based on previous work (Valencia and Alonso 1997, Valencia 1998), we registered 18 new records for Camisea (Table 4). The most abundant species in the traps was *Onthophagus* sp. 4 (169 individuals), followed by *Deltochilum* sp. 1 (99 individuals) and *Coprophanaeus* sp.1 (96 individuals), a pattern previously noted for the region (Valencia 1998).

Trophic and functional segregation by traps is clearly shown in the case of Scarabeidae. Only 15 species were sampled with pan pitfall traps, while 53 species were found in the bait pitfall traps (Table 4). Species composition by presumed feeding preference (based on trap choice) was coprophagous, 17 species (30%); copro-necrophagous, 14 species (24.6%); generalists, 11 species (19.3 %); and necrophagous, 10 species (17.5%).

4.5 Summary

In summary, our work represents the documentation of arthropod diversity at the Pagoreni well site and surroundings, based on several unrelated taxonomic groups: Araneae, Orthoptera, Coleoptera and Coleoptera-Scarabaeidae. Among the Araneae, we recorded 83 species from 19 different families with Oonopidae, Lycosidae and Corinnidae the most abundant in the samples. In the family Orthoptera, the Gryllidae were the most abundant in the traps; 11 species were recorded. We found 103 species of Coleoptera in 13 major families; the most abundant in the samples were Chrysomelidae, Carabidae, and Curculionidae. In the Coleoptera-Scarabeidae, 57 distinct species were recorded, primarily from bait pitfall traps. Eighteen were new records for the Lower Urubamba Region.

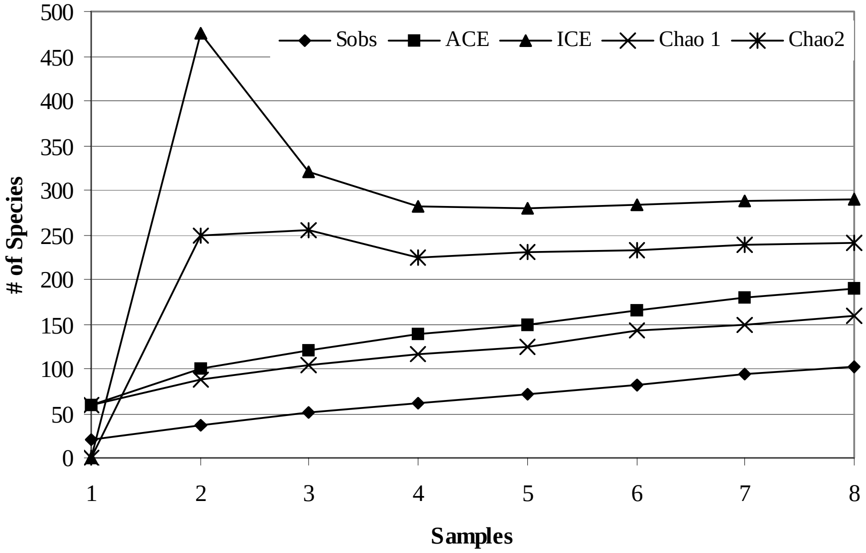

Figure 6. Abundance- and incidence-based species diversity estimators for Coleoptera at all Pagoreni sampling sites (sobs = # of species observed in the pooled *n*-samples [accumulated], ACE = abundance-based coverage estimator of species richness, ICE = incidence-based coverage estimator of species richness, Chao1 = Chao1 richness estimator, Chao2 = Chao2 richness estimator).

Our study indicates that arthropod diversity assessments can be done and samples readily obtained through the sampling and data management protocol we used. The most significant challenge is the processing bottleneck — going from the raw samples in the field to segregated taxa amenable to further study and analysis in the laboratory.

Table 4. Scarabeidae sampled from pitfall and bait pitfall traps at the Pagoreni well site (57 species, 898 individuals total; listed by bait type, functional group and feeding preference [A= Saprophagous, N=Necrophagous, CN=Copro-necrophagous, C Coprophagous, G=Generalist, S=Stenophagous, O=Oliphagous, E=Euriphagous]).

Genus	# Individuals	Pan Pitfall Traps	Bait: Fruit	Bait: Fish	Bait: Human Excrement	Bait: Chicken	Functional Group	Feeding Preference
Anaides sp. 1	21	X	X	X	X	X	E	G
Anaides sp. 2	27	X		X	X	X	E	CN
Aphodius sp. 1	8			X	X		E	CN
Ateuchus sp. 5	3				X		S	C
Canthidium sp. 3	3	X			X		E	G
Canthidium sp. 4	12	X		X	X		E	G
Canthidium sp. 5	1	X					S	
Canthidium sp. 6	1				X		S	C
Canthon sp. 3	14				X		S	C
Canthon sp. 5	4					X	S	N
Canthon sp. 6	14	X			X		E	G
Canthon sp. 8	1				X		S	C
Canthon sp. 9	4				X		S	C
Canthonina sp. 1	2			X		X	O	N
Copris sp. 1	1	X					S	
Coprophanaeus sp. 1	96			X	X		E	CN
Coprophanaeus sp. 3	16		X	X		X	E	G
Coprophanaeus sp. 4	7			X		X	O	N
Coprophanaeus sp. 5	2			X		X	O	N
Deltochilum sp. 1	99	X		X	X	X	E	CN
Deltochilum sp. 2	4			X	X		E	CN
Deltochilum sp. 4	14		X	X	X	X	E	G
Deltochilum sp. 5	10				X	X	E	CN
Deltochilum sp. 7	2			X		X	O	N
Deltochilum sp. 9	1		X				S	A
Dichotomius sp. 3	1			X			S	N
Dichotomius sp. 5	3				X	X	E	CN
Eurysternus sp. 2	6				X		S	C
Eurysternus sp. 3	15			X	X	X	E	CN
Eurysternus sp. 4	61			X	X	X	E	CN
Eurysternus sp. 5	53			X	X	X	E	CN
Eurysternus sp. 6	8				X		S	C
Ontherus sp. 2	6			X		X	O	N
Onthocharis sp. 1	2				X		S	C
Onthophagus sp. 2	3		X	X			E	G

Table 4. Continued

Genus	# Individuals	Pan Pitfall Traps	Bait: Fruit	Bait: Fish	Bait: Human Excrement	Bait: Chicken	Functional Group	Feeding Preference
Onthophagus sp. 4	169	X	X	X	X	X	E	G
Onthophagus sp. 9	77				X		S	C
Onthophagus sp. 11	1			X			S	N
Oxysternon sp. 1	5				X	X	E	CN
Oxysternon sp. 2	1				X		S	C
Oxysternon sp. 3	2				X		S	C
Phanaeus sp. 1	1				X		S	C
Phanaeus sp. 4	1				X		S	C
Phanaeus sp. 5	1				X		S	C
Pinotus sp. 1	4					X	S	N
Pinotus sp. 2	9		X	X	X	X	E	G
Pinotus sp. 3	3	X	X			X	E	G
Pinotus sp. 4	2			X	X		E	CN
Pinotus sp. 5	8				X	X	E	CN
Pseudataenius sp.	1	X					S	
undetermined sp. 4	9	X		X	X	X	E	CN
undetermined sp. 5	1				X		S	C
undetermined sp. 8	7	X					S	
undetermined sp. 9	60	X	X	X	X	X	E	G
undetermined sp. 11	2	X			X		E	C
undetermined sp. 12	1				X		S	C
Uroxys sp. 3	1			X			S	N

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Diversity and Community Structure of the Spiders of the Lower Urubamba Region, Peru

Saida Córdova and Janine Duarez

(reprinted from Alonso and Dallmeier 1998)

1 Introduction

Spiders have had great success in occupying almost all terrestrial environments. They are extremely diverse, exhibiting a broad range of behavioral strategies and morphological and physiological adaptations (Turnbull 1973).

Spiders are first-level predators on the food chain that have developed several feeding strategies (Coddington and Levi 1991). As such, they play an important role in controlling insect populations.

One of the ways that spiders share their habitat resources is through spatial segregation. The separation can be vertical and horizontal or it may be the result of vegetation structure (Robinson 1981). These factors help explain the distribution, richness and abundance of spiders in different microhabitats.

The principal objective of the present work was to list the species that are found in the study area, analyze the family and species richness, observe the microhabitats that they occupy and determine the spider communities present at the Cashiriari-3 well site — all to serve as the foundation for future monitoring.

2 Methods

The Cashiriari-3 well site is located in the highlands of the Cashiriari drainage in the Camisea region, Cusco Department, Peru. Field work was conducted for 16 days, including at least 72 effective sampling hours, during November and December 1997.

Sampling methods were as follows:

***** viewing the vegetation and other surfaces, known as "looking up;"
***** viewing the vegetation and ground, called "looking up and down;" and
***** viewing the ground between dead leaves and fallen trunks, or "looking down."

Samples were made in seven quadrants of the one-hectare plot at Cashiriari-3 (Comiskey *et al.* this volume). Each quadrant was 20 x 20 meters (m). Five of the quadrants were included in a transect of the plot. Two others were chosen randomly as reference points. We also took some samples along trails at the plot.

During the first hour of daytime work, we looked down for samples. We spent the second hour looking up for samples above the vegetation. Generally this was accomplished from 0900 to 1600 hours. Samples from the trails were generally taken at night (2000 to 2300 hours), employing the looking-up-and-down method.

3 Results and Discussion

3.1 Species composition

We registered 26 families represented by 445 adult individuals and 252 morphospecies (individuals that are grouped into the same species based on morphological characteristics) (see Appendix 1). The families displaying the greatest number of species were Araneidae with 97 species (38% of all species) and Theridiidae with 36 species (14%). Together, these families accounted for more than one-half of the total adult species sampled.

The most common species in the Araneidae family were found in many microhabitats from the ground up to the trees. The genus *Micrathena* was the most species rich with 12 species. The genera *Alpaida, Eustala* and *Parawixia* were represented by five, four and four species, respectively. The genus *Spilasma* contained the largest number of individuals (10) in the family. More than half (55%) of the species were represented by just one or two individuals. This is typical of tropical rainforests.

In the Theridiidae family, the richest genus was the *Arqyrodes* (six species), followed by the *Episinus* (four species). The genus *Thwaitesia* had the largest number of individuals (22). Forty-one percent of the species in this family were represented by one or two individuals.

The third most abundant family was Ulobridae, with 19 species, or 7% of the species sampled. The *Uloborus* genus had the most species, and *Philoponella* had the most individuals (13). Twenty-eight percent of the Uloboridae species had one or two individuals.

3.2 Community structure

The species within the families were organized into four groups according to their capture strategy (see below). Note that there are several modifications in each group (Silva and Coddington 1996).

3.2.1 Orb weavers

The most abundant group (53% of all species) consisted of orb weaver spiders, which spin their webs arranged in two or three dimensions. The genus *Spilasma* varied from others in web shape, while other genera varied in web dimensions and orientation.

In this group, the Araneidae family contained 97 species and 147 individuals, or 71% of all individuals in the family. These spiders occupy diverse microhabitats on the ground and in trees. There were 49 morphospecies, some of which still await identification. The *Alpaida, Acacesia, Araneus, Chaetasis, Eustala, Hypognatha, Mangora, Micrathena, Parawixia, Spilasma*, and *Wagneriana* have also been reported near Pakitza, Manu.

Individuals of the genus *Deinopis* (one species and eight individuals) were found at night, primarily in dry leaves. Tetragnathidae, represented by nine species and 10 individuals, construct circular webs of horizontal orientation in various microhabitats. The most abundant genus was *Leucauge*, while Theridiosomatidae had 10 species and 14 individuals. Uloboridae, with 19 species and 46 individuals, are solitary in nature, camouflaging themselves in vegetation. These spiders can usually be found in rolled-up dry leaves. Individuals colonies were also collected for the genus *Philoponella,* while only one individual of the genus Symphitognathidae was found at Cashiriari-3.

3.2.2 Sheet-line weavers

Sheet-line weavers made up the second most abundant group (19% of all species). Characteristically, these spiders hunt by recognizing signals that their prey emit when making contact with the web.

Theridiidae was the dominant family, with 75% of all species in the group. Spiders in the genus *Hahniidae* (two species and two individuals) spin very delicate webs that are easy to see.

Spiders of the Linyphiidae (five species, seven individuals) are very small and fairly uncommon in neotropical lowland forests. They occupy several microhabitats from the ground up the trees.

Pholcidae spiders (three species and 19 individuals) spin conspicuous webs found from the ground up to the trees. This genus is found throughout Cashiriari-3, occurring most frequently at the base of trees up to one meter in height.

Scytodidae (one species and eight individuals) are associated with dry leaves; nearly all of these samples were collected at night.

The Theridiidae (36 species and 75 individuals) are found in many microhabitats from the ground up to the trees. These spiders vary in size from small to medium and may be solitary or colonists or, as with the cleptoparsites (individual spiders that feed on prey captured in the webs of other spiders), they may be web constructors.

We also found one individual (male) of one species of Synotaxidae during night collections.

3.2.3 Ambush predators

The ambush predators accounted for 13% of all species collected. Spiders in this group are generally quiet for long periods of time, waiting for their prey.

Ctenidae was the dominant family, with 47% of the species (15 species, 25 individuals). These spiders have nocturnal habits and occupy different microhabitats from the ground up to the trees. Some genera (*Ancylometes*, *Ctenus*, and *Centroctenus*) were found over leaves or stones that were very close to the edge of streams. It appears that an unrecorded species was found in this family.

Heteropodidae (10 species and 11 individuals) display nocturnal habits and generally are found over leaves at night or inside rolled-up leaves in the day.

Mimetidae (one species, one individual) was represented by just the genus *Gelanor*. This family contains small- and medium-sized spiders that prey on other spiders by lying in wait or invading the webs of their prey (Chickering 1956).

The Oxyopidae (one species, one individual) are active during the day, living on leaves or branches where they pursue their prey. In the neotropics, they are represented by six genera.

The Pisauridae (one species and one individual) are good hunters. They are active during the day and are found across various types of dead-leaf habitats. Many live near water or on the surface of water. The female carries the fertilized eggs with her mouth parts.

Spiders of the Thomisidae (three species and four individuals) lie in wait for their prey, camouflaged in the flowers or other parts of plants such as bark. Some can change color.

Trechaleidae (one species, one individual) are active during the day and are found across various microhabitats in dead leaves and near humid areas (rivers, lagoons and swamps).

3.2.4 Cursorial hunters

This group does not use webs for capture. Rather, these spiders move slowly in their habitats in search of prey. The group contains 15% of all species sampled.

The Anyphaenidae (six species and nine individuals) live in foliage and hide among rolled-up leaves.

Caponiidae (one species, one individual) spiders run quickly and are found in dry climates and under hot rocks.

Spiders of the Corinnidae (seven species, nine individuals) sometimes resemble ant species that share the same microhabitats.

The majority of Lycosidae (three species, eight individuals) hunt their prey on the ground and in vegetation. A few species weave webs or build traps on the ground. The females carry the egg sacs with their mandibles.

Miturgidae (one species, one individual) are found in low-lying bushy vegetation. They take refuge in dry, large rolled-up leaves dressed inside with silk. These spiders are quite rare and have nocturnal habits.

The Oonopidae (four species and four individuals) are tiny spiders that normally measure from one to three millimeters in length and are frequently armed with numerous spines. They live in dead leaves or below tree trunks. Most are found in tropical zones, but sometimes in temperate climates.

Spiders of the Salticidae (16 species, 26 individuals) are found in almost all microhabitats, including dead leaves and the trunks, leaves, and bark of trees. Most were collected during the day.

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Appendix 1. List of spiders found at the Cashiriari-3 well site.

ORB WEAVERS

Araneidae

Parawixia kochi
Parawixia spp. (3 species)
Micrathena triangularispinosa
Micrathena triangularis
Micrathena plana
Micrathena spp. (9 species)
Taczanowskia sp.
Acacesia cf. *benigna*
Acacesia sp.
Wagneriana undecimtuberculatta
Wagneriana spp. (2 species)
Eustala spp. (4 species)
Hypognatha spp. (3 species)
Alpaida truncata
Alpaida delicata
Alpaida spp. (3 species)
Spilasma duodecimgutata
Spilasma sp.
Araneus spp. (2 species)
Metazygia sp.
Witica sp.
Mangora spp. (3 species)
Eriophora sp.
Enacrosoma sp.
Eustala sp.
Larinia sp.
Chaetasis sp.
Araneidae spp. (49 species)

Deinopidae

Deinopis sp.

Tetragnathidae

Leucauge spp. (3 species)
Cyrtognatha sp.
Tetragnathidae spp. (5 species)

Theridiosomatidae

Ogulnius sp.
Theridiosoma spp. (2 species)
Natlo spp. (2 species)
Theridiosomatidae spp. (5 species)

Uloboridae

Miagrammopes spp. (3 species)
Uloborus spp. (4 species)
Philoponella republicana

Appendix 1. Continued

- *Philoponella* spp. (2 species)
- Uloboridae spp. (9 species)

Symphytognathidae

- Symphytognathidae sp.

SHEET LINE WEAVERS

Hahniidae

- Hahniidae spp. (2 species)

Linyphiidae

- *Dubiaranea* sp.?
- Linyphiidae spp. (4 species)

Pholcidae

- Pholcidae spp. (3 species)

Scytodidae

- *Scytodes* sp.

Theridiidae

- *Achaearanea* spp. (2 species)
- *Argyrodes atennuattus*
- *Argyrodes* spp. (5 species)
- *Chrosiothes* sp.
- *Dipoena* cf. *tiro*
- *Dipoena* spp. (2 species)
- *Echinotheridion* sp.?
- *Episinus* spp. (4 species)
- *Helvibis* spp. (2 species)
- *Phoroncidia* sp.
- *Theridion* sp.
- *Thwaitesia* spp. (2 species)
- Theridiidae spp. (14 species)

Synotaxidae

- Synotaxidae sp.

AMBUSH PREDATORS

Ctenidae

- *Ancylometes bogotensis*
- *Ancylometes* spp. (2 species)
- *Centroctenus auberti*
- *Centroctenus* sp.
- *Ctenus carvalhoi*
- *Ctenus* cf. *crulsi*
- *Ctenus* cf. *inaha*
- *Ctenus villasboasi*
- *Cupiennius* cf. *granadensis*
- *Enoploctenus* sp.
- *Phoneutria* sp. ?
- Ctenidae spp. (2 species)

Heteropodidae

- *Olios* sp. ?
- Heteropodidae spp. (9 species)

Mimetidae

- *Gelanor* sp.

Oxyopidae

- Oxyopidae sp. 1

Pisauridae

- *Taumasia* sp.

Thomisidae

- *Tmarus* sp.
- Thomisidae spp. (2 species)

Trechaleidae

- Trechaleidae sp.

CURSORIAL HUNTERS

Anyphaenidae

- Anyphaenidae spp. (6 species)

Caponiidae

- Caponiidae sp.

Corinnidae

- *Castianeira* sp.
- *Corina* sp.
- *Myrmecium* sp.
- Corinnidae spp. (4 species)

Lycosidae

- *Porrimosa* sp.
- Lycosidae spp. (2 species)

Miturgidae

- Miturgidae sp.

Oonopidae

- Oonopidae spp. (4 species)

Salticidae

- Salticidae spp. (16 species)

Undetermined

- Aranoidea (3 species)

Assessment of the Scorpions of Lower Urubamba Region, Peru

José Antonio Ochoa and Gorky Valencia

1 Introduction

The scorpion fauna of South America has been comprehensively described for several countries, including Argentina (Maury 1979, Acosta and Maury 1998), Colombia (Lourenco 1997, Lourenco and Otero Patiño 1998) and Ecuador (Lourenco 1995a). For Peru, however, descriptions have been sketchy.

The earliest records of scorpions in Peru date from the late nineteenth and early twentieth centuries, when naturalists often described species inaccurately. As an example, the description of *Brachistosternus ehrenbergi*, the first recorded species of Peruvian scorpions, reported "Peru" as the type location.

Mello-Leitao (1945) conducted the first thorough assessment of Peruvian scorpions, listing 14 species and subspecies. In the Peruvian Amazon, recorded species included *Teuthraustes amazonicus* from Pebas and the area from Moyobamba to the Huallaga River, *Chactopsis insignis* from Moyobamba and *Tityus metuendus* from Iquitos. Subsequently, Francke (1977) published what is considered the most recent list of the scorpion fauna in Peru, showing 37 species and subspecies for the entire country, but only seven from the Peruvian Amazon.

Building on Francke's list, isolated records have been published that increased the number of species reported. But most of these lists cover areas in northern and central Peru, leaving the southern part of the country — and particularly the area covered by lowland tropical forest — unexplored (Aguilar 1968; Arboleda *et al*. 1973; Cáceres *et al*. 1972; Lourenco 1984a,b, 1986a, 1987, 1992, 1995b; Maury 1974, 1975).

This study was part of a major effort to assess and monitor the biodiversity in the Lower Urubamba Region (LUR) of southeastern Peru. Shell Prospecting and Development, Peru sponsored the project as part of its exploration for natural gas deposits in region. The Smithsonian Institution's Monitoring and Assessment of Biodiversity Program coordinated the biodiversity study. This volume documents the richness of the flora and fauna in the area (see also Dallmeier and Alonso 1997; Alonso and Dallmeier 1998, 1999), while this article provides the results of the assessment of the scorpions collected during 1997 and 1998. We also present the first list of all species of scorpions registered in the area, as well as a review of available literature concerning those species.

2 Study area

The LUR takes its name from the Urubamba River. The region is a large, hilly valley surrounded by mountains, with steeply sloping hills ranging in elevation from less than 500 meters (m) to more than 1000 m (slopes between 50° and 70°). Average annual precipitation is 3500 millimeters, and the annual average temperature is 22° C. Lowland, tropical, primary rainforest dominates the area (Comiskey *et al.* this volume). We focused our efforts on the six sites shown in Table 1.

3 Methods

Opportunistic sampling and a variety of traps commonly used to sample arthropods comprised our primary sampling methods. We conducted all sampling within a series of one-hectare (ha) and 0.1-ha permanent vegetation research plots (Comiskey *et al.* this volume, Campbell *et al*. In press). A brief description of the methodology and traps follows.

3.1 Opportunistic sampling

We searched the forests in a non-systematic manner and collected scorpions from the lower understory layer, leaf litter, fallen trees and holes.

3.2 Pitfall traps

At each site, we buried 40 disposable cups (each 255 cubic centimeters and filled one-third with 70% ethyl alcohol to preserve the specimens) so that the lip of each cup was level with the ground. We placed the cups in two rows of 20 cups. The pitfall traps were used mainly in 1997.

3.3 Pan traps (pan pitfall traps)

We buried yellow bowls 27 centimeters (cm) in diameter and 8 cm high in two rows of five traps each (10 total). The bowls were situated at ground level. We filled each trap with a solution of water, liquid detergent (a surfactant) and saturated salt (a preservative).

3.4 Malaise pan traps

Similar in size to the pan traps, these gray traps were set in rows of five directly beneath the central net of aerial malaise traps described by Finnamore (this volume).

We checked the traps each day of the study, collecting and separating all materials and preparing the specimens. Author Ochoa was responsible for initial examination and identification of the material, based on the literature, which presented fundamental morphological features and pigmentation patterns. We deposited the specimens at the Universidad Nacional Mayor de San Marcos in Lima.

4 Results and Discussion

We recorded six species of scorpions in the LUR — five from the family Buthidae and one from the family Chactidae (Table 2). This is the largest number of species recorded at a single site in Peru, although Ochoa (unpublished data) also recorded six species in Cajamarca, Peru. To compare, other regions in South America — Imataca in Venezuela, Manaus in Brazil, parts of French Guyana (Lourenco 1986a) and Chacani in Argentina (Acosta and Maury 1998) — posted slightly higher richness values (between seven and nine species). Those results, however, represent multiple research efforts over longer periods of time than this study.

This study adds to the knowledge regarding species distribution in South America. *Tityus silvestris* and *T. ecuadorensis* have wide distributions, with *T. silvestris* occurring throughout Guyana and Brazil and *T. ecuadorensis* occurring throughout the eastern Andean piedmont in Ecuador and Peru (called Lourenco's Andean Corridor; Lourenco 1986b). The genus *Ananteris* is regarded as rare and endemic throughout its range (Lourenco 1982). Thus the existence of a species from this genus was a highlight of our study — the first record of *Ananteris* in Peru. The genus *Chactas* typically occurs in Colombia and Venezuela. As these countries are considered to be the dispersion center for this genus, our record may widen that distribution range.

Species richness was highest at Pagoreni (five species). No other site had more than two species. The Pagoreni

Table 1. Six sites for scorpion assessments in the Lower Urubamba Region, Peru (1997 and 1998).

Site	Latitude (S)	Longitude (W)	Altitude (m)
Cashiriari-2	11º 51' 15.3"	72º 46' 45.6"	579
Segakiato	11º 48' 23"	72º 52' 51"	340
Las Malvinas	11º 52' 37"	72º 56' 48"	360
Shivankoreni	11º 47' 20"	72º 55' 07"	390
Pagoreni	11º 42' 22.5"	72º 54' 10.7"	465
San Martín - 3	11º 47' 09.8"	72º 42' 05.3"	474

Table 2. Scorpions registered in the Lower Urubamba Region, Peru (species listed by site and collection method).

	Site[1]						Methods[2]
Species	Cash-2	Sega	Lasm	Shiv	Pag	Sanm-3	
Buthidae							
Ananteris sp.					X		P
Tityus ecuadorensis				X	X	X	O, F
Tityus silvestris					X		F, O
Tityus sp. 1					X		P
Tityus sp. 2	X	X					O, F
Chactidae							
Chactas sp.		X	X		X	X	O, Mp
Total	1	2	1	1	5	2	

[1] Cash-2 = Cashiriari-2, Sega = Segakiato, Lasm = Las Malvinas, Shiv = Shivankoreni, Pag = Pagoreni, Sanm-3 = San Martín-3.
[2] P = pan traps, F = pitfall traps, O = opportunistic collection, Mp = malaise pan traps.

findings represent a record number of sympatric species for Peru. Note that researchers also recorded the highest richness of trees (Comiskey *et al*. this volume), large mammals (Boddicker *et al*. this volume) and Coleoptera Scarabaeinae (Valencia this volume) at Pagoreni.

Chactas sp. and *T. ecuadorensis* were the most widespread scorpion species. They were recorded at four and three of the six sites, respectively. The other scorpion species were recorded only at one or two sites (Table 2).

The three methods were effective at assessing scorpions. Opportunistic collecting yielded four species (Table 2). However, it is important to note that this technique was the most intensively employed because researchers studying other taxonomic groups and habitats helped collect scorpions. Pitfall traps yielded three species, while pan traps and malaise pan traps combined yielded three species (Table 2).

Overall biodiversity in the LUR, discussed in this volume, is incredibly rich, and the scorpion fauna is no exception. We believe that future studies in the region will produce an even more extensive list of scorpion species. We suggest that future studies focus on more intensive and quantitative sampling to increase understanding of the relationships between the scorpions and their habitat. In addition, further taxonomic studies on the specimens collected and identified to the genus level may result in reclassification as new species. This would indicate high levels of endemism and diversity for this area in Peru and for the neotropics in general.

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Species Richness of the Wasp Community of the Lower Urubamba Region, Peru

Albert T. Finnamore

1 Introduction

Wasps, with more than 100,000 described species, are among the five largest groups of animals known to science. The Order Hymenoptera includes bees, ants, predatory wasps, parasitic wasps and sawflies among others. Hymenoptera occupy virtually all microhabitats in terrestrial ecosystems, but are almost completely absent from aquatic habitats. They are among the most beneficial groups of organisms from a human perspective and one of the most important to ecosystem dynamics. As examples, bees are essential pollinators of many flowering plants, and ants are the dominant animals in most terrestrial ecosystems — very often, the "drivers" in tropical ecosystems. Predatory and parasitic wasps regulate the populations of most groups of insects and spiders, including the populations of other wasps.

Wasps are seldom used in environmental assessments or ecosystem monitoring because it is very difficult to obtain species-level identification of specimens. In addition, in the tropics there are few identification guides for Hymenoptera, and there is a shortage of highly trained tropical Hymenoptera specialists. Because of their high species diversity and the various functions they perform in ecosystems, however, the wasps are uniquely positioned to provide early evidence of changes in the environments they occupy.

As part of the Smithsonian Institution/Monitoring and Assessment of Biodiversity Program's biodiversity assessment project at the Pagoreni well site in southeastern Peru, the author worked with Peruvian students to evaluate the Hymenoptera. The objectives were to describe the structure of the Hymenoptera species assemblages associated with vegetation plots in the vicinity of the Pagoreni well site, determine the groups of Hymenoptera most suitable for ecosystem assessments in the study area and determine the effectiveness of the protocols for sampling Hymenoptera.

2 Methods

The assessment of Hymenoptera diversity took place from May 10 to May 24, 1998. We selected vegetation plots 2, 3, 8 and 10 (see Alonso *et al.* 1999) at Pagoreni for trap placement. We chose the plots based on forest type and degree of natural disturbance (Campbell *et al.* In press). The plots had been established by the botanical team in April 1998, using a randomly placed, modified Whittaker design (Shmida 1984, Stohlgren *et al.* 1995).

Sampling protocols generally followed the recommendations of Finnamore (1997) and Finnamore *et al.* (1998) and included Berlese extraction of litter samples, pan traps, Malaise traps, aerial (or canopy) Malaise traps and light traps. Only samples from the pan, Malaise and aerial Malaise techniques were processed for inclusion in this assessment.

2.1 Pan traps

Pan traps are shallow, relatively large bowls (27 centimeters in diameter by 8 centimeters deep). We placed the traps into the ground flush with the top rim of the trap. We filled each trap three-quarters with water and enough salt (a preservative) to make a saturated solution and added about five drops of liquid detergent as a surfactant to break the surface tension of the water, thus causing the insects to drown.

We used yellow-colored pan traps. Insects, particularly flying insects, are differentially attracted to color, but most are attracted to bright yellow. As a result, pan traps attract a broad spectrum of low-flying insects.

We installed 10 pan traps in each vegetation plot. Before installation, we numbered each pan trap on the inner top rim with waterproof ink. We used a shovel to cut through and remove the root mat and soil and create a depression closely approximating the size of the pan trap, taking care to minimize disturbance in the adjacent microhabitat.

Every 48 hours, we serviced the traps by scooping out the contents with an aquarium net (dragging the net gently near the bottom of each trap in one direction several times) and then either reusing the old solution or replacing it with fresh water, salt and detergent. Before scooping we removed large objects such as leaves, twigs or small vertebrates that may have fallen into the trap.

2.2 Malaise traps

Malaise traps capture flying insects up to one meter above ground level in or above surface vegetation. They are most effective in sampling arthropods along the edge effects of forest communities, but they can be used in forests, wetlands and grasslands and non-vegetated ecosystems such as dunes, shorelines, salt flats or rock surfaces. While Malaise traps are expensive and relatively difficult to install, they are easy to service and are among the most productive samplers in relation to species richness and number of specimens captured.

The Malaise trap is large, open-sided and tent like. It functions as a flight intercept for insects. Insects strike the central panel of the trap and attempt to avoid the barrier either by dropping to the ground or by flying upward. Those flying upward are contained by the roof and concentrated in the collecting head of the trap, where they drown in alcohol. The trap is black in color with a white roof, which reinforces any positive response to light in diurnal insects. The collecting head is attached to the higher end of the trap, taking advantage of the tendency for insects with a positive response to light to move upward.

We placed light gray pan traps along the middle panel to sample insects that drop to the ground after contact. We placed the pans on top of the ground. This ensures that only insects intercepted by the Malaise trap end up in the pans and permits the analysis of Malaise material separately from pan trap material.

The Malaise trap was suspended between vertical poles placed at each end of the trap. The poles were each held upright and in place by three cords tied to stakes in the ground. Locking aluminum extension poles are easiest to use but because they break under extreme wind, more flexible wooden poles may be appropriate. The collecting head is constructed of white, translucent plastic and should contain a side vent, near its top, covered with fine mesh material to allow air to flow (but not insects) through the collecting head. Otherwise, insects may be repelled by the hot, dead air space formed by an unventilated collecting head or trapped by condensation on the upper, inner surface of the collecting head where they will decompose.

We installed Malaise traps in two-person teams, orienting the collecting head (high end of the trap) toward the lightest part of the habitat in the forest. We cut back shrub vegetation directly beneath the trap to a height of several centimeters above the ground surface.

We placed two traps at each vegetation plot — one at the high point, the other at the low point. We serviced the traps every 48 hours by removing the Malaise head and replacing it with another filled with fresh alcohol. The head containing specimens was labeled with site, trap number and date. The cap from the replacement head was used to seal the head containing specimens. We also serviced the pan traps under the Malaise central panel by scooping out the contents with an aquarium net in the same manner as with the pan traps.

2.3 Aerial malaise trap

The aerial Malaise trap is recommended for general sampling of arthropods (e.g., aerial dispersers, tourist guild) that have a positive response to light and move through the three-dimensional space of the canopy. The main body of the trap consists of a rectangular cross-

Table 1. Georeference of the high point of each vegetation plot used for arthropod sampling (readings obtained using Garmin GPS 12 XL in map datum WGS 84).

Plot	Latitude	Longitude
Plot 2	11°42.214' S	72°53.885' W
Plot 3	11°42.111' S	72°53.926' W
Plot 8	11°42.195' S	72°54.080' W
Plot 10	11°42.277' S	72°54.753' W

panel of dark netting with a triangular roof of white netting connected to a collecting head. A triangular bottom of dark netting is connected to a collecting jar, which has overflow holes to void excess rainfall. Trap shape and support are maintained by a top and bottom frame constructed of PVC piping with shock-cord running through it.

We placed one aerial Malaise trap in the mid-level canopy as close as possible to the center of each vegetation plot. We suspended a monofilament line over a branch in the mid-level canopy (using a fishing pole and lead weights) and pulled a cord over the branch by attaching it to the monofilament. We then attached the aerial Malaise trap to one end of the cord and pulled it into the canopy gap. We filled the top and bottom collecting heads with alcohol.

To service the traps, we lowered the trap every 48 hours and removed the collecting heads, replacing them with others filled with fresh alcohol. The heads containing specimens were labeled with site, trap number and date, and we used the caps from the replacement heads to seal the heads containing specimens.

2.4 Specimen processing

We processed each trap separately and completed a label containing the site, trap number and date of collection for all specimens and subsamples of the specimens. We processed all specimens in the field camp laboratory on the same day that we collected them from the traps. We rinsed the contents of each sample under a gentle stream of water for several minutes to remove dirt, salt and detergent and then placed the specimens in a specimen bag covered with alcohol to at least the level of sample volume. The labels were placed inside the bags with the specimens.

We sorted the samples to ordinal level. Social insects such as ants are frequently sampled in very high numbers because of the proximity of the traps to a colony or to an ant trail. In these cases, the sorters removed only a few of each of the species that they recognized. Hymenoptera were then processed by the author to morphospecies level. All specimens were removed from alcohol and air-dried for a few minutes until surface microsculpture became apparent. One specimen of each species was selected for mounting and used as a morphotype for comparison of morphospecies in other samples. Each morphospecies was assigned a reference number. All specimens of each morphospecies in each sample were identified and counted, and the results were entered into a spreadsheet for analysis.

2.5 Data analysis

We entered morphospecies data into the EstimateS version 5 species estimation program (Colwell 1997). We used the Abundance-based Coverage Estimator (ACE) and the Incidence-based Coverage Estimator (ICE), available in the EstimateS package, to estimate species richness at each site, at all sites and for selected groups at all sites. We also used ACE and ICE to calculate the proportion of common species to infrequent species at the sites and for selected groups.

Table 2. Summary of Hymenoptera species sampled in traps at the Pagoreni well site (Chalcidoids, 12 species identified at one site, excluded; CMT = canopy malaise trap; Mt = malaise trap; P = pan trap).

Site	2			3			8		10	
Date	13-May		21-May	12-May		18-May	14-May	20-May	13-May	
Trap	Mt, CMT	P	P	Mt, CMT	P	P	P	P	P	Species Total
Apiformes	11	1	0	14	0	0	0	0	2	26
Sphecidae	4	1	1	2	0	2	0	3	0	12
Pompilidae	1	1	0	0	1	0	1	1	0	4
Vespidae	14	1	4	12	0	0	0	0	1	25
Formicidae	12	59	30	4	26	6	50	5	34	105
Mutillidae	0	0	2	0	0	0	0	0	0	2
Tiphiidae	1	2	2	0	1	0	1	1	1	6
Bethylidae	27	2	4	8	1	1	0	0	1	35
Scleroggibidae	1	0	0	0	0	0	0	0	0	1
Dryinidae	0	1	2	0	1	0	1	0	0	3
Chrysididae	0	1	0	0	0	0	0	0	0	1
Braconidae	19	11	8	14	1	5	4	5	3	53
Ichneumonidae	4	8	3	2	3	1	1	0	4	26
Evaniidae	7	1	0	4	0	1	0	0	0	12
Ceraphronidae	6	6	3	0	3	3	3	1	2	9
Diapriidae	9	8	6	4	1	6	3	3	3	24
Platygastridae	15	5	2	3	0	0	1	0	0	17
Scelionidae	15	13	10	4	9	4	10	9	11	33
Cynipoids	9	1	0	5	0	3	1	0	1	16
Tenthredinidae	0	0	0	1	0	0	0	0	0	1
TOTAL	155	122	77	77	47	32	76	28	63	411

Table 3. Species estimations for wasps (Hymenoptera), 306 species, excluding ants (Formicidae) (ACE = abundance-based coverage estimator of species richness; ICE = incidence-based coverage estimator of species richness).

	Plot 2 pan traps	Plot 3 pan traps	Plot 8 pan traps	Plot 10 pan traps	Plots 2, 3, 8, 10 pan traps	Plots 2, 3 Malaise traps
Observed species	96	41	40	29	142	193
Specimens	225	59	97	62	432	378
ACE	263	143	107	87	348	494
ICE	294	164	104	111	367	828
Common species	2	0	2	0	8	3
Infrequent species	261	143	105	87	340	375
Ratio (common: infrequent)	1:131	0:143	1:52.5	0:87	1:42.5	1:125

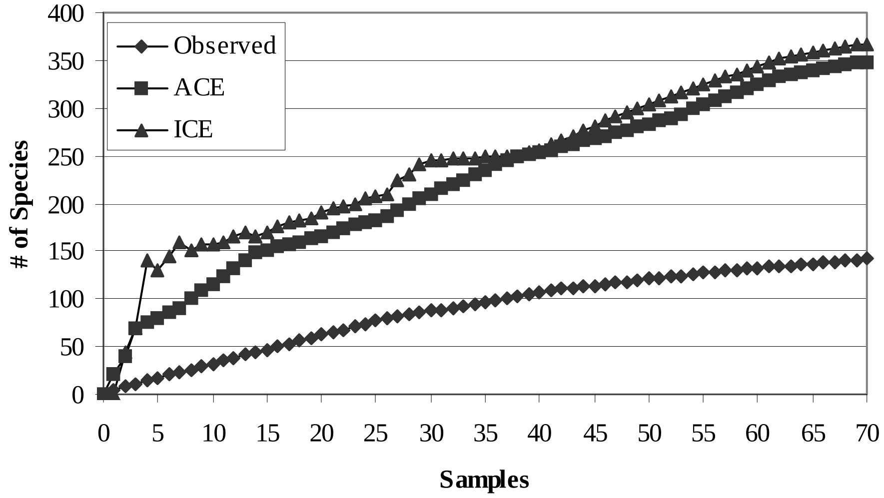

Figure 1. Estimation of Hymenoptera species richness, excluding ants, at plots 2, 3, 8 and 10, Pagoreni (432 specimens, pan trap data).

3 Results and Discussion

Vegetation plots 2, 3 and 8 were in relatively similar forest types, while plot 10 differed in a number of aspects, but especially in its greater abundance of lianas. Plot 3 offered a chance to sample the arthropod fauna in vegetation modified by a natural disturbance. A single canopy emergent tree was estimated to have fallen within the previous decade (see Comiskey *et al*. this volume); it spanned the width of the plot. Global position readings taken at the high point of the four plots are presented in Table 1.

The 20 days of field time permitted 14 consecutive 24-hour sampling periods (after trap installation and removal). Traps were serviced on a two-day cycle and produced about 360 samples. Morphospecies of Hymenoptera were sorted from 20% (76) of the samples over a 10-day period, representing two servicing periods or four days of sampling time. An average of 7.6 samples per day were processed to morphospecies level.

A total of 423 morphospecies of wasps were found in the 76 samples examined. A summary of the groups

Table 4. Species estimation for ants (Formicidae), 105 species (ACE = abundance-based coverage estimator of species richness; ICE = incidence-based coverage estimator of species richness).

	Plot 2 pan traps	Plot 3 pan traps	Plot 8 pan traps	Plot 10 pan traps	Plots 2, 3, 8, 10 pan traps	Plots 2, 3 Malaise traps
Observed species	66	30	52	34	103	12
ACE	102	90	170	79	156	25
ICE	104	95	184	87	158	42
Common species	1	1	0	0	4	0
Infrequent species	103	94	184	87	154	42
Ratio (common: infrequent)	1:103	1:94	0:184	0:87	1:38.5	0:42

Table 5. Species estimation based on major groups of Hymenoptera at the four Pagoreni vegetation plots (ACE = abundance-based coverage estimator of species richness; ICE = incidence-based coverage estimator of species richness; Proctos = proctotrupoid families *s.l.*).

Plots 2, 3, 8, 10 Pan traps	Aculates except ants	Ants(Formicidae)	Ichneumonoids	Proctos
Observed species	36	103	43	57
Specimens	64	na	71	290
ACE	95	156	102	98
ICE	140	158	154	99
Common species	1	4	1	6
Infrequent species	94	154	101	92
Ratio (common:infrequent)	1:94	1:38.5	1:101	1:15.5

sampled at each site is presented in Table 2. One group, the superfamily Chalcidoidea, was excluded because specimens collapsed after drying. The aculeate wasps (Apiformes to Chrysididae in Table 2), with 220 species, accounted for the single largest faunal component sampled at the sites. One aculeate family, the ants (Formicidae), with 105 species, clearly dominated in species richness at all sites sampled. It was followed by the proctotrupoid groups (Ceraphronidae, Diapriidae, Platygastridae and Scelionidae) with 86 species combined and the ichneumonoids (Braconidae and Ichneumonidae) with 79 species.

We used ACE and ICE to estimate species richness for all four plots using pan trap data and data from Malaise and aerial Malaise traps for plots 2 and 3. The results of those calculations are presented in Tables 3 and 4. Figure 1 presents the species estimation curves generated by the ACE and ICE calculations for pooled plot data.

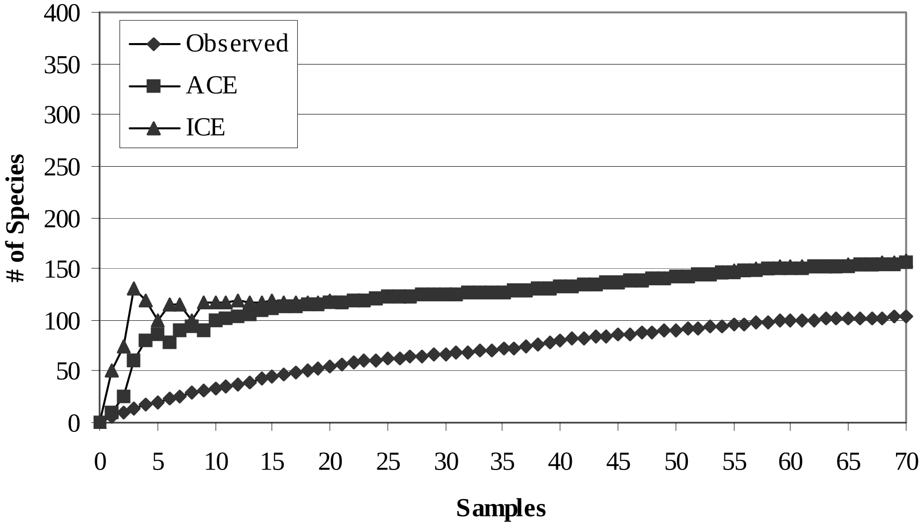

Figure 2. Estimation of ant species richness at plots 2, 3, 8 and 10, Pagoreni (pan trap data).

Table 6. Regional scale, common morphospecies abundance distribution among vegetation plots (* additional specimens of these species obtained from malaise sampling).

Morphospecies reference numbers	Plot 2	Plot 3	Plot 8	Plot 10	Total specimens
Ants F1	9	11	0	2	22
F2	11	10	1	3	25
F4	10	2	1	3	16
F33*	6	0	4	0	10
F35	5	0	6	0	11
Braconid B16	9	1	2	0	12
Procto C3*	6	2	1	1	10
D12	1	0	19	0	20
D14	8	1	3	0	12
S7	20	3	14	2	39
S12	29	7	9	10	55
S13	8	0	1	2	11
Eucoilid E12	0	1	1	10	12
Total specimens	122	38	62	33	255
Total species	12	9	12	9	

The number of samples sorted to morphospecies for plots 2 and 10 was insufficient to obtain the asymptote of the estimation curves, indicating that the resulting estimates contain substantial error. However, ant data from all four plots were sufficient, or nearly so, to obtain the asymptote of the estimation curves, indicating that the number of samples sorted was sufficient to provide an estimation of species richness given the number of workers sampled. On the regional scale when data for plots 2, 3, 8 and 10 were pooled and the regional species estimations were calculated, the ant data provided a much flatter curve than the Hymenoptera data, excluding ants (Figures 1 and 2). The Malaise trap data also indicated that insufficient samples were processed to obtain meaningful results. The Malaise trap and pan trap samples shared only 50 (12%) species of which the proctotrupoid groups accounted for 28 species (56%).

The total estimated species richness for the Pagoreni sites sampled was calculated using the more conservative ACE estimates by adding the figures for pooled pan traps and Malaise traps (Table 3), subtracting the common species (12%), and then adding the ant species estimates for pooled pan traps (Table 4). New morphospecies of ants in the Malaise traps were insignificant. That calculation produced an estimate of about 900 species of wasps that could be expected to be sampled at the four Pagoreni sampling sites using the current sampling protocols.

Common species in Tables 3, 4 and 5 were considered to be those species with more than 10 specimens in a sample or those species occurring in more than 10 samples. The common species for each plot in Tables 3 and 4 showed either one, two or no species. These figures were a clear indication of insufficient samples processed to identify the common species and were reflected in the very high ratios of common to infrequent species. On a regional scale (pooled plot data), 13 common species were identified because of the higher number of samples used. These were presented in the pooled data columns (plots 2, 3, 8, 10) in Tables 3 and 4 and for all columns in Table 5. The proctotrupoids demonstrated the lowest ratios of common to infrequent species (1:15) on a regional scale. The ants were next (1:39), followed distantly by the aculeates (1:94) and the ichneumonoids (1:101). These ratios, especially for ants and the proctotrupoid families, can be monitored for change over time to provide evidence of medium and large-scale changes in the ability of the Pagoreni ecosystems to function.

The distribution of common species among the plots is presented in Table 6. Plots 2 and 3 (respectively, undisturbed and disturbed) were situated in close proximity to each other in a similar forest type. Plot 2 demonstrated a greater species richness overall (162 species in pan traps) than plot 3 (71 species), and plot 2 also had a greater richness in common species. Leaving aside the ant fauna, plot 2 produced 11.8 specimens per common species as determined on a regional scale, while plot 3 produced only 2.5 specimens per common species. The greatest differences between plots 2 and 3 were evident in the preponderance of ant specimens in samples from plot 3. We estimated that 98% of the specimens in samples from plot 3 were comprised of ant workers of the morphospecies listed for that plot in Table 6. The amount of ant material sampled at many of the pan traps in plot 3 could be measured in large fractions of a liter. No other trap in any plot demonstrated such a dominance of ants. Unfortunately, the methodology used to subsample ants (see methodology section) de-emphasized those differences and rendered the ant data much less useful. Since residues of all processed samples were archived, the appropriate data could still be obtained from the samples.

Changes in specimen processing protocols for ants will be needed to obtain data for analysis of common species assemblages. One method is to count the specimens of each ant morphospecies in a known subsample volume, then multiply by the sample volume. Changes in abundances of these species can be monitored over time to provide evidence of small-scale changes in the arthropod structure at Pagoreni.

3.1 Summary

***** Field logistics and infrastructure for the Pagoreni arthropod team were well organized and managed.

***** Based on the number of trap replicates and the ability to generate data that can be used for species richness estimates, the most suitable groups of Hymenoptera for ecosystem monitoring are the proctotrupoid families (Ceraphronidae, Diapriidae, Platygastridae and Scelionidae) and the ants (Formicidae). Malaise trap samples contained high proportions of aculeate wasps other than ants; it is expected that they will also prove suitable for ecosystem monitoring when similar numbers of Malaise samples are processed.

***** The number of trap replicates appears to be suitable for providing data and results in the short sampling window (14 days), given that a greater proportion of the samples will be processed to morphospecies level than the 20% processed to date.

***** Changes in the specimen processing protocols for ants must be made to provide abundance data (i.e., count the specimens of each ant morphospecies in a known subsample volume, then multiply by the sample volume).

***** Processing of samples to morphospecies in the field is an inefficient use of resources. Only 21% of the samples could be processed, an insufficient amount to produce results at plot scale and barely sufficient to produce results on a regional scale.

***** Field staff should try to obtain samples from as many vegetation plots as possible in each locality. Only four of the 10 vegetation plots at Pagoreni have associated arthropod data sets.

***** Processing all samples to morphospecies level can take two months for every locality sampled. Product and report timelines should be adjusted accordingly.

***** Data analysis and report production can take two to three additional weeks for each locality sampled. Timelines should be adjusted to accordingly.

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Assessment of the Ants of the Lower Urubamba Region, Peru

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1 Introduction

Traditional biological assessment and monitoring programs often devote little attention to the millions of tiny creatures such as microbes and insects that inhabit Earth (Wilson 1988). Ignoring the invertebrates, however, dismisses one of the most important components of the ecosystem. Invertebrates are by far more speciose and numerically dominant than the larger taxa, and they contribute more biomass to ecosystems (Wilson 1987, Gaston 1991). Conservation planning can benefit greatly by including the diverse invertebrate group, which occupies a large number of functional niches and microhabitats throughout the world. There is great potential for the use of arthropods in conservation planning (Kremen *et al*. 1993), and conservation biologists find invertebrates ideal to study because they are readily observed and easily sampled. Many are also sensitive indicators of environmental change.

The family Formicidae — the ants — is particularly well suited for assessment and monitoring programs. Ants are diverse (approximately 9500 described species in 13 subfamilies) and found in abundance in almost every habitat (Holldobler and Wilson 1990). They are numerically dominant in many tropical forest canopy studies, comprising 19% to 50% of the arthropods (Basset *et al*. 1991). One study in the Brazilian Amazon found that ants contributed 80% of the insect biomass and more than 30% of all animal biomass (Fittkau and Klinge 1973). Ants are also ecologically important because they function at many levels in an ecosystem — as predators, prey and detritivores — and have diverse associations with plants as seed dispersers, protectors and herbivores.

Since ants are common and apparent in almost every habitat, they are readily sampled. And many ant species are highly sensitive to microclimate and habitat structure and thus respond rapidly to environmental changes (Majer 1983, Andersen 1990, Bestelmyer and Wiens 1996).

Because of these characteristics, ants are both a profound and logical component of the ecosystem to include in biodiversity assessment and monitoring programs. In the Lower Urubamba Region (LUR) of southeastern Peru, we sampled ants as part of the biodiversity project conducted by the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) in partnership with Shell Prospecting and Development (Peru) B.V. (SPDP). In 1996, the company reestablished a natural gas exploration endeavor in the LUR and asked SI/MAB to initiate a biodiversity assessment and monitoring effort to collect information on potential environmental impacts for use in decision-making.

Below, we summarize the methods used to sample ants in the LUR and discuss our findings from the sampling effort.

2 Study area

The LUR is located in the Lower Urubamba River Valley between Manu National Park and Apurimac Reserve Zone along the eastern foothills of the Andes Mountains (12^o south latitude, 73^o west longitude). The Urubamba, Camisea and Cashiriari rivers run through the valley.

Temperatures in the study area range from 23.5^{o}C to 24.5^{o}C, and the relative humidity typically exceeds 80%. Although the temperature varies little over the year, there are definite wet and dry seasons. Mean annual rainfall, between 3000 and 3500 millimeters, occurs mostly from October through April.

SPDP drilled four test well sites in the study area — San Martin-3, Cashiriari-2, Cashiriari-3 and Pagoreni. The company also planned to construct a gas processing plant and a pipeline to carry the gas from the LUR across the Andes to Peru's Pacific Coast.

3 Methods

We investigated the richness and abundance of ground-dwelling ants in the forest near the San Martin-3 well site and camp from March 8 through March 18, 1997. We sampled ants in biodiversity plot #1 (Comiskey *et al*. this volume), located approximately 500 meters (m) downhill from the camp.

Several techniques have been developed to sample invertebrates, including ants. Factors to consider in choosing the most appropriate sampling methods include the purpose of the project, the habitat and available personnel and financial resources. We selected two standardized, quantitative methods — leaf-litter extraction and pitfall traps — for use at San Martin-3 in a time-compressed effort to record leaf-litter and ground-dwelling ant fauna.

3.1 Leaf-litter extraction

We sampled ant nests and stray, foraging ants. We established two 140-m transects across the biodiversity plot at San Martin-3, locating sampling points every 10 m along the transects, for a total of 30 sampling points. We marked off a one-m^2 quadrat at each point and examined all leaf litter, twigs and rotting logs in the plot for ants. We also scattered cookies over the plot to attract ants and then followed them back to their nests. The samples were preserved in vials containing 70% ethanol.

In examining the leaf litter at each sampling point, we sifted a one-m^2 area of leaf litter (including twigs and rotting branches) to remove all large leaves and pieces of wood. The sifter consisted of a one-centimeter $(cm)^2$ wire mesh screen enclosed in a cotton sack with two handles for shaking. The sack was tied off at the bottom to retain the sifted litter and then opened to move the litter to a bag for transport to the laboratory. At the laboratory, we carefully transferred the contents to a cloth mesh bag over a white plastic sheet or tray. Any ants escaping during this process were captured and preserved in vials of ethanol.

At each sampling point, we also placed a mesh bag containing litter into Winkler sacks and attached the bags with clips to the top wire frame of the sack. We closed each sack at its top, tied a cup of alcohol to the bottom of the sack and hung the sack vertically for 48 hours. The intent was to allow active arthropods such as ants to move through the litter and out of the mesh bag where they fell to the bottom of the Winkler sack and into the cup. We removed all ants from the cups and preserved them in vials of ethanol.

3.2 Pitfall traps

At each corner of each one-m^2 quadrat, we established a pitfall trap by digging a small hole and placing a 0.3 liter plastic drinking cup into it. Soil and leaf litter were replaced around the cup so that its top was even with the soil surface. Approximately 3 cm of ethanol were poured into each cup as a preservative. We laid large leaves over the cups to prevent rain from entering.

Pitfall traps sample active ants and other arthropods as the animals move along the soil and litter surface and then fall into the cup. Pitfall traps were left out for 48 hours, then emptied. Any arthropods in the cups were removed and preserved in vials of ethanol.

3.3 Data analysis and species identification

Analyses of species diversity are difficult for social insects such as ants because the number of individuals sampled does not necessarily reflect the abundance of species, a parameter that is needed to build diversity indices. This occurs because some ant species with large colony sizes may recruit many workers to a bait or send a large number of workers out to forage, while other ant species forage solitarily. For ants and other social insects, abundance is best measured as the number of nests (the reproductive "unit") of each species in an area, which is determined through the intensive sampling method described above. If nests are not sampled, the frequency of capture (measured by the number of samples or traps in which a species is found) can be used to estimate abundance. Species identification was conducted at M. Kaspari's laboratory at the University of Oklahoma.

4 Results and Discussion

A total of 121 ant species were recorded during the study both as strays and in nests. They represent five of the six subfamilies that occur in South America (Appendix 1). The subfamily Myrmicinae was represented by the most species (74), Ponerinae by 33 species, Formicinae by ten species, Dolichoderinae by three species and Pseudomyrmicinae by one species (Appendix 1). Not surprisingly, our sampling method because it centers on leaf-litter and soil-nesting ants did not result in samples of the subfamily Ecitoninae (nomadic army ants) and only one of the subfamily Pseudomyrmicinae, since they are almost exclusively arboreal nesters. These results reflect the general pattern of diversity within ant subfamilies in the New World, where Myrmicinae is the most speciose subfamily overall (Bolton 1996).

The genus *Pheidole* was the most speciose in this sample, with 36 species (Appendix 1). This genus, containing more than 600 species, is also one of the most speciose around the world. The genera *Hypoponera* (11 species, subfamily Ponerinae), Gnamptogenys (eight species, subfamily Ponerinae), *Solenopsis* (eight species, subfamily Myrmicinae) *Paratrechina* (seven species, subfamily Formicinae) and *Crematogaster* (seven species, subfamily Myrmicinae) were also fairly diverse, as they are throughout the neotropics. Twelve (40%) of the 30 genera were represented by only one species.

While a few species were fairly common, 55 — or 45% — of the 121 species were sampled in only one quadrat (Figure 1). The shape of this figure is typical for most diversity studies and indicates that some species are not common in the forest near San Martin-3. Further research in the area should provide more information. *Megalomyrmex* cf *glaesar* was the most widespread ant species, nesting in 17 of the 30 quadrats. Three ant species were found in ten or eleven quadrats: *Crematogaster* _sm3, *Paratrechina* _sm1, and *Pheidole* _nvSM6 (Figure 1). Little is known about the biology of these species, but our results indicate that they are fairly common leaf litter and soil nesters in the area. As predators and scavengers, these species likely have a substantial impact on the arthropod fauna in this microhabitat.

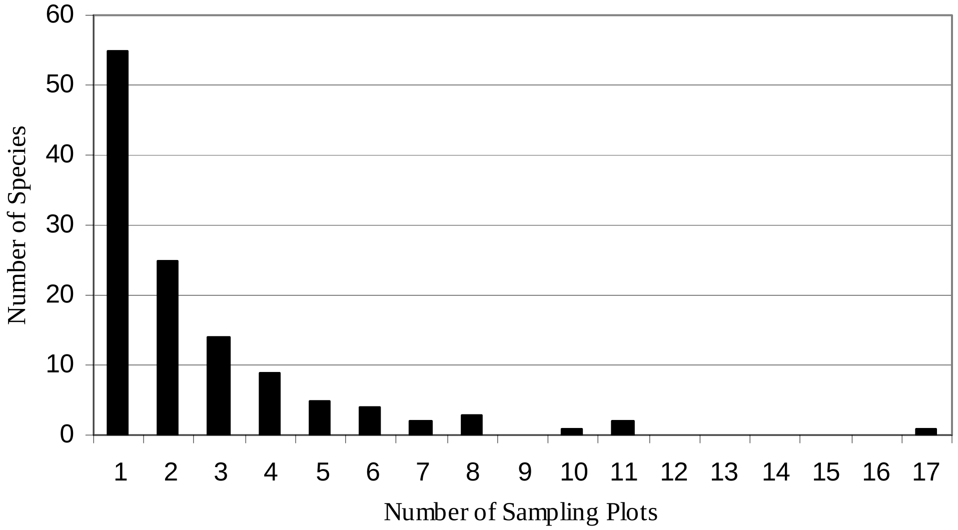

Figure 1. Distribution of rare and common speciess recorded at the San Martin-3 biodiversity plot. For example, 55 species were recorded in only one plot, 25 species were recorded in two plots, etc.

The number of worker ants per nest varies between species; some species have nests of 10 ants, while others have nests of more than a million ants. Therefore, it is difficult to estimate the number of individual ants in a given area, but it is likely that their numbers and biomass significantly exceed that of all other animal species. And because of the various roles that they play in any ecosystem, ants are certain to be an essential element in the functioning of the forest at San Martin-3.

Overall, protocols are improving to estimate the number of ant species that are likely to exist in a study area (Agosti *et al*. 2000). The sampling method used here enabled us to record a large portion of the leaf-litter and soil-nesting ant species, but it did not allow us to sample all ants in the area. The species richness of ants in other neotropical areas has been found to exceed 600 species in a 100-hectare lowland rainforest. (J. Longino personal communication), 156 species in lowland rainforest in Brazil (Delabie and Majer 1996) and more than 150 species in the Tambopata region of Peru (S. Cover personal communication). Thus, this study shows the Lower Urubamba Region has a highly diverse ant fauna.

Many more species of ants will be found when other microhabitats are sampled since this study focused only on the leaf-litter and soil ant fauna. Tree canopies in tropical forests contain a high diversity of ant species not found on the forest floor, and different techniques such as the canopy-fog method should be used to record ants in the LUR's forest strata.

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Appendix 1. Ant species sampled through focus on leaf litter and soil nests in the San Martin-3 biodiversity plot, Lower Urubamba Region (sampling occurred March 8-24, 1997).

Subfamily	Genus	Species	Authority*	Date
Ponerinae				
	Anochetus	*neglectus*	Emery	1894
	Anochetus	*targionii*	Emery	1894
	Ectatomma	*lugens*	Emery	1894
	Gnamptogenys	_sm1_	MEK morphospecies	
	Gnamptogenys	_sm2_	MEK morphospecies	
	Gnamptogenys	*continua*	Mayr	1887
	Gnamptogenys	*haenschei*	Emery	1902
	Gnamptogenys	*horni*	Santschi	1929
	Gnamptogenys	*mordax*	F Smith	1858
	Gnamptogenys	*relicta*	Mann	1916
	Gnamptogenys	*teffensis*	Santschi	1929
	Hypoponera	_sm1_	MEK morphospecies	
	Hypoponera	_sm10_	MEK morphospecies	
	Hypoponera	_sm11_	MEK morphospecies	
	Hypoponera	_sm2_	MEK morphospecies	
	Hypoponera	_sm3_	MEK morphospecies	
	Hypoponera	_sm4_	MEK morphospecies	
	Hypoponera	_sm5_	MEK morphospecies	
	Hypoponera	_sm6_	MEK morphospecies	
	Hypoponera	_sm7_	MEK morphospecies	
	Hypoponera	_sm8_	MEK morphospecies	
	Hypoponera	_sm9_	MEK morphospecies	
	Odontomachus	*brunneus*	Patton	1894
	Odontomachus	*erythrocephalus*	Emery	1890
	Odontomachus	*haematodes*	Linnaeus	1758
	Pachycondyla	*apicalis*	Latreille	1802
	Pachycondyla	*constricta*	Mayr	1884
	Pachycondyla	*crassinoda*	Latreille	1802

Appendix 1. Continued

Subfamily	Genus	Species	Authority*	Date
Dolichoderinae				
	Dolichoderus	_sm1_	MEK morphospecies	
	Dolichoderus	*bispinosus*	Olivier	1792
	Dolichoderus	*decollatus*	F Smith	1858
Myrmicinae				
	Apterostigma	_sm1_	MEK morphospecies	
	Apterostigma	_sm2_	MEK morphospecies	
	Apterostigma	_sm3_	MEK morphospecies	
	Apterostigma	_sm4_	MEK morphospecies	
	Basiceros	*conjugans*	Brown	1974
	Basiceros	*singularis*	F Smith	1858
	Carebarella	_sm1_	MEK morphospecies	
	Crematogaster	_sm1_	MEK morphospecies	
	Crematogaster	_sm2_	MEK morphospecies	
	Crematogaster	_sm3_	MEK morphospecies	
	Crematogaster	_sm4_	MEK morphospecies	
	Crematogaster	_sm5_	MEK morphospecies	
	Crematogaster	_sm6_	MEK morphospecies	
	Crematogaster	_sm7_	MEK morphospecies	
	Cyphomyrmex	*laevigatus*	Weber	1938
	Cyphomyrmex	*minutus*	Mayr	1862
	Cyphomyrmex	*rimosus*	Spinola	1851
	Hylomyrma	_novSM1_	MEK morphospecies	
	Hylomyrma	*praepotens*	Kempf	1973
	Lachnomyrmex	_nvsm1_	MEK morphospecies	
	Megalomyrmex	cf *glaesarius*	MEK morphospecies	
	Megalomyrmex	_nvsm1_	MEK morphospecies	
	Mycocepurus	*smithii*	Forel	1893
	Oligomyrmex	_sm1_	MEK morphospecies	
	Pheidole	_sm10_	MEK morphospecies	
	Pheidole	_sm11_	MEK morphospecies	
	Pheidole	_sm12_	MEK morphospecies	
	Pheidole	_sm13_	MEK morphospecies	
	Pheidole	_sm14_	MEK morphospecies	
	Pheidole	_sm15_	MEK morphospecies	
	Pheidole	_sm16_	MEK morphospecies	
	Pheidole	_sm17_	MEK morphospecies	
	Pheidole	_sm18_	MEK morphospecies	
	Pheidole	_sm19_	MEK morphospecies	
	Pheidole	_sm20_	MEK morphospecies	
	Pheidole	_sm21_	MEK morphospecies	
	Pheidole	_sm22_	MEK morphospecies	
	Pheidole	_sm23_	MEK morphospecies	
	Pheidole	_sm8_	MEK morphospecies	
	Pheidole	sm9	MEK morphospecies	

Appendix 1. Continued

Subfamily	Genus	Species	Authority*	Date
	Pheidole	*amazonica*	MS Wilson and Brown	
	Pheidole	*astur*	MS Wilson and Brown	
	Pheidole	*auriger*	MS Wilson and Brown	
	Pheidole	*cramptoni*	WM Wheeler	1916
	Pheidole	*demeter*	MS Wilson and Brown	
	Pheidole	*diligens*	F Smith	1858
	Pheidole	*ednae*	MS Wilson and Brown	
	Pheidole	*mendicula*	WM Wheeler	1925
	Pheidole	*midas*	MS Wilson and Brown	
	Pheidole	_nvSM1_	MEK morphospecies	
	Pheidole	_nvSM2_	MEK morphospecies	
	Pheidole	_nvSM3_	MEK morphospecies	
	Pheidole	_nvSM4_	MEK morphospecies	
	Pheidole	_nvSM5_	MEK morphospecies	
	Pheidole	_nvSM6_	MEK morphospecies	
	Pheidole	_nvSM7_	MEK morphospecies	
	Pheidole	*peruviana*	MS Wilson and Brown	
	Pheidole	*phaleops*	MS Wilson and Brown	
	Pheidole	*sensitiva*	Borgmeier	1959
	Pheidole	*zeteki*	MR Smith	1947
	Pyramica	_sm1_	MEK morphospecies	
	Rogeria	_nvsm1_	MEK morphospecies	
	Solenopsis	_sm1_	MEK morphospecies	
	Solenopsis	_sm2_	MEK morphospecies	
	Solenopsis	_SM3_	MEK morphospecies	
	Solenopsis	_sm4_	MEK morphospecies	
	Solenopsis	_sm5_	MEK morphospecies	
	Solenopsis	_sm6_	MEK morphospecies	
	Solenopsis	_sm7_	MEK morphospecies	
	Solenopsis	_sm8_	MEK morphospecies	
	Strumigenys	*longispinosus*	Brown	1958
	Strumigenys	*trinadensis*	Wheeler	1922
	Trachymyrmex	_sm1_	MEK morphospecies	
	Wasmannia	*auropunctata*	Roger	1863
Pseudomyrmicinae				
	Pseudomyrmex	sm1	MEK morphospecies	

* MEK = M. Kaspari

Biodiversity Assessment of the Diurnal Butterflies of the Lower Urubamba Region, Peru

Gorky Valencia and Alfonso Alonso

(reprinted from Alonso and Dallmeier 1998)

1 Introduction

The Lower Urubamba Region is a large area that includes the watersheds and inflowing streams located below the Urubamba River from the Pongo de Mainique to the end of the Ucayali River. The area's location and geographical characteristics have restricted human encroachment, and therefore the biology of the Lower Urubamba is little known.

As to the fauna, the region is of particular importance (Rodríguez 1997). Specific to butterflies, Lamas (1989) estimates that less than 25% of potential butterfly species in the region have been recorded. In some portions of the Lower Urubamba, no work has been done, but it has been postulated that the region is likely very rich in butterfly species and may be a transition zone between centers of endemism (Lamas 1982).

A great deal of work was accomplished in Phase II of this project. Those efforts have enriched knowledge with respect to many species in the Lower Urubamba, including butterflies (Alonso and Valencia 1997). This paper presents the results of the assessment of butterflies during Phase III.

2 Methods

2.1 Site descriptions

The study was conducted from September 15 through December 10, 1997, at the Cashiriari-3 well site and its environs and along the streams feeding the Camisea and Urubamba rivers. In general, the geography is irregular, with terraces along the streams that occasionally widen and hills divided by a large number of smaller brooks. The vegetative cover is primarily successive mature forest.

Sampling sites included (Table 1):

Las Malvinas. This village is populated by colonists who raise small herds of cattle and farm, hunt, and fish in the marginal areas of the Lower Urubamba River and south of the native Camisea community. The assessment was concentrated around the nearby base camp and in a transect approximately 1.6 kilometers (km) in length that crossed a disturbed area as it ascended a hill. Mature forest dominated the undisturbed portion of the transect. Sampling took place from September 16 to September 26.

Table 1. Location of base camps.

Camp	Latitude	Longitude	Elevation (m)	Sampling date
Las Malvinas	11º52’37" S	72º56’48” W	360	Sept. 15-26
Segakiato	11º48’23” S	72º52’51” W	340	Sept. 28-Oct. 15
Konkariari	11º48'S	72º52' W	300	Oct. 17-29
Cashiriari-3	11º52'57" S	72º39’02" W	690	Nov. 1-Dec. 10

Segakiato. This native community is located on the Camisea River southeast of the Camisea community. The assessment was completed around the base camp found near the river bank about three km to the north of the Segakiato community. Two trails originate from the camp. One, to the east, ascends a hill, passing through grazing and cultivated lands with disturbed forest. The other traverses the bank of a rivulet and climbs up a small precipice. We sampled at this site from September 28 to October 10.

Shivankoreni. Located east of the Camisea community, this native village is somewhat larger than nearby Segakiato. Sampling was done along two routes into this area. To reach a parcel to the north, we traveled by boat from Segakiato and collected samples along short stretches of beach. To reach a second parcel, we traveled by boat from the research base at Konkariari (north of the Camisea community). At this site, there was much evidence of seasonal floods and some agriculture. Tree heights were low compared to other research areas. Sampling took place from October 11 to October 23.

Peruanita. This small village is populated by colonists who raise cattle in large pastures on the right bank of the Urubamba River. It is northwest of the Camisea community. The research site was located near Konkariari Creek in irregular geography with forested borders. The trail we used crossed a brook and rose until it reached an elevated terrace. Bamboo was present, and some portions of the site contained dense vegetation. Sampling was done from October 24 to October 29.

Cashiriari-3. The research site at this well (in the highlands of the Cashiriari drainage southeast of the Camisea community) is near the top of a hill. Vegetation is dense. Sampling was done north of the camp at a lower elevation and along streams to the top of a nearby hill.

2.2 Field sampling

Butterflies were sampled using traditional entomology nets. We placed each sample in individual, small glassine paper envelopes (the exception: a female and male of the same species found copulating were put into the same envelope) and recorded the date of capture on the outside of the envelope. At the end of each day, the samples were dried for approximately 12 hours in the camp stove. Next, we isolated each sample in a hermetic receptacle and preserved it in naphthalene. We sampled only adult butterflies.

Most of the samples were taken in transects of the research plots and in surrounding areas. At Cashiriari-3, we took advantage of a colpa (salar) of the river to capture hydrophyllic species (Vargas *et al*. 1992). Collection was normally conducted by one of the authors and supported by local guides Federico Ramírez, Justino Martín, Daniel Aladino, Fernando Cabrera and Teófilo Pascal, among others. The guides were particularly helpful in finding and capturing the butterflies.

Preliminary identification of the samples has been completed to at least the morphotype level. Specialists will continue the identification process at the institutions where the samples will be deposited.

We documented our findings in relation to richness (number of species) and abundance (number of individuals of each species). A significant number of individuals of the Ithomiinae subfamily were sampled. These butterflies fly relatively slowly and are normally found in a specific habitat. The biodiversity index prepared by Beccaloni and Gaston (1994) was very helpful in analyzing the data. Lamas *et al.* (1996) show that Ithomiinae species may be good indicators of overall species richness in forested neotropical environments. He found a relation of 4.5% Ithomiinae species to the total estimated butterfly populations in a sample area. Note that caution should be used in applying this percentage; actual results from each study must be tested against this hypothesis.

3 Results and Discussion

The species found in this study are presented in Appendix 1. We found 264 species of Rhopalocera, represented by 558 individuals, in two superfamilies: Papilionoidea (90.9% of total richness with 240 species) and Hesperioidea (9.1% of total richness with 24 species and

Table 2. Population characteristics of the Rhopalocera by sampling site.

	Las Malvinas	Segakiato	Shivankoreni	Peruanita	Cashiriari-3
# of species	34	96	120	8	157
# of individuals	36	130	167	9	216
# of new records	15	56	52	1	46
Unique species	6	33	49	1	47
Collection days	11	13	13	6	38

5.38% of total abundance with 30 individuals. It is likely that Hesperioidea species are under-represented in this count; their rapid flight and nervous behavior make them difficult to capture.

Appendix 2 presents comparisons of our findings in this phase of the biodiversity study with those from the San Martin-3 and Cashiriari-2 well sites (Phase II).

In the Papilionoidea, the richest and most abundant subfamily was Nymphalidae with 180 species and 432 individuals (68.2% and 77.4%, respectively).

Within the Nymphalidae, the subfamilies Limenitinae and Ithomiinae were the richest; each had 43 species. Danainae was the least species rich (two species). In abundance, the most important subfamilies were Satyrinae with 106 individuals and Ithomiinae with 100 individuals. The least important was Danainae with only four individuals.

One reason for the great difference in abundance is that the Limenitinae subfamily members are dispersed throughout a number of habitats and species. The Ithomiinae, on the other hand, have limited flight ranges and specific habitat preferences that facilitate capture. The Danainae have always been a modestly represented group. In relation to abundance, the Satyrinae have been observed in large populations of individuals in generally specific habitats.

Table 2 indicates distribution of richness and abundance by location and other population characteristics. Cashiriari-3 displayed the greatest species richness and abundance, but the site exhibiting the most unique or exclusive species was Shivankoreni. These results were partly influenced by the number of days invested in sampling at each site. Species richness and abundance numbers are highest in direct proportion to the number of collection days. However, at Segakiato and Shivankoreni the close quantities demonstrate a number of newly registered species and exclusive species. This phenomenon is partly explained by the geography of the sites.

The poorest sites were Las Malvinas and Konkariari. The collection time for those sites was relatively short. In addition, colonist activities and disturbed forest cover are likely to have a role in restricting species richness and abundance.

3.1 Diversity

Our findings indicate that the species of the Ithomiinae subfamily are adequate representations of butterflies in the study area, taking into consideration their behavior and published studies (Beccaloni and Gaston 1994, Lamas *et al*. 1996). The information obtained at San Martin-3 and Cashiriari-2 makes it possible to compare findings (Appendix 2; Alonso and Valencia 1997).

Comparisons of the species richness of the Ithomiinae (Table 3) showed that San Martin-3 possessed the greatest number of exclusive species — 10, or 41.7% of all Ithomiinae species at that site. Cashiriari-2 was next with seven species and the largest percentage (43.8%), followed by Cashiriari-3 with seven species (31.8%). At Las Malvinas, only one species was exclusive (12.5%), and at Peruanita no exclusive species were found.

Segakiato and Shivankoreni shared the most species (11, or 52.4%); San Martin-3 and Cashiriari-3 shared nine species (37.5%). Peruanita shared the fewest species of all locations.

San Martin-3 and Cashiriari-2, with the greatest numbers of exclusive species, are characterized by the presence of vegetative bamboo formations (somewhat less so at Cashiriari-2). These formations may in some way influence the rate of butterfly endemism as well as other life forms such as vertebrates (birds; Servat 1996) and invertebrates (Odonates; Louton *et al*. 1996 cited in Londoño 1996). These sites also shared a greater proportion of species even though they are separated by the Camisea River. The width of the river is evidently not enough to inhibit travel. Thus, one must be careful in assuming that rivers restrict the distribution of at least some species (Patton *et al*. 1994, cited in Lamas *et al*. 1996).

Cashiriari-3 had fewer exclusive and shared species than San Martin-3 and Cashiriari-2. This may be due in part to its domination by bamboo formations and the season when the two latter sites were sampled.

Segakiato and Shivankoreni exhibited more faunal closeness than did Las Malvinas and Peruanita. There is need for more study at the latter sites to determine the precise reasons for their lack of endemism and sharing of species.

Estimates of Rhopalocera (Table 4) were based on Ithomiinae, as noted earlier, following Beccaloni and Gaston (1994). Findings from Phase III provide an estimate of 956 species (264 collected). Across all plots sampled thus far in all phases of the study, the actual proportion of the species is 19.1%. This might be attributed to our large collection effort that resulted in a greater quantity of samples.

Dividing the total number of Rhopalocera species at each site by the number of Ithomiinae species elicits more uniformity in the data. The average proportion is 5.4%, taking into account a variation of 1.7. Using the Beccaloni and Gaston index for the entire study area, the estimated population is 1,333 species of Rhopalocera. This is slightly superior to the 1,307 known Rhopalocera species at Pakitza, Manu (Robbins *et al*. 1996). The register for Manu establishes that site as one of the richest in the world for diurnal butterflies.

In support of these estimates, we note that registered species of fauna in the study area represent 28.8% of potential species.

The accumulation of newly registered species by location and sampling days demonstrates a somewhat irregular pattern. Still, it indicates that 579 days would be needed to register all estimated species in the study area (quantity extrapolated by lineal regression; r = 0.97). Discounting the time already spent on this activity, 385

Table 3. Comparison of Ithomiinae species among sampling sites (numbers before parentheses = number of Ithomiinae species at each site; numbers in parentheses = % of Ithomiinae species of all species at the site; SM3 = San Martin-3, Cash2 = Cashiriari-2, LasM = Las Malvinas, Seg = Segakiato, Shiv = Shivankoreni, Peru = Peruanita, Cash3 = Cashiriari-3).

	Site	SM3	Cash2	LasM	Seg	Shiv	Peru	Cash3
Site	# of species							
SM3	24	10 (41.7)	6 (25.0)	2 (8.3)	4 (16.7)	4 (16.7)	-	9 (37.5)
Cash2	16		7 (43.8)	2 (12.5)	4 (22.2)	4 (19.0)	1 (6.3)	7 (31.8)
LasM	8			1 (12.7)	5 (27.7)	4 (19.0)	-	3 (13.6)
Seg	18				3 (16.7)	11 (52.4)	-	5 (22.7)
Shiv	21					6 (28.6)	1 (4.8)	6 (27.3)
Peru	2						-	2 (9.1)
Cash3	22							7 (31.8)

Table 4. Estimated number of Rhopalocera species (# of Rhopalocera species found (d) and estimated (b) based on # of Ithomiinae species/site (a); estimated proportion (c) based on Beccaloni and Gaston (1994); proportion (e) = percent of Ithomiinae (a) within the Rhopalocera (d); estimated proportion (f) obtained by dividing total # of Rhopalocera by # of Ithomiinae at each site; SM3 = San Martin-3, Cash2 = Cashiriari-2, LasM = Las Malvinas, Seg = Segakiato, Shiv = Shivankoreni, Peru = Peruanita, Cash3 = Cashiriari-3).

	Site							Totals	
	SM-3	Cash-2	LasM	Seg	Shiv	Peru	Cash3	Phase III	All records Lower Urubamba
a. # Ithomiinae species/site	24	16	8	18	21	2	22	43	60
b. # estimated Rhopalocera species/site	533	356	177	400	467	44	488	956	1333
c. Ithomiinae as % of Rhopalocera estimate	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
d. # of Rhopalocera species/site	133	94	34	96	120	8	157	264	384
e. % of Ithomiinae species within Rhopalocera	18	17	23.5	19	17.5	25	14	16.3	15.6
f. Ithomiinae species as % of Rhopalocera species	5.5	5.9	4.3	5.3	5.7	4	7.1	6.1	6.4

more days of collection would be required using the same methodology. This time should be distributed throughout the study area and during different seasons of the year.

Finally, according to the data gathered to date, Cashiriari-3 contained the greatest overall diversity, followed by San Martin-3. The least diverse sites were Las Malvinas and Peruanita.

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Appendix 1. Diurnal butterflies collected during phase III at five sites (alphabetically by species in superfamilies, families, and subfamilies per Robbins *et al.* 1996; * = new registration at the site; % = total individuals of a species compared to total individuals collected). Sites are as follows: LM = Las Malvinas, Sega = Segakiato, Shiv = Shivankoreni, Peru = Peruanita and Cash-3 = Cashiriari-3.

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Order Lepidoptera								558	100
Division Rhopalocera								558	100
Superfamily Papilionoidea								528	94.6
Family Nymphalidae								432	77.4
Subfamily Heliconiinae								46	8.2
Agraulis vanillae			1					1	0.2
*Dione juno**			1					1	0.2
Dryas iulia			2	3		1		6	1.1
Heliconius demeter ssp.*				1				1	0.2
Heliconius erato emma			3	1		1		5	0.9
Heliconius melpomene aff. *scnunkei*				2		1	2	5	0.9
Heliconius sara ssp.		1	3	3				7	1.3
Heliconius sp. 5	1		2	1				4	0.7
Heliconius wallacei ssp.*			1					1	0.2
Laparus doris doris			1	4	4	3	1	9	1.6
Laparus sp. 1*				1				1	0.2
Neruda aode ssp.*			1					1	0.2
*Philaethria dido**			1	2		1		4	0.7

Appendix 1. Continued.

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Subfamily Nymphalinae								36	6.5
Anartia sp. 1*	1							1	0.2
Castilia sp. 1*				1		4		5	0.9
Castilia sp. 2*						1	1	2	0.4
Eresia aff. *mechanitis*				3		1		4	0.7
Eresia clara						1	1	2	0.4
Eresia sp. 1*	1		3	1			1	6	1.1
Eresia sp. 2*			1			1		2	0.4
Eresia sp. 3*						2		2	0.4
Eresia sp. 4*						1		1	0.2
Microtia aff. *elva*			1	2		3		6	1.1
Nymphalinae sp. 2*				2				2	0.4
Tegosa sp. 1*				3				3	0.5
Subfamily Limenitidinae								96	17.2
Adelpha sp.3				2				2	0.4
Adelpha sp. 5	1		2					3	0.5
Adelpha sp. 6*			1			1		2	0.4
Adelpha sp. 7*				1				1	0.2
Adelpha sp. 8*							1	1	0.2
Asterope sp.1*			1					1	0.2
Baeotus sp. 1*				1	1			2	0.4
Baeotus sp. 2*				1				1	0.2
Callicore sp. 2			3					3	0.5
Callicore sp. 4*			1					1	0.2
Callicore sp. 5*			3	1				4	0.7
Catonephele aff. *orites**	1		1	3			1	6	1.1
*Catonephele numilia**				2				2	0.4
Colobura sp. 1	1	1	1	1		1		5	0.9
Diaethria sp. 1				1	1			2	0.4
Dynamine sp. 1				1				1	0.2
Dynamine sp. 2*						1		1	0.2
Dynamine sp. 3*	1				1			2	0.4
Eunica aff. *pomana**				1		1		2	0.4
Eunica sp. 1*			1	2				3	0.5
Eunica sp. 2*		1						1	0.2
Eunica sp. 3*				1				1	0.2
Eunica sp. 5*			1					1	0.2
Eunica sp. 6*				1				1	0.2
*Eresia sp. 3**						2		2	0.4
Hamadryas aff. *amphinome**						1		1	0.2
Hamadryas arinome ssp.				1				1	0.2
Hamadryas sp. 2*	1		1					2	0.4
Historis odius dious		1						1	0.2
Marpesia aff. *iole*				1				1	0.2

Appendix 1. Continued.

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Marpesia sp. 1				1		5		6	1.1
Marpesia sp. 2			1	2				3	0.5
Nessaea sp. 1							1	1	0.2
Nessaea sp. 2*	1			1		1		3	0.5
Panacea sp. 1*			1		1		1	3	0.5
Pyrrhogyra sp. 2				1		1	3	5	0.9
Pyrrhogyra sp. 3				2		2		4	0.7
Pyrrhogyra sp. 4*		1	1					2	0.4
Pyrrhogyra sp. 5*				1		1		2	0.4
*Smyrna blomfildia**			2					2	0.4
Temenis aff. *laothoe*			3			2		5	0.9
Temenis pulchra		1						1	0.2
Tigridia acesta				1		1		2	0.4
Subfamily Charaxinae								18	3.2
Archaeoprepona sp.1*					1			1	0.02
Consul fabius ssp.*				2				2	0.4
Charaxinae sp. 1							1	1	0.2
Charaxinae sp. 2*						1		1	0.2
Memphis ryphea ssp.*				1				1	0.2
Memphis sp. 2	1							1	0.2
Memphis sp. 5				1				1	0.2
Memphis sp. 8*				1				1	0.2
Memphis sp. 9*			1	1				2	0.4
Memphis sp. 10*	1							1	0.2
Memphis sp. 11*				1				1	0.2
Memphis sp. 12*				1				1	0.2
Prepona omphale ssp.*	1							1	0.2
Siderone sp. 1							1	1	0.2
*Zaretis itys**	2							2	0.4
Subfamily Morphinae								16	2.9
Antirrhea sp.1							3	3	0.5
Morpho menelaus						2	1	3	0.5
Morpho sp. 3	1	1		1	1		2	6	1.1
Morpho sp. 5*			1	2		1		4	0.7
Subfamily Brassolinae								10	1.8
Catoblepia sp. 1*			1					1	0.2
Catoblepia sp. 2*			1					1	0.2
Caligo illioneus			4	1				5	0.9
Caligo sp. 2*			1					1	0.2
Eryphanis sp. 2*							1	1	0.2
*Opsiphanes quiteria**			1					1	0.2
Subfamily Satyrinae								106	19.0
Cithaerias pireta aurorina				1		2		3	0.5
Cithaerias sp. 1*	1		1		1		1	4	0.7

Appendix 1. Continued.

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Cissia gulnare	1					5	3	9	1.6
Cissia sp. 5						1		1	0.2
Cissia sp. 6						1	1	2	0.4
Cissia sp. 10						1	1	2	0.4
Cissia sp. 15						2	1	3	0.5
Cissia sp. 17				2				2	0.4
Cissia sp. 18			3					3	0.5
Cissia sp. 19*							1	1	0.2
Cissia sp. 20*				1				1	0.2
Cissia sp. 21*						1		1	0.2
Cissia sp. 22*						2	1	3	0.5
Cissia sp. 23*						2		2	0.4
Cissia sp. 24*				1			1	2	0.4
Cissia sp. 25*			1	1				2	0.4
Cissia sp. 26*			1					1	0.4
Cissia sp. 27*				2				2	0.4
Cissia sp. 28*	1							1	0.2
Chloreuptychia sp. 1							3	3	0.5
Chloreuptychia sp. 3	1					1		2	0.4
Chloreuptychia sp. 4						1		1	0.2
Chloreuptychia sp. 6				2			5	7	1.3
Cyllopsis sp. 1					1		1	2	0.4
Euptychia sp. 3*						1		1	0.2
Euptychia sp. 4*						2		2	0.4
Haetera piera			1	1			1	3	0.5
Manataria sp. 1	1							1	0.2
Megeuptychia aff. *antonoe**				1				1	0.2
Megeuptychia sp. 1*			1					1	0.2
*Pierella hortona ssp.**			1	1				2	0.4
Pierella lamia			1	3			2	6	1.1
Pierella lena ssp.							1	1	0.2
Pierella sp. 3	1		2				3	6	1.1
Pierella sp. 5*			1	1				2	0.4
Taygetis sp. 5"a"	1		1	1				3	0.5
Taygetis sp. 6						1		1	0.2
Taygetis sp. 7	1		1	1		1	1	5	0.9
Taygetis sp. 10*			1					1	0.2
Taygetis sp. 11*						1	3	4	0.7
Taygetis sp. 12				1		1		2	0.4
Taygetis sp. 13	1					2	1	4	0.7
Subfamily Danainae								4	0.7
Eutresis sp. 2*			2				1	3	0.5
*Lycorea cleobaea**						1		1	0.2

Appendix 1. Continued.

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Subfamily Ithomiinae								100	17.9
Aeria sp. 1*			1	3				4	0.7
Aeria sp. 2*				2				2	0.4
*Callithomia juruaensis**			3	3				6	1.1
Callithomia sp. 1*		1						1	0.2
Dircenna sp. 1*							1	1	0.2
Episcada sp.4*	1		1					2	0.4
Episcada sp.5*						1		1	0.2
Hypoleria sp. 2						1	2	3	0.5
Hypoleria sp. 3*				3		3	1	7	1.3
Hypoleria sp. 4*						1		1	0.2
Hypoleria sp. 5			1	1		1		3	0.5
Hypoleria virginia aff. *vitiosa*	1		1	1	1	1		5	0.9
Hypothyris sp. 2						1		1	0.2
Ithomia ? sp. 1				1				1	0.2
Ithomia sp. 2*							1	1	0.2
Ithomia sp. 3			4				1	5	0.9
Ithomiinae sp. 2	1						1	2	0.4
Ithomiinae sp. 5*				1				1	0.2
Ithomiinae sp. 6			1	1			1	3	0.5
Ithomiinae sp. 7*							1	1	0.2
Mechantis lysimnia aff. *acreana*	1		1					2	0.4
*Mechantis mazaeus visenda**				2				2	0.4
*Mechantis polymnia polymnia**			1	1				2	0.4
Mechantis sp. 2			2			1	1	4	0.7
Melinaea menophilus aff. ernestoi*			1					1	0.2
Melinaea sp. 3	1		2	2				5	0.9
Melinaea sp. 5*	1	1		1				3	0.5
Melinaea sp. 6*	1							1	0.2
Melinaea sp. 7*		1		1				2	0.4
Melinaea sp. 7"a"*	1			1		1		3	0.5
Melinaea sp. 7"b"*		1		1				2	0.4
Melinaea sp. 8*			1					1	0.2
Melinaea sp. 9*				1				1	0.2
Oleria cer denuta			1	1		2		4	0.7
Oleria denuta ssp.							1	1	0.2
Oleria sp. 1						1		1	0.2
Oleria sp. 3					1	3		4	0.7
Oleria sp. 6						1		1	0.2
Oleria sp. 7*				2				2	0.4
Oleria sp. 8*					1	2		3	0.5
Rhodussa cantobrica ssp.*			1	1				2	0.4
Scada sp. 3*							1	1	0.2

Appendix 1. Continued.

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Family Riodinidae								58	10.4
Subfamily Riodininae								58	10.4
Ancyluris sp. 1				1		1		2	0.4
Cariomothis sp. 1*						1	1	2	0.4
Cariomothis sp. 2*						1		1	0.2
Charis aff. *gynaea*						1		1	0.2
Charis aff. auius	1					1		2	0.4
Charis sp. 1*				1				1	0.2
Charis sp. 2*						1		1	0.2
Cremna sp. 1*							2	2	0.4
Eurybia aff. *unxia*			1			1		2	0.4
Eurybia elvina				1				1	0.2
Eurybia sp. 1*			2					2	0.4
Eurybia sp. 2 aff. *elvina**						1		1	0.2
Emesis aff. *ocypore**				1				1	0.2
*Emesis lucinda**				1				1	0.2
Juditha sp. 1*			1					1	0.2
Juditha sp. 2*				1		1		2	0.4
Juditha sp. 3*						1	1	2	0.4
Metacharis sp. 1*			1	1				2	0.4
Mesosemia sp. 1				5				5	0.9
Mesosemia sp. 2							1	1	0.2
Mesosemia sp. 3			2	1				3	0.5
Mesosemia sp. 5				2				2	0.4
Mesosemia sp. 8*				1		1		2	0.4
Mesosemia sp. 9*						1		1	0.2
Napaea sp. 2				1		2		3	0.5
Napaea sp. 4*				1				1	0.2
Napaea sp. 5*				1				1	0.2
Napaea sp. 6*				1		2		3	0.5
Nymphidium sp. 3*						1		1	0.2
Parcella sp. 1						1		1	0.2
Rhetus periander			1	2				3	0.5
Sarota sp. 1*				1				1	0.2
Synargis sp. 2						1		1	0.2
Synargis sp. 3*			1					1	0.2
Theope sp. 2*				1				1	0.2
Family Lycaenidae								8	1.4
Subfamily Theclinae								8	1.4
Thecla sp. 3*							1	1	0.2
Thecla sp. 4*						1	1	2	0.4
Thecla sp. 5*				1				1	0.2
Thecla sp. 6*				1				1	0.2
Thecla sp. 7*			1	1				2	0.4

Appendix 1. Continued

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Thecla sp. 8*						1		1	0.2
Family Pieridae								24	4.3
Subfamily Dismorphiinae								4	0.7
Enantia sp. 1*			2	1		1		4	0.7
Subfamily Pierinae								20	3.6
Anteos sp. 1*			1					1	0.2
*Anteos menippe**			1			3		4	0.7
Aphrissa sp. 1						1		1	0.2
Aphrissa sp. 2						3		3	0.5
Aphrissa sp. 3*				1				1	0.2
Appias sp. 1						1		1	0.2
Appias sp. 2*			1					1	0.2
Appias sp. 3*				1				1	0.2
Itaballia sp. 1*				1				1	0.2
Perrhybris aff. *pyrrha*				1				1	0.2
Perryhbris sp. 1				2		1		3	0.5
*Phoebis neocypris rurina**						1		1	0.2
*Phoebis philea philea**						1		1	0.2
Family Papilionidae								6	1.1
Subfamily Papilioninae								6	1.1
*Battus crassus crassus**				1				1	0.2
*Mimoides xynias xynias**			1					1	0.2
*Parides aeneas damis?**				1				1	0.2
*Parides sesostris sesostris**				2				2	0.4
Protographium agesilaus autosilaus "peruvianus"			1					1	0.2
Superfamily Hesperioidea								30	5.4
Family Hesperiidae								30	5.4
Subfamily Pyrrhopyginae								5	0.9
Acolastus aff. *metalescens**						1		1	0.2
Acolastus sp. 2						1		1	0.2
*Pyrrhopyge fluminis**			1					1	0.2
*Pyrrohpyge sergius**						1	1	2	0.4
Subfamily Pyrginae								14	2.5
Hesperiidae sp. 1*		1						1	0.2
Paches sp. 1			1				1	2	0.4
Paches sp. 4*			1					1	0.2
Pyrgus sp. 1*			1					1	0.2
*Sophista cramerianus**				1				1	0.2
Thymele sp. 3*	2							2	0.4
Timochares sp. 2	1						1	2	0.4
Timochares sp. 3	1						1	2	0.4
Timochares sp. 4*				1				1	0.2
Timochares sp. 5*				1				1	0.2

Appendix 1. Continued

	# of individuals collected by site and date								
	LM	Sega		Shiv	Peru	Cash-3			
Species	Sept.	Sept.	Oct.	Oct.	Oct.	Nov.	Dec.	Total	%
Subfamily Hesperiinae								11	2.0
Artines sp. 1*							1	1	0.2
Dalla sp. 2*			1					1	0.2
*Hesperiidae sp. 2**			2					2	0.4
Lerodea sp. 1*				1				1	0.2
Lerodea sp. 2*			1					1	0.2
Lerodea sp. 3*						1		1	0.2
Lycas aff. *gerasa**							1	1	0.2
Lycas sp. 1*						1		1	0.2
Prenes aff. b*rino**							1	1	0.2
Prenes sp. 1*				1				1	0.2
TOTAL	36	11	119	167	9	129	87	558	100

Appendix 2. Diurnal butterflies collected at San Martin-3 and Cashiriari-2 during Phase II (alphabetically by species in superfamilies, families and subfamilies per Robbins *et al.* 1996; * = new record at site.

	# of individuals collected by site and date			
	San Martin-3	Cashiriari-2		
Species	May	May	June	TOTAL
Order Lepidoptera				
Division Rhopalocera				
Superfamily Papilionoidea				
Family Nymphalidae				
Subfamily Heliconiinae				
Heliconius erato ssp.?*			1	1
Heliconius sara ssp.			1	1
*Laparus doris doris**			2	2
Subfamily Nymphalinae				
*Eresia clara**			1	1
Junonia sp. 1*		1		1
Microtia aff. *elva**			1	1
Siproeta stelenes			1	1
Subfamily Limenitidinae				
Adelphia sp. 1		1		1
Adelphia sp. 3		1		1
Adelphia sp. 5*			1	1
Callicore sp. 2			1	1
*Dynamine chryseis**			1	1
Dynamine sp. 1*			2	2
Eunica sp. 4		3		3
*Historis acheronta**			1	1
Marpesia aff. *iloe**			1	1
*Marpesia berania**			2	2
Marpesia sp. 1			3	3
Marpesia sp. 2*		1	1	2
Nessaea sp. 1*			1	1
Panacea prola		1	6	7
Pyrrhogyra sp. 3		1	2	3
Temenis aff. *laothoe*		1	1	2
Subfamily Charaxinae				
Memphis aff. *pithyusa**			1	1
Memphis sp. 7*			1	1
Subfamily Apaturinae				
Daxocopa sp. 1		1		1
Subfamily Morphinae				
Morpho sp. 3*		1	1	2
Morpho sp. 4*		1		1
Subfamily Satyrinae				
Cissia sp. 6		1		1
Cithaerias pireta aurorina			2	2
Satyrinae sp. 1		1		1

Appendix 2. Continued

# of individuals collected by site and date				
	San Martin-3	Cashiriari-2		
Species	May	May	June	TOTAL
Subfamily Ithomiinae				
Aeria eurimedia ssp.*			1	1
Ceratinia aff. *hopfferi**		1		1
Mechanitis lysimnia aff. *acreana**			1	1
Ithomiinae sp. 6		1		1
Melinaea ethra ssp.			4	4
Oleria sp. 2			1	1
Oleria sp. 5*			1	1
Oleria sp. 6			1	1
Family Riodinidae				
Subfamily Riodininae				
Ancyluris sp. 1*			1	1
Baeotis sp. 1*	1			1
Charis aff. *auius**			3	3
Eurybia elvina		1		1
Lasaia sp. 1*			1	1
Napaea sp. 3*			1	1
*Rhetus periander**			4	4
Family Pieridae				
Subfamily Dismorphiinae				
Pseudopieris sp. 1		1	1	2
Subfamily Pierinae				
Appias sp. 1			2	2
Superfamily Hesperioidea				
Family Hesperiidae				
Subfamily Pyrginae				
Achlyodes sp. 1*			1	1
Ancistrocampta sp. 1*			1	1
Chiomara sp. 1*			1	1
Paches sp. 1*			1	1
Paches sp. 2*			1	1
Paches sp. 3*			1	1
Timochares sp. 6*			1	1
Thymele sp. 2*		2	2	4
Eudamus aff. *proteus**			2	2
*Timochares sp. 2**		1	1	2
*Timochares sp. 3**		1	1	2
Subfamily Hesperiinae				
Euroto aff. *accius**			1	1
TOTAL	1	21	71	93

Biodiversity Assessment of the Nocturnal Butterflies of the Lower Urubamba Region, Peru

Juan Grados

(reprinted from Alonso and Dallmeier 1998)

1 Introduction

Nocturnal butterflies (polillas; moths) are a group of insects that includes more than 100 families, many of which are present exclusively in the neotropics. They display several stages during their life cycles, including egg, larval, pupa, and adult. The larval stage is particularly important within the trophic food chain. Nocturnal butterflies are primary prey for amphibians, bats, and marsupials and for other invertebrates. In their adult stages, many species of nocturnal butterflies take nourishment from the nectar of flowers and thus function as pollinators for the reproduction of a variety of plant species.

Overall, nocturnal butterflies come in a large variety of forms. Some have transparent wings and a thin basal abdominal section, similar to many wasps; close observation is necessary to distinguish between the two. Others have wings with bright colors and metallic colored abdomens, and still others are very similar to coleoptera (beetles).

As the general and common names indicate, nocturnal butterflies are active at night, but it is speculated that the activity of many is diurnal. A relationship seems to exist between the development of the hearing organ and patterns of activity for nocturnal moths (Kreusel and Häuser 1997). That relationship, the moths' abilities as complex mimics of other organisms and their day and night activity periods are likely key to understanding the evolution of these species.

Of special note in this study is the group of nocturnal butterflies commonly known as wasp moths (Ctenuchinae). The group is divided into three tribes — Amatini, Ctenuchini, and Eucromini. The latter two tribes are found in the neotropics, and they contain the most species. Wasp moths are medium to small in size. Many are brightly colored and are mimics of other species (Scoble 1995).

2 Methods

Nocturnal butterflies are attracted by different sources of light. This knowledge enables researchers to carry out diversity studies. Highly recommended light sources are black (ultraviolet [UV]) and mercury (MV). Both types were used in this study, either in combination or separately. Specimens sampled were placed in jars of cyanide with calcium in low concentrations. Some specimens were mounted in entomological pin boxes, while others were transported to the lab in glassine envelopes.

Sampling took place at San Martin-3 (11°47' S, 72°41' W; 480 meters [m] in elevation), Las Malvinas (11°52'32" S, 72° 56'48" W; 360 m in elevation), Plot #4 (11°52' S, 72°55' W; 480 m in elevation), Segakiato (11°48' S, 72°52' W; 300 m in elevation), Konkariari Creek and Cashiriari-3 (11°52' S, 72°39' W; 690 m in elevation).

Eighteen days were spent sampling at San Martin-3. Sampling at Las Malvinas, a community of colonists near the Urubamba River, occurred over eight days on a natural terrace close to the permanent biodiversity monitoring plot (#4); two days were spent sampling in that plot, and 12 days at Segakiato along the Camisea River, about 15 minutes by river transport from the

Machiguenga community of the same name. Just one day was spent sampling at Konkariari Creek and six days at the Cashiriari-3 camp.

3 Results and Discussion

Analysis of samples from San Martin-3 indicated a total of 101 species. At Las Malvinas, 147 species were registered, including *Napata* nr. *albiplaga*, which has been recorded only at that site. In all, 61 of the 165 species at these sites were new species for the Camisea area, averaging about eight new species each day during the study (Appendix 1).

At Segakiato, we registered 111 species, including 12 new records for an average of one new species per day. Unfavorable weather conditions during the last few days at this site caused the collection to diminish considerably. The small number (21) of species registered at the Konkariari site was partly a result of adverse weather conditions and the fact that only one day was spent sampling.

At the Cashiriari-3 well site, 114 species were registered, 10 of which were new for an average of 1.6 new species each day. It is likely that further analysis will uncover additional new species at the site. At Cashiriari-2, the presence of *Pterygopterus clavippenis* was registered, a species found only at that site.

A review of Appendix 1 indicates that some species were present only at some of the sampled points. In particular, at Las Malvinas we recorded not only the largest number of species but also the largest number of exclusive species. However, it is too early to draw conclusions concerning exclusivity. Lengthy sampling is needed before such conclusions are warranted.

We spent more days at San Martin-3 than at the other sites, yet sampled more species at Las Malvinas, at Segakiato and at Cashiriari-3. Differences in elevation at Las Malvinas seemed to influence the number of registered species. At Segakiato, it is likely that diverse habitats (samples were made along the river bank and at the margin of primary forest) affected the sampling rate. At the higher elevations of Cashiriari-3, where 114 species were registered in just six days, the habitat was heterogeneous forest with some areas dominated by bamboo and with steep cliffs that facilitated the sampling effort. In relation to the last point, it seems probable that we would find species which are present at the other study sites.

In comparing these preliminary findings to other sites where nocturnal butterflies have been studied, we must emphasize that the samples were made at elevations between 300 and 700 m above sea level. For example, at Barro Colorado Island (Panama), 139 species of Ctenuchinae have been reported from a 1500-hectare area (Forbes 1939, Dietrich 1990). In the current study, 145 species were reported from the combined effort at the much smaller sites of San Martin-3 and Segakiato. Recognizing that the elevations of Barro Colorado and the Lower Urubamba Region are not the same, it is still interesting to make quantitative comparisons so as to obtain an idea of the diversity of Lower Urubamba nocturnal butterflies. It is possible to state that this area is one of the richest in Peru for these organisms.

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Appendix 1. Nocturnal butterflies found in phases II and III. The genera are ordered following Draudt (1915); SM=San Martin-3; LM=Las Malvinas; PC4=Plot #4; SE=Segakiato; KON=Konkariari; CAS=Cashiriari-3.

Genera	SM	LM	PC4	SE	KON	CAS
Orcynia calcarata (Walker 1854)	X				X	
Pseudosphex nr. *fassli* (Draudt 1915)	X	X		X		X
Isanthrene nr. *crabronides* (Dognin 1912)	X					
Isanthrene nr. *varia* (Walker 1854)	X		X		X	
Isanthrene porphyria (Walker 1854)		X				X
Isanthrene sp. 1	X			X		
Isanthrene sp. 2		X				
Autochloris cuma (Druce 1897)		X				
Autochloris ethela (Schaus 1924)	X					X
Autochloris sp. 1				X		
Sarosa acutior (R. Felder 1874)	X	X		X		X
Sarosa sp. 1	X		X			
Phoenicoprocta vacillans (Walker 1856)	X	X				X
Phoenicoprocta nr. *sanguinea* (Walker 1854)	X					
Pheia albisigna (Walker 1854)		X				X
Loxophlebia nr. *chrysobasis* (Dognin 1912)	X		X		X	
Loxophlebia nr. *diaphana* (Sepp 1848)				X		
Loxophlebia nr. *geminata* (Schaus 1905)		X				
Loxophlebia nr. *picta* (Walker 1854)	X	X		X		X
Loxophlebia triangulifera (R. Felder 1869)	X	X		X		X
Mesothen nr. *bisexualis* (Dognin 1912)	X	X		X		X
Mesothen nr. *pyrrha* (Schaus 1889)?		X				X
Chrostosoma cardinalis (Schaus 1898)	X	X		X		X
Chrostosoma nr. *decisa* (Walker 1864)	X					
Chrostosoma nr. *haematica* (Perty 1834)	X	X	X	X	X	
Chrostosoma nr. *mediana* (Schaus 1928)			X			
Chrostosoma sp. 1		X		X		
Nyridela chalciope (Hübner 1827)	X					X
Leucotmemis albigutta (Schaus 1905)	X	X				
Leucotmemis nr. *nexa* (Herrich-Schäffer 1854)	X				X	
Leucotmemis varipes (Walker 1854)	X	X		X		X
Cosmosoma achemonides (Dognin 1907)	X			X		
Cosmosoma coccinifera (Dognin 1912)						X
Cosmosoma flavothorax (Rothschild 1910)	X	X		X		X
Cosmosoma galathea (Schaus 1912)	X	X				X

Appendix 1. Continued

Genera	SM	LM	PC4	SE	KON	CAS
Cosmosoma oroyanum (Rothschild 1911)	X	X				
Cosmosoma phoenicophora (Dognin 1909)	X			X		X
Cosmosoma regia (Schaus 1894)	X			X		
Cosmosoma nr. *remotum* (Walker 1854)	X	X		X		
Cosmosoma stibosticta (Butler 1876)	X	X		X		X
Cosmosoma subflamma (Walker 1854)		X				X
Cosmosoma telephus (Walker 1854)	X	X		X	X	X
Cosmosoma nr. *teuthras* (Butler 1876)	X	X				
Cosmosoma sp. 1	X	X		X		
Cosmosoma sp. 2				X		
Cosmosoma sp. 3	X				X	
“*Lepidoneiva*” *erubescens* (Butler 1876)	X	X		X		X
Poecilosoma chrysis (Hübner 1827)	X		X			
Poecilosoma eone (Hübner 1827)	X				X	
Mystrocneme varipes (Walker 1854)	X	X				
Dixophlebia quadristigata (Walker 1864)	X	X		X		
Saurita vindonissa (Druce 1883)	X		X		X	
Saurita nr. *venezuelensis* (Klages 1906)				X	X	
Saurita sp. 1		X		X		
Saurita sp. 2		X				
Saurita sp. 3		X		X		
Psoloptera thoracica (Walker 1854)	X	X		X	X	X
Macrocneme sp. 1	X	X		X		
Agyrtidia uranophila (Walker 1866)	X			X		X
Histiaea nr. *amazonica* (Butler 1876)		X				
Histiaea hoffmannsi (Rothschild 1911)	X					
Histiaea proserpina (Hübner 1827)	X	X		X		
Histiaea tina (Walker 1854)	X	X				X
Histiaea sp. 1		X				
Calonotus chalcipleura (Hampson 1898)	X		X		X	
Calonotus nr. *helymus* (Cramer 1775)		X		X		
Calonotus sp. 1	X	X		X		
Poliopastea sp. 1	X			X		
Corematura chrysogastra (Perty 1834)				X		
Paraethria nr. *flavosignata* (Rothschild 1911)					X	
Argyroeides nr. *ceres* (Druce 1893)		X	X			
Hypocladia militaris (Butler 1877)	X	X		X	X	X
Hypocladis nr. *parsipuncta* (Hampson 1909)				X		X
Diptilium proleuca (Druce 1905)	X	X	X		X	
Diptilium sp. 1		X		X		
Metastatia pyrrhorrhoea (Hübner 1827)			X			
Chrysostola nr. *discoplaga* (Schaus 1905)	X					
Chrysosotola pelopia (Druce 1897)			X			
Chrysostola sp. 1	X	X		X		
Chrysostola sp. 2					X	
Ecdemus nr. *hypoleucus* (Herrich-Schäffer 1854)	X	X		X		X

Appendix 1. Continued

Genera	SM	LM	PC4	SE	KON	CAS
Ecdemus nr. *pereirai* (L. Travassos 1940)	X	X				X
Teucer carmania (Druce 1883)	X	X	X	X		
Teucer hypophaea (Hampson 1905)		X		X		X
Teucer sp. 1	X	X		X		X
Teucer glaucopis (Felder 1869)	X	X				X
Pterygopterus clavippenis (Butler 1876)	X*	X*		X*		
Epanycles imperiales (Walker 1854)	X	X		X	X	X
Episcepsis capysca (Schaus 1910)	X	X		X		X
Episcepsis demonis (Druce 1896)	X	X	X	X		X
Episcepsis nr. *dodaba* (Dyar 1910)	X		X			
Episcepsis nr. *hampsoni* (Rothschild 1911)	X		X			
Episcepsis nr. *inortata* (Walker 1856)		X		X		X
Episcepsis lenaeus (Cramer 1780)	X	X		X		X
Episcepsis scintillans (Rothschild 1911)	X	X				X
Episcepsis nr. *sixola* (Schaus 1910)	X	X		X		X
Episcepsis nr. *venata* (Butler 1877)	X		X		X	
Ceramdia sp. 1?			X			
Androcharta cassotis (Druce 1883)						X
Androcharta diversipennis (Walker 1854)	X	X				X
Androcharta hoffmanssi (Rothschild 1912)	X		X	X		
Androcharta meones (Cramer 1780)	X		X			X
Napata albimaculata (Hampson 1901)	X	X				X
Napata nr. *flaviceps* (Hampson 1901)						X
Napata walkeri (Druce 1889)	X	X		X		X
Napata nr. *albiplaga* (Walker 1854)			X			
Loxozona nr. *nitens* (Rothschild 1912)	X	X	X	X		
Cyanopepla nr. *amata* (Druce 1890)			X	X		
Epidesma nr. *aurimacula* (Schaus 1890)	X	X	X	X	X	
Epidesma nr. *klagesi* (Rothschild 1912)	X	X	X	X		X
Epidesma hoffmannsi (Rothschild 1912)	X	X		X		X
Epidesma oceola (Dyar 1910)?	X	X				
Epidesma nr. *ursula* (Stoll 1781)	X	X	X	X		
Coreura sp. 1						X
Pseudoaclytia opponens (Walker 1864)	X	X		X	X	X
Pseudoaclytia nr. *minor* (Schaus 1905)	X	X		X		
Athyphopsis nr. *modesta* (Butler 1878)	X					X
Sciopsyche tropica (Walker 1854)	X	X				X
Patreliura capys (Cramer 1775)	X	X		X		
Lymire nr. *strigivenia* (Druce 1898?)	X	X		X	X	X
Pseudophenoptera chimaera (Rothschild 1911)				X		X
Xantopleura perspicua (Walker 1866)		X				X
Cacostatia sapphira (Staundiger 1875)						X
Schasiura mimica (Butler 1877)	X	X		X		X
Tipuloides rubriceps (Dognin 1912)	X	X		X		X
Osmocneme bracata (Draudt 1915)	X	X				X
Acytia heber (Cramer 1780)	X	X		X		X

Appendix 1. Continued

Genera	SM	LM	PC4	SE	KON	CAS
Aclytia klagesi (Rothschild 1912)	X	X		X		X
Aclytia reducta (Rothschild 1912)	X	X		X		X
Acytia sp. 1		X				
Acytia sp. 2		X		X		
Ptychothrichus nr. *zeus* (Schaus 1894)		X				
Delphyre nr. *hebes* (Walker 1854)	X	X		X	X	X
“Neacerea” dizona (Druce 1898)	X	X		X	X	X
“Neacerea” nr. *flaviceps* (Druce 1905)				X		X
“Neacerea” nr. *lemoulti* (Draudt 1915)	X	X		X		X
“Neacerea” macella (Dognin 1911)	X	X				
“Neacerea” rufiventris (Schaus 1894)						X
“Neacerea” nr. *tetilla* (Dognin 1898)	X			X		
Agyrta garleppi (Rothschild 1912)		X				
Heliura nr. *fulvipincta* (Kaye 1911)				X		X
Heliura phaeosoma (Druce 1905)					X	
Heliura nr. *rhodophila* (Walker 1856)		X			X	X
Heliura nr. *stolli* (Rothschild 1912)		X	X	X		X
Heliura zonata (Druce 1905)		X		X		X
Eucereum complicatum (Butler 1877)	X	X		X	X	
Eucereum nr. *chalcodon* (Druce 1893)	X	X				
Eucereum facundum (Draudt 1915)	X	X				X
Eucereum formosum (Dognin 1905)						X
Eucereum nr. *fuscoirroratum* (Rothschild 1912)	X	X				X
Eucereum nr. *intranotatum* (Dognin 1912)	X		X		X	
Eucereum nr. *leria* (Druce 1884)	X	X		X		X
Eucereum maja (Druce 1884)	X					X
Eucereum nr. *maricum* (Cramer 1775)	X	X		X		X
Eucereum marmoratum (Butler 1877)	X	X		X		X
Eucereum metoidesis (Hampson 1905)	X					
Eucereum nr. *minutum* (Druce 1884)	X	X	X		X	X
Eucereum obscurum (Möschler 1872)	X	X		X		X
Eucereum nr. *punctatum* (Guérin 1844)	X	X				
Eucereum nr. *pagina* (Hampson 1914)	X			X		X
Eucereum parascyton (Hampson 1914)		X	X	X		X
Eucereum nr. *pseudoarchias* (Hampson 1898)	X	X		X		
Eucereum nr. *pyrozonum* (Hampson 1911)	X	X		X		X
Eucereum quadricolor (Walker 1855)	X					
Eucereum reniferum (Hampson 1898)		X				X
Eucereum servator (Kaye 1914)					X	
Eucereum sarisa (Draudt 1915)	X	X		X		X
Eucereum scyton (Cramer 1777)	X	X		X		X
Eucereum setosum (Sepp 1848)	X	X	X	X		X
Ecereum varium (Walker 1854)	X	X	X	X		X
Eucereum sp. 1		X		X		X
Eucereum sp. 2		X				
Eucereum sp. 4		X	X	X		

Appendix 1. Continued

Genera	SM	LM	PC4	SE	KON	CAS
Eucereum sp. 5		X				
Correbia lycoides (Walker 1854)	X	X		X		X
Correbia nr. *minima* (Druce 1903)	X	X		X		X
Correbia nr. *calopteridia* (Butler 1878)	X				X	X
Correbia nr. *terminalis* (Walker 1856)		X				X
Hyaleucerea constinotata (Dognin 1900)	X					
Hyaleucerea erythrotrelus (Walker 1854)	X		X			
Hyaleucerea nr. *fusiformis* (Walker 1854)	X		X			
Hyaleucerea gigantea (Druce 1884)	X	X		X		X
Hyaleucerea leucosticta (Druce 1905)		X				X
Hyaleucerea morosa (Schaus 1910)	X					X
Hyaleucerea vulnerata (Butler 1875)	X	X		X		X
Genus unknown sp. 1		X		X	X	
Genus unknown sp. 2	X	X		X		X
Genus unknown sp. 3		X		X	X	X

* Sampled at Cashiriari-3 by G. Valencia

Biodiversity Assessment of the Hedylidae of the Lower Urubamba Region, Peru

Juan Grados

(reprinted from Alonso and Dallmeier 1998)

1 Introduction

The usual way in which butterflies and moths are differentiated is by color patterns and flying habits. Butterflies normally exhibit a variety of bright colors and diurnal flying habits, while moths are expected to have brown, gray and earthy colors and nocturnal flying habits.

These distinctions do not always hold. There are many cases of moths with diurnal flying habits, including the species of Arctiidae and Castniidae. For example, on the banks of the Amazon River, it is not uncommon to see a bluish green insect with white tails on the hind wings, which could easily pass as a butterfly. It is actually a moth of the Uraniidae family. On the other hand, there are brown, gray or cryptic-colored butterflies such as some Satyrinae.

The general classification system places butterflies into two superfamilies: the Rhopalocera: Hesperioidea and the Papilionoidea. The other superfamilies include moths forming the Heterocera group.

The Hedylidae were considered by Prout (1910, 1931) as a Geometridae tribe because their abdominal form is similar to many butterflies. The generic group names were combined by Scoble (1990) because of a lack of differences among them. In particular, they were quite similar with respect to male genitalia, venation and the form of the wing, legs and antennae. The new

Table 1. Hedylidae recorded at San Martin-3 (SM), Las Malvinas (LM) and Segakiato (SE) in the Lower Urubamba.

Species	SM	LM	SE
Macrosoma albifascia (Warren 1904)		+	
M. bahiata (F and R 1875)	+		
M. conifera (Warren 1897)	+	+	
M. coscoja (Dognin 1900)	+	+	
M. heliconiaria (Guenée 1857)	+	+	+
M. hedylaria (Warren 1894)	+	+	
M. hyacinthina (Warren 1905)	+	+	
M. klagesi (Prout 1916)	+		
M. minutipuncta (Prout 1916)	+		
M. lucivittata (Walker 1863)	+		+
M. muscerdata (F and R 1875)	+		
M. nigrimacula (Warren 1897)	+	+	
M. rubedinaria (Walker 1862)	+	+	+
M. satellitiata (Guenée 1857)	+	+	

superfamily was named Hedyloidea within the Heterocera.

The Hedylidae are a small group of moths. The group's 35 species are distributed in central Mexico and southern Peru, across central Bolivia and southwestern Brazil and in Cuba and Trinidad (Scoble 1990, 1995). There have been no exhaustive studies in the neotropics related to this group, although it is known that 20 species occur in Brazil (Scoble 1990).

2 Methods

Samples of Hedylidae in the Lower Urubamba were accomplished following the methods described for the Ctenuchinae (see Grados this volume). The work took place at the San Martin-3 well site, at the Las Malvinas locality and near the Native community of Segakiato.

3 Results

Of the 35 species of Hedylidae known worldwide, 26 species occur in Peru (Lamas and Grados 1998). At San Martin-3, we registered 12 of those 26 species; at Las Malvinas, we recorded nine species; and at Segakiato, we recorded three species (Table 1).

The total number of different species was 14. This means that at least 53% of the Hedylidae known in Peru are found in the Lower Urubamba.

To summarize, it appears that Peru contains more Hedylidae species than any other country (Lamas and Grados 1998). However, there are many sites, including Tambopata and Manu, where additional inventories are needed before comparisons can be made. It also appears that the Lower Urubamba is the most diverse area for Hedylids in Peru.

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Diversity and Trophic Relationships of Dung Beetles of the Lower Urubamba Region, Peru

Gorky Valencia

1 Introduction

From 1996 to 1998, the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) conducted an assessment of biodiversity in the Lower Urubamba Region of Peru in partnership with Shell Prospecting and Development Peru. The company, which was exploring and drilling for natural gas in the region, asked the Smithsonian to conduct a biodiversity assessment and provide information for use in making environmentally sound management decisions. The work took place at various sites surrounding four of the company's natural gas drilling wells.

As part of the SI/MAB project, I sought to identify the species of Scarabaeinae beetles present in the region and measure the effectiveness of various types of traps and types of bait for assessing Scarabaeinae beetles.

2 Study area

The Lower Urubamba Region in southeastern Peru takes its name from the Urubamba River, which flows north through Pongo de Mainique and converges with the Ucayali River, a tributary of the Amazon River. The region includes lowlands, mountains and hills with elevations ranging from less than 500 meters (m) to more than 1000 m and slopes ranging between 25% and 70%. Lowland tropical forest is the dominant forest type (Comiskey *et al*. this volume). Rainfall can reach 3500 millimeters (mm) per year, with the rainy season occurring from October to April. The average annual temperature is 22°C and varies little throughout the year. Alonso *et al*. (this volume) provide a detailed description of the study area, its people and its history.

Study sites were focused around four natural gas drilling sites. At each site, biologists established a one-hectare (ha) plot (Comiskey *et al*. this volume) and 10 smaller 0.1-ha plots (Campbell *et al*. In press) to assess vegetation. The vegetation studies provided the basic habitat descriptions upon which many of the faunal assessments were based. I conducted the Scarabaeinae study at the San Martin-3, Cashiriari-2, Cashiriari-3 and Pagoreni well sites.

3 Methods

I used baited pitfall traps (Morón and Terrón 1984, Valencia and Alonso 1997) to assess beetles and also collected specimens from non-baited malaise traps, canopy malaise traps and yellow pan traps in conjunction with the assessment of Hymenoptera (Finnamore this volume). In addition, I counted specimens that other researchers sampled opportunistically. For a description of the method used to process specimens, see Finnamore (this volume).

3.1 Baited pitfall traps

The principle guiding use of pitfall traps is to attract select groups of Scarabaeinae through olfactory baits. The traps used in this study consisted of white, disposable, cone-shaped plastic containers one liter (l) in capacity with hermetic lids. Each trap had four symmetrical openings, or entry windows, measuring 3 by 4 centimeters and located 5 mm beneath the lid level. I filled each trap with approximately 0.1 l of preserving solution (diluted alcohol or a solution of soap, salt and saturated water) and suspended a smaller disposable receptacle containing 100 grams of bait inside the trap. The final step was to puncture the lids (four series of 19 holes) for aeration.

I buried the traps so that the bottoms of the windows were at ground level and generally located them on level terrain.

I set the traps in the vegetation plots in series of four traps in square patterns, 4 m on a side. Four series were placed in each one ha plot in a larger square pattern 50 m on a side, the square being centered in the one-ha plot. Two series of traps were set 45 m apart in each of the 0.1- ha plots. I baited each trap in each series of four with a different bait (chicken, feces, fish or fruit). Chicken and fish baits consisted of uncooked meat left to decompose in open air for two days prior to use. Fruit bait consisted of papaya, banana and bread yeast diluted in water and left to ferment in a closed container at air temperature for two days. Feces bait consisted of human feces left in open air for three days prior to use.

The traps were checked every 48 hours. I gathered samples and placed them in whirl-pack bags, which contained alcohol (70%) as preservative and were labeled with the pertinent information (sampling location, plot identification, month, day, trap number and bait used).

Specimens were identified by comparing the samples with morphospecies previously identified and by consulting literature and identification keys (Edmonds 1972, Woodruff 1973, Halffter and Halffter 1977, Halffter and Martínez 1977, Howden and Young 1981, Jessop 1985, Howden and Gill 1987, Morón *et al*. 1988, Edmonds 1994). Additional identification compared samples with previously identified specimens belonging to the Museo de Historia Natural of the Universidad Mayor de San Marcos, Lima and to the Museo de Historia Natural of the Universidad de San Antonio Abad del Cusco. Taxonomic ordering considered Scarabaeinae a sub-family of Scarabaeidae (Browne and Scholtz 1999), while designation and ordering of tribes and genus followed Hanski and Cambefort (1991).

3.2 Diversity analysis

I used Sorenson's qualitative index of similarity to compare species composition among sites (Magurran 1988). The formula to calculate the index was:

$$S=2a / [2a+b+c]$$

where

S = Sorenson's qualitative index of similarity
a = total number of species shared at sites 1 and 2
b = number of species not shared and/or exclusives to site 1
c = number of species not shared and/or exclusives to site 2

4 Results and Discussion

I recorded 86 species of Scarabaeinae from six tribes (Appendix 1). The Dichotomiini was the richest tribe with 37 species, while *Cantidium* was the best represented genus with 14 species, followed by *Deltochilum* (10 species) and *Onthophagus* (eight species). Howden and Nealis (1975) observed similar patterns in Leticia, Colombia, where *Canthidium* was the best represented genus, and *Bdelyrus* and *Cryptocanthon* were the least represented. Pagoreni was the richest site with 63 species, followed by San Martin-3 (50 species) and Cashiriari-2 and Cashiriari-3 (41 species each).

The 86 Scarabaeinae species recorded in this study represent the greatest richness of this group yet recorded in the neotropics for a comparable sampling area (Howden and Nealis 1975, Klein 1989, Celi and Dávalos 1999, Hernández and Vaz de Mello 1999, Vaz de Mello and Oliveira *et al.* 1999 [and other works cited in Halffter 1991]). However, higher richness has been recorded for larger areas (Howden and Young 1981, Escobar 1999, Vaz de Mello and Louzada *et al.* 1999).

Cashiriari-2 and Pagoreni showed the most similarity in samples based on Sorenson's qualitative index of similarity (0.71), followed by Pagoreni and San Martin-3 (0.67), Pagoreni and Cashiriari-3 (0.60), San Martin-3 and Cashiriari-3 (0.55), San Martin-3 and Cashiriari-2 and Cashiriari-3 (0.49). Of the 86 species recorded, 28 (33%) were unique to one site, and 14 (16%) were common to all sites (Appendix 1). San Martin-3 had the largest number (10) of unique species, followed by Cashiriari-3 with eight, Pagoreni with seven and Cashiriari-2 with three.

Feces was the most effective bait. Fifty-six species were recorded using feces, 42 species using chicken, 41 species using fish and 12 species using fermented fruit (Appendix 1). Fifty-five species were sampled in traps with no bait, 11 of them recorded only from non-baited traps: malaise pan traps (44 species), pan traps (17 species, and canopy malaise traps (seven species; Appendix 1). These findings demonstrate the effectiveness of using multiple baits and traps for sampling Scarabaeinae.

The Scarabainae fauna provides a valuable service to the human communities established in the area because it may compensate for deficiencies in sanitary conditions. It has been demonstrated that Scarabaeinae destroy eggs and larvae of nematodes and other gastrointestinal parasites that affect man and other vertebrates. (Howden and Nealis 1975, Klein 1989). They also contribute to decreasing eggs and larvae of dipterons, which also are dangerous to vertebrates (Martínez 1959, Halffter and Matthews 1966, Hanski and Cambefort 1991). Therefore, it is necessary to continue to study the Scarabainae fauna. I suggest future studies focus on habitat relationships of the various species and monitoring studies to investigate the impacts of natural gas exploration in the region.

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Appendix 1. Species of Scarabaeinae recorded in the Lower Urubamba Region, southeastern Peru (species ordered by tribe according to Hanski and Cambefort [1991] and listed by site [SM-3 = San Martin-3, Cash-2 = Cashiriari-2, Cash-3 = Cashiriari-3, Pag = Pagoreni]; samples obtained from baited pitfall traps and non-baited traps; type of bait listed for species obtained from baited traps; type of trap listed for species obtained from non-baited traps).

	Site				Bait [a]	Additional Traps [b]
Species	SM-3	Cash-2	Cash-3	Pag		
Canthonini (27 spp.)						
Genus *Canthochilum* Chapin, 1934						
Canthochilum sp. 1		X				P
Genus *Canthon* Hoffmannsegg, 1817						
Subgenus *Canthon* Hoffmannsegg, 1817						
Canthon C. group *ciannelus* 1				X	fi	
Canthon C. "linea" juvencus 1			X	X		CM, MP
Canthon C. "linea" juvencus 2		X			c, fe, fi	O
Canthon C. nr. morsei Howden, 1966				X	c, fi	MP
Canthon C. sp. 1	X	X		X	fe	CM
Canthon C. sp. 2			X			O
Canthon C. sp. 3	X				fi	
Subgenus *Goniocanthon* Pereira and Martinez, 1956						
Canthon G. *smaragdulus* Fabricius, 1781	X	X		X	fe	O
Genus *Canthonella* Chapin, 1930						
Canthonella sp. 1		X		X	fe	P
Canthonella sp. 2				X	fe	P
Genus *Cryptocanthon* Balthasar, 1942						
Cryptocanthon sp. 1	X				fi	MP
Genus *Deltochilum* Eschscholtz, 1822						
Deltochilum carinatum Westwood, 1837		X	X	X	c, fe, fi	
Deltochilum nr. *gibbosum* Fabricius, 1775	X	X	X	X	c, fe, fi, fr	
Deltochilum gibbosum spp.		X	X	X	c, fe, fi	
Deltochilum laevigatum Balthasar, 1939	X	X	X	X	c, fe, fi	P,MP
Deltochilum sericeum Paulian, 1938	X				fe	
Deltochilum vivalgum Burmeister	X	X		X	fr	MP, P
Deltochilum sp. 2	X		X	X	c, fe, fi	
Deltochilum sp. 6		X		X	fe, fi	
Deltochilum sp. 8		X	X	X	c, fi	MP
Deltochilum sp. 12		X				P
Genus *Pseudocanthon* Bates, 1887						
Pseudocanthon sp. 3	X				c	
Genus *Scybalocanthon* Martinez, 1948						
Scybalocanthon sp. 1	X			X	c, fe	P
Genus *Sylvicanthon* Halffter and Martinez, 1977						
Sylvicanthon sp. 2	X	X	X	X	c, fe	MP
Sylvicanthon sp. 3	X	X	X	X	fe, fi	
Sylvicanthon sp. 5	X					MP

Appendix 1. Continued

	Site				Bait [a]	Additional Traps [b]
Species	SM-3	Cash-2	Cash-3	Pag		
Coprini (1 sp.)						
Genus *Copris* Müller, 1764						
Copris sp.1		X		X		P, MP
Dichotomiini (37 spp.)						
Genus *Ateuchus* Weber, 1801						
Ateuchus sp. 5				X	fe	
Ateuchus sp. 8		X		X	c, fe, fi	MP
Ateuchus sp. 9	X				fe	MP
Ateuchus sp.10		X		X	c, fe, fi, fr	MP,P
Genus *Bdelyrus* Harold, 1869						
Bdelyrus sp. 1			X		fe	
Genus *Canthidium* Erichson, 1847						
Canthidium sp. 2	X	X		X	c, fr	MP
Canthidium sp. 3	X		X	X	c, fe, fi	MP,P
Canthidium sp. 4		X		X	fe, fi	MP,P
Canthidium sp. 5	X	X		X	c, fe	MP,P
Canthidium sp. 6		X		X	fe	MP
Canthidium sp. 8	X			X	c	
Canthidium sp. 9		X		X	fe	MP,P
Canthidium sp. 10			X			MP
Canthidium sp. 11	X					MP
Canthidium sp. 12	X					MP
Canthidium sp. 13	X		X	X	fe	MP,P
Canthidium sp. 14			X		fe	
Canthidium sp. 15	X	X	X	X	c, fe, fi	MP
Canthidium sp. 17		X		X		MP
Genus *Dichotomius* Hope, 1838						
Dichotomius ohausi Luederwaldt, 1923	X		X	X	c, fe, fi, fr	
Dichotomius prietoi Martinez	X	X	X	X	c, fe	MP
Dichotomius sp. 1	X	X	X	X	c, fe, fi	MP
Dichotomius sp. 2	X	X	X	X	c, fe, fi, fr	
Dichotomius sp. 11			X	X	c, fe, fi, fr	
Dichotomius sp. 12				X	c, fi	
Dichotomius sp. 14				X	fe	
Genus *Onthocharis* Westwood, 1847						
Onthocharis sp. 2			X			MP
Genus Ontherus Erichson, 1847						
Ontherus sp. 1	X		X		fe, fi	
Ontherus sp. 2		X		X	c, fi	MP, CM
Ontherus sp. 6				X		MP
Genus *Scatimus* Erichson, 1847						
Scatimus sp. 1			X		fe	
Scatimus sp. 5	X					P

Appendix 1. Continued

	Site				Bait [a]	Additional Traps [b]
Species	SM-3	Cash-2	Cash-3	Pag		
Genus *Uroxys* Westwood, 1842						
Uroxys sp. 2	X	X		X	fe	MP, P, CM
Uroxys sp. 3	X	X		X	fi	MP, P
Uroxys sp. 4	X	X	X	X	fe	MP
Uroxys sp. 6	X					MP
Eurysternini (5 spp.)						
Genus *Eurysternus* Dalman, 1824						
Eurysternus caribaeus Herbst, 1789	X	X	X	X	c, fe, fi	MP
Eurysternus deplanatus Germar, 1824			X	X	fe, fi	
Eurysternus hirtellus Dalman, 1824	X		X	X	c, fe, fi	MP
Eurysternus plebejus Harold, 1880	X		X	X	c, fe, fi	
Eurysternus velutinus Bates, 1887		X	X	X	c, fe, fi	
Onthophagini (8 spp.)						
Genus *Onthophagus* Latreille, 1802						
Onthophagus nr. *clypeatus* Blanchard, 1843	X			X	c, fe, fi, fr	
Onthophagus haematopus Harold, 1875	X	X	X	X	c, fe, fi, fr	MP, CM
Onthophagus group *hirculus* nr. *osculatii* Guerin, 1955	X		X	X	c, fe, fi	
Onthophagus xanthomerus Bates, 1889	X	X	X	X	c, fe, fi, fr	MP, P
Onthophagus group *hirculus* sp. 1	X	X		X	c, fe, fi	
Onthophagus group *hirculus* sp. 2	X	X	X		c, fe, fr	CM
Onthophagus sp. 2	X	X	X	X	c, fe, fi, fr	
Onthophagus sp. 12			X		fe	
Phanaeini (9 spp.)						
Genus *Coprophanaeus* Olsoufieff, 1924						
Coprophanaeus telamon telamon Erichson, 1847	X	X	X	X	c, fe, fi	MP
Coprophanaeus sp. 4	X		X	X	c, fi	
Coprophanaeus sp. 5	X			X	c, fi	MP
Coprophanaeus sp. 6	X			X	c, fi	
Genus *Oxysternon* Laporte de Castlenau, 1840						
Subgenus *Oxysternon* Laporte de Castlenau, 1840						
Oxysternon O. conspicillatum Weber, 1801	X		X	X	c, fe	MP
Oxysternon O. group *silenum* 1	X			X	fe	MP
Oxysternon O. group *silenum* 2			X			MP
Genus *Phanaeus* Macleay, 1819						
Subgenus *Notiophanaeus* Edmonds, 1994						
Phanaeus N. cambeforti Arnaud, 1982		X	X	X	fi	MP, P
Phanaeus N. chalcomelas Perty, 1830	X			X	fi	MP
TOTAL SPECIES	50	41	41	63		

[a] Bait types: c = chicken, fe = feces, fi = fish, fr = fruit

[b] Trap types: CM = canopy Malaise trap, MP = Malaise pan trap (intercepting flying trap), O = opportunistic sampling, P = pan trap

Assessment of Amphibians and Reptiles of the Lower Urubamba Region, Peru

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1 Introduction

Throughout the world, many amphibian populations are declining at alarming rates (Blaustein and Wake 1990, Phillips 1990, Wyman 1990, Wake 1991, Blaustein and Wake *et al*. 1994, Blaustein and Wake 1995, Green 1997, Houlahan *et al*. 2000). Reasons for the declines include habitat loss and degradation (Lannoo *et al*. 1994, Delis *et al*. 1996), acid precipitation (Wyman 1988, Sadinski and Dunson 1992), UV-B radiation (Blaustein and Hoffman *et al*. 1994), pathogens (Blaustein and Hokit *et al*. 1994, Anderson 1995), introduction of exotic species (Schwalbe and Rosen 1988, Fisher and Shaffer 1996), harvesting by humans (Hayes and Jennings 1986) and natural population fluctuations (Pechmann *et al*. 1991). These factors, which affect other taxa as well, make it all the more important to assess and monitor amphibian and reptile populations, especially in previously unexplored regions.

Amphibians are extremely helpful to the broader study of ecosystem functioning. Their life cycles involve both aquatic and terrestrial habitats. Their permeable skins and mostly cutaneous respiration make them sensitive to pollutants. Their nutrition level is high. They constitute an appreciable portion of the biomass in many ecosystems (Wake 1991). Therefore, they often serve as valuable indicators of ecosystem health.

In 1996, Shell Prospecting and Development Peru (SPDP) began to explore the Lower Urubamba Region in southeastern Peru for natural gas deposits. SPDP established four exploration sites and planned to construct additional infrastructure, including a power plant and a pipeline to transport the gas across the Andes to the Pacific. Because the region is rich in biodiversity and knowing that development could impact biodiversity, the company enlisted the aid of the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB). Together, SI/MAB and SPDP saw an opportunity to acquire further understanding of this diverse ecosystem while ensuring that development of natural gas would have minimal impacts on the region's biodiversity.

The primary objectives of our work were to gather baseline data on the distribution and abundance of the herpetofauna in the region, increase understanding of the potential effects of gas development on the herpetofauna and devise management strategies to minimize the impacts of that development. Here, we present an assessment of the herpetofauna of the Lower Urubamba Region based on our studies and drawing from the work of all those who participated in the assessment of reptiles and amphibians during the term of the project (Cordova and Aguilar 1997; Icochea and Mitchell 1997; Morales 1997; Mitchell 1997; Reynolds *et al*. 1997; Icochea *et al*. 1998, 1999).

2 Study area

The Lower Urubamba Region lies deep within the forests of southwestern Amazonia at the confluence of the Urubamba, Camisea and Cashiriari rivers in southeastern Peru. The region is part of an extensive expanse of unbroken, lowland tropical forest extending from Manu National Park to the foothills of the Andes.

The study area, approximately 600 kilometers^2 in size, is located at 12° south latitude, 73° west longitude. We assessed the amphibian and reptile community at the four gas wells sites — San Martin-3 (Sanm-3), Cashiriari-2 (Cash-2), Cashiriari-3 (Cash-3) and Pagoreni (Pag) — and at two sites — Segakiato (Sega) and Peruanita (Perua) — along the Urubamba and Camisea rivers. Comiskey *et al.* (this volume) provide detailed descriptions of the vegetation at each site. Basically, all of the sites are mature, non-flooded, tropical rainforest. Steeply sloping hills prevented the formation of large areas of seasonal standing water. The arborescent bamboo, *Guadua sarcocarpa*, is abundant at Sanm-3, Cash-3 and Perua, but absent from the other sites. Tree falls, landslides and other natural disturbances are common throughout the area, while human disturbances in the region are negligible.

The Lower Urubamba Region experiences seasonal patterns in precipitation, with mean annual rainfall averaging between 3000 and 3500 millimeters. Rainfall occurs mostly from October through April, with a peak in December (Dallmeier and Alonso 1997). Mean temperatures range from 23.5° C to 24.5° C, while the relative humidity normally exceeds 80%.

3 Methods

Researchers assessed the amphibian and reptile communities at Sanm-3 and Cash-2 from March through June of 1997 (Cordova and Aguilar 1997, Icochea and Mitchell 1997, Mitchell 1997, Reynolds *et al.* 1997), at Cash-3 from October through December of 1997 (Icochea *et al.* 1998), at Pag from April through May of 1998 (Icochea *et al.* 1999) and at all sites from September through November of 1998 (Icochea *et al.* 1999). Field teams collected data for two to four weeks at each site.

We collected at least one voucher specimen for each species recorded. Each specimen was euthanized, tagged with its own unique code, preserved in a small quantity of diluted formaldehyde and stored in alcohol. We deposited all vouchers in the Museo de Historia Natural, Universidad Nacional Mayor de San Marcos, Peru (MUSM) and the Smithsonian Institution, National Museum of Natural History, Washington, DC (NMNH).

We used the collection of amphibians and reptiles at MUSM and NMNH as aids to identify the specimens, along with the following literature: Savage (1960), Brame and Wake (1963), Uzzell (1966), Peters and Orejas-Miranda (1970), Peters and Donoso-Barros (1970), Dixon and Soini (1975, 1977), Duellman (1978a,b,c,d), Wake *et al.* (1982), Vanzolini (1986), Campbell and Lamar (1989), Rodríguez and Myers (1993), Rodríguez (1994), Rodríguez and Duellman (1994), Avila-Pires (1995), Duellman and Mendelson (1995) and Vitt and De la Torre (1996).

The sampling design entailed subjective selection of assessment sites to ensure adequate sampling of all habitats and maximize the number of species encountered. This included day and night sampling along trails and streams, in primary forest and at the well sites. Methods, discussed below, included visual and audible searches, trapping and quadrat sampling (Heyer *et al.* 1994). We also recorded some species through fortuitous sampling.

3.1 Visual and audible searches

We used the visual encounter survey (Campbell and Christman 1982, Corn and Bury 1990, Crump and Scott 1994) and audio strip transect (Zimmerman 1994) methods for night sampling after establishing sampling transects along trails, streams and ridgetops and systematically through parts of the forest. For the visual encounter survey, we walked the transects and intensively searched for animals sitting on the ground, under rocks and logs and perched on leaves or branches. For the audio strip transect, we listened for and identified the calls of male frogs along the transects. We made no attempts to quantify abundance.

3.2 Trapping

We used two trapping techniques — sticky (glue) traps and pitfall traps. Sticky traps are constructed of glue-coated cardboard; animals that step onto the glue become stuck. We placed sticky traps in open areas of the forest and on tree branches, fallen tree trunks, bamboo shoots and the ground. We also set a series of pitfall traps along 15-meter (m) lines, burying six 10-liter buckets at ground level at equal distances from each other. We erected an aluminum flashing fence supported by wooden stakes along the bucket line. Animals would encounter and follow the fence until they fell into the buckets and were unable to escape.

3.3 Quadrat sampling

We used both unfenced and fenced quadrats. Unfenced litter quadrats are commonly used in New World tropics and elsewhere as a quantitative measure of forest floor herpetological communities. To establish these quadrats, we delineated a 10 x 10-m area, then thoroughly examined and removed all leaf litter within the plot while recording all amphibians and reptiles encountered. In fenced plots, also 10 x 10 m in size, we excluded all vegetation extending upwards from ground level through the canopy along the perimeter of the plot. We then erected fences of greased aluminum flashing with walls 0.5 m in height at the plot perimeters to serve as a barrier to amphibian and reptile movement into or out of the plot during the study period. We inspected vegetation in each plot and removed it down to the soil substrate. All amphibians and reptiles encountered were identified.

4 Results and Discussion

We recorded 74 amphibians (Appendix 1) and 84 reptiles (Appendix 2) in the Lower Urubamba Region. Frogs (Anura) accounted for 70 of the amphibian species recorded, and nearly three-quarters (74.3%) of those frogs were from two families — Hylidae (25 species) and Leptodactylidae (27 species). Among the reptiles, 79 species were from the Order Squamata, including 49 species of snakes (35 of which were Colubridae) and 29 species of lizards.

As tables 1, 2 and 3 indicate, both the amphibian and reptile communities in the Lower Urubamba Region are similar in richness and diversity to other sites in western Amazonia. The Lower Urubamba Region is most similar to nearby Manu National Park (Pakitza and Cocha Cashu stations).

4.1 Notable occurrences

The lizard *Neusticurus juruazensis* and the snake *Ninia hudsoni* were new records for Peru. The lizard was found at Cash-2, Cash-3 and Pag, and the snake at Cash-2 and Cash-3.

The coral snake (*Micrurus* sp.) that we recorded resembled *M. corallinus*, but was definitely a different species. It has also been recorded at Pakitza (Víctor Morales personal communication).

We sampled one individual of the snake *Dipsas* cf. *peruana*, which differed from a similar snake known in

Table 1. Comparison of similarity indices and number of species in common for frogs (Anura) between the Lower Urubamba Region, Peru (LUR) and seven sites in western Amazonia (70 species recorded in the LUR; sources: Duellman and Thomas (1996), Morales and McDiarmid (1996), Duellman (1978a)).

	Cuzco Amazonico, Madre de Dios, Peru	Pakitza, Manu N.P., Madre de Dios, Peru	Cocha Cashu, Madre de Dios, Peru	Balta, Alto Purús, Ucayali, Peru	Panguana, Huánuco, Peru	Explorama, Loreto, Peru	Santa Cecilia, Ecuador
# of species	63	67	72	55	53	65	84
# of species in common	39	44	50	35	39	35	42
Jaccard's index	0.42	0.47	0.54	0.39	0.47	0.36	0.38
Sorenson's index	0.59	0.64	0.70	0.56	0.63	0.52	0.55

Table 2. Comparison of similarity indices and number of species in common for lizards (Squamata: Sauria) between the Lower Urubamba Region, Peru (LUR) and seven sites in western Amazonia (29 species recorded in the LUR; sources: Da Silva and Sites (1995), Morales and McDiarmid (1996), Duellman (1978a)).

	Santa Cecilia, Ecuador	Iquitos Region, Loreto, Peru	Pakitza, Manu N.P., Madre de Dios, Peru	Cuzco Amazonico, Madre de Dios, Peru	Samuel, Brazil	INPA, Manaus, Brazil	Belem, Brazil
# of species	30	38	22	23	33	24	32
# of species in common	19	22	17	16	18	10	13
Jaccard's index	0.48	0.49	0.50	0.44	0.41	0.23	0.27
Sorenson's index	0.64	0.66	0.67	0.62	0.58	0.38	0.43

the zone by the presence of transverse yellow stripes on its back. This is not in accordance with any other known species.

The lizard *Anolis dissimilis* that we found is an arboreal species rarely recorded. The only other known record from Peru is in the Madre de Dios department.

The small lizard *Bachia trisanale abendrothi* inhabits the humid leaf litter. The vermiforme body of our specimen had limited markings on the extremities, a characteristic not frequently encountered. We located nine individuals in a 1248-m^2 area (26 x 48 m) at the Peruanita camp. The majority were dead, having dehydrated because of the loss of their protective vegetative cover when the area was cleared for the camp. We rehydrated the dead specimens on site before preserving them. This register is within the limits of the lizard's southern distribution (Dixon 1973). However, further taxonomic studies are needed for these specimens.

Frogs of the genus *Eleutherodactylus* were common throughout the study area. Frogs of this genus develop directly from an egg to the adult stage without a free-living aquatic tadpole stage and thus do not necessarily depend on standing water for their development (Reynolds *et al.* 1997). As noted earlier, the topography of the region prohibited the accumulation of large pools of standing water. This situation may promote the presence of species that are less dependent on water during some phase of their life.

The small frog *Adenomera* sp. that we recorded differed from the other known members of the genus (see Heyer 1977). Our specimen had a much flatter external edge on its snout compared to specimens from other locales in the region. Four individuals were sampled, and the frog's song was recorded on tape. Further studies are required to determine the taxonomic status of this specimen.

The caecilian *Epicrionops bicolor* is registered for the western slopes of the Peruvian and Ecuadorian Andes and is characteristic of cloud forests. Our adult individual was recorded at Cash-2 and Cash-3. *Hyla phyllognatha*, a frog typical of western Andean montane forests, is frequently confused with frogs of the Centrolenidae family. We recorded this species at Pag, Cash-2 and Cash-3 along with other species that are typical of cloud forests in this area. Interestingly, Comiskey *et al.* (this volume) recorded several montane plant species at Cash-3, Solari *et al.* (this volume) recorded several montane mammals at the same site and Angehr *et al.* (this volume) recorded several montane birds there.

4.2 Methodology considerations

The methods chosen were successful at establishing the baseline data on the herpetofauna present in the Lower Urubamba Region. Based on experiences gathered during this assessment, visual encounter surveys along transects at night elicited more information on species richness than any other method.

The difference in numbers of amphibians encountered using traditional unfenced quadrats versus the fenced quadrats was striking. For example, Reynolds *et al.* (1997) found that at Sanm-3, the unfenced quadrats produced three anurans (one dendrobatid and two *Eleutherodactylus*), whereas the fenced quadrats produced 29 anurans (including five microhylids not encountered during any other sampling effort) and one snake (*Corallus hortulanus*). Despite the encouraging effectiveness of the fenced quadrats, researchers should consider the costs. The fenced quadrats were labor intensive and highly destructive to vegetation. These traits may not be desirable in many situations. Furthermore, Reynolds *et al.* (1997) suggest that replicates of this methodology are needed to properly evaluate its effectiveness in determining estimates of absolute abundance relative to the unfenced quadrats, which are less destructive and require less labor and time.

Sticky traps were highly effective for sampling lizards. Reynolds *et al.* (1997) suggested placing sticky traps on the ground as well as on low branches and bamboo stems in areas of broken sunlight and shade. Using sticky traps, we and Reynolds *et al.* (1997) were successful in capturing many lizards that were never or only rarely seen during visual surveys, including *Ameiva ameiva*, *Anolis fuscoauratus*, *A. dissimilis*, *A. trachyderma*, *Arthrosaura reticulata*, *Cercosaura ocellata*, *Gonatodes hasemanni*, *Iphisa elegans*, *Neusticurus ecpleopus*, *Prionodactylus argulus*, *Stenocercus roseiventris* and *Thecadactylus rapicauda*. Sticky traps enabled Reynolds *et al.* (1997) to sample some larger lizards (for example, *Anolis punctatus*, *Kentropyx pelviceps* and *Mabuya bistriata*) in densely vegetated areas where sampling by hand was hindered.

From our work over three years, we conclude that the herpetofauna in the Lower Urubamba Region is among the richest known in the neotropics. We suggest that future studies obtain data on abundance of select groups, investigate traditional uses of amphibians and reptiles by local human communities and monitor the aquatic life stages of amphibians, especially in the areas where treated water from gas exploration is delivered for storage.

Table 3. Comparison of similarity indices and number of species in common for snakes (Squamata: Serpentes) between the Lower Urubamba Region, Peru (LUR) and eight sites in western Amazonia (49 species recorded in the LUR; sources: Da Silva and Sites (1995), Morales and McDiarmid (1996), Arizabal (1996), Duellman (1978a)).

	Santa Cecilia, Ecuador	Iquitos Region, Loreto, Peru	Leticia, Colombia	Cocha Cashu, P.N. Manu, Madre de Dios, Peru	Pakitza, P.N. Manu, Madre de Dios, Peru	Cuzco Amazonico, Madre de Dios, Peru	Samuel, Brazil	INPA, Manaos, Brazil
# of species	53	88	65	47	31	49	92	61
# of species in common	38	41	34	34	21	31	39	32
Jaccard's index	0.59	0.43	0.43	0.55	0.36	0.53	0.39	0.41
Sorenson's index	0.75	0.60	0.60	0.71	0.53	0.63	0.55	0.58

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Appendix 1. Amphibian species recorded at six sites in the Lower Urubamba Region, Peru (74 species total).

Species	San Martin-3	Cashiriari-2	Segakiato	Peruanita	Cashiriari-3	Pagoreni
Gymnophiona						
Caecilidae (1 spp.)						
Caecilia cf. *tentaculata*	X	-	-	X	X	X
Rhinatrematidae (1 spp.)						
Epicrionops cf. *bicolor*	-	X	-	-	X	-
Caudata						
Plethodontidae (2 spp.)						
Bolitoglossa cf. *altamazonica*	X	X	X	X	X	-
Bolitoglossa sp.	-	-	-	-	-	X
Anura						
Bufonidae (4 spp.)						
Atelopus spumarius	-	X	-	-	X	-
Bufo glaberrimus	-	-	X	-	X	-
Bufo marinus	X	X	X	-	X	X
Bufo typhonius group	X	X	X	X	X	X
Centrolenidae (3 spp.)						
Cochranella cf. *spiculata*	X	-	-	-	X	X
Hyalinobatrachium cf. *bergeri*	X	-	-	-	X	X
Hyalinobatrachium cf. *munozorum*	X	-	-	-	X	-
Dendrobatidae (7 spp.)						
Colostethus trilineatus	-	X	-	-	-	-
Dendrobates biolat	X	-	-	-	X	-
Dendrobates ventrimaculatus group	X	-	-	-	-	-
Epipedobates femoralis	X	X	X	X	X	X
Epipedobates macero	X	X	X	X	X	X
Epipedobates pictus	-	-	-	X	-	-
Epipedobates trivittatus	-	-	-	X	-	-
Hylidae (25 spp.)						
Agalychnis craspedopus	-	-	X	-	-	-
Hemiphractus cf. *johnsoni*	X	X	-	-	X	X
Hemiphractus scutatus	X	-	-	-	X	-
Hyla boans	-	-	-	X	-	X
Hyla fasciata	-	-	-	X	-	-
Hyla geographica	X	-	-	-	X	X
Hyla lanciformis	X	X	-	X	X	X
Hyla cf. *leali*	-	-	-	X	-	-
Hyla leucophyllata	-	-	-	X	-	-
Hyla marmorata	X	X	-	-	-	-
Hyla parviceps	X	X	-	-	X	-
Hyla phyllognatha	-	X	-	-	X	X
Hyla rhodopepla	-	-	-	-	X	-
Hyla sp.	-	X	X	-	-	-
Osteocephalus leprieurii	X	X	X	X	X	X
Osteocephalus taurinus	-	X	X	-	X	X
Osteocephalus sp.	X	X	-	X	-	-

Appendix 1. Continued

Species	San Martin-3	Cashiriari-2	Segakiato	Peruanita	Cashiriari-3	Pagoreni
Phrynohyas coriacea	-	X	-	X	-	-
Phrynohyas resinifictrix	X	-	-	-	-	X
Phrynohyas venulosa	-	X	-	-	-	-
Phyllomedusa tarsius	X	X	-	-	X	X
Phyllomedusa tomopterna	X	X	-	-	X	X
Phyllomedusa vaillanti	X	-	-	X	X	X
Scinax garbei	X	-	-	X	-	-
Scinax rubra	X	X	-	X	X	X
Leptodactylidae (27 spp.)						
Adenomera hylaedactyla	X	-	X	X	X	X
Adenomera sp.	-	X	X	-	-	X
Ceratophrys cornuta	-	-	X	-	-	-
Eleutherodactylus acuminatus	X	-	X	X	X	X
Eleutherodactylus cf. *altamazonicus*	X	X	-	X	X	-
Eleutherodactylus carvalhoi	X	X	-	X	X	X
Eleutherodactylus conspicillatus group	X	X	-	X	X	X
Eleutherodactylus cf. *diadematus*	X	X	-	-	X	X
Eleutherodactylus fenestratus	X	X	X	X	X	X
Eleutherodactylus lacrimosus	X	-	-	X	X	-
Eleutherodactylus cf. *lythrodes*	X	X	-	-	X	X
Eleutherodactylus ockendeni	X	-	X	X	X	X
Eleutherodactylus peruvianus	X	X	X	-	X	X
Eleutherodactylus sulcatus	X	-	-	-	X	-
Eleutherodactylus toftae	X	X	X	X	X	X
Eleutherodactylus unistrigatus group	X	X	X	X	X	X
Eleutherodactylus cf. *ventrimarmoratus*	X	X	-	X	X	X
Ischnocnema quixensis	X	X	-	X	X	X
Leptodactylus knudseni	-	-	-	-	X	X
Leptodactylus leptodactyloides	X	X	X	-	X	-
Leptodactylus mystaceus	-	-	-	X	-	-
Leptodactylus pentadactylus	X	X	-	X	X	X
Leptodactylus cf. *petersii*	X	-	X	X	X	-
Leptodactylus rhodonotus	X	X	X	-	X	X
Lithodytes lineatus	X	-	X	-	-	X
Phyllonastes myrmecoides	X	X	-	-	-	X
Physalaemus petersi	-	-	-	X	-	-
Microhylidae (4 spp.)						
Chiasmocleis cf. *ventrimaculata*	-	-	-	X	-	-
Ctenophryne geayi	X	X	-	-	X	-
Hamptophryne boliviana	-	-	-	X	-	-
Syncope antenori	X	-	-	-	X	-
Total Caudata Species	1	1	1	1	1	1
Total Gymnophiona Species	1	1	0	1	2	1
Total Anura Species	47	37	22	34	46	37
Total Species	49	39	23	36	49	39

Appendix 2. Reptile species recorded at six sites in the Lower Urubamba Region, Peru (84 species total).

Species	San Martin-3	Cashiriari-2	Segakiato	Peruanita	Cashiriari-3	Pagoreni
Crocodylia						
Alligatoridae (3 spp.)						
Caiman crocodilus	-	-	-	X	-	-
Paleosuchus palpebrosus	-	X	-	X	-	-
Paleosuchus trigonatus	X	-	-	-	-	-
Testudines						
Chelidae (1 spp.)						
Phrynops geoffroanus	-	-	X	-	-	-
Testudinidae (1 spp.)						
Geochelone denticulata	X	-	-	-	X	-
Squamata: Amphisbaenia						
Amphisbaenidae (1 spp.)						
Amphisbaena fuliginosa	-	X	-	-	X	-
Squamata: Sauria						
Gekkonidae (3 spp.)						
Gonatodes hasemani	X	X	-	-	-	-
Pseudogonatodes guianensis	X	X	-	X	X	X
Thecadactylus rapicauda	X	X	-	-	X	X
Gymnophthalmidae (9 spp.)						
Alopoglossus angulatus	X	X	-	X	-	X
Alopoglossus buckleyi	X	X	-	-	X	X
Arthrosaura reticulata	-	-	-	-	-	X
Bachia trisanale abendrothi	-	-	-	X	-	-
Cercosaura ocellata	X	X	-	-	-	-
Iphisa elegans	X	-	-	-	-	X
Neusticurus ecpleopus	X	X	X	X	X	X
Neusticurus juruazensis	-	X	-	-	X	X
Prionodactylus argulus	X	X	-	X	X	X
Hoplocercidae (2 spp.)						
Enyalioides laticeps	-	-	-	-	-	X
Enyalioides palpebralis	X	-	-	X	-	-
Polychrotidae (8 spp.)						
Anolis dissimilis	X	-	-	-	-	-
Anolis fuscoauratus	X	X	X	X	X	X
Anolis nitens tandai	X	-	-	X	-	X
Anolis ortonii	-	X	-	-	X	-
Anolis punctatus	X	X	-	-	X	X
Anolis trachyderma	X	X	X	X	X	X
Anolis transversalis	X	-	X	-	-	X
Polychrus liogaster	X	-	-	-	-	-
Scincidae (1 spp.)						
Mabuya bistriata	X	-	-	-	X	X

Appendix 2. Continued

Species	San Martin-3	Cashiriari-2	Segakiato	Peruanita	Cashiriari-3	Pagoreni
Teiidae (3 spp.)						
Ameiva ameiva	X	X	-	-	-	X
Kentropyx pelviceps	X	X	X	-	X	X
Tupinambis teguixin	X	-	-	-	X	-
Tropiduridae (3 spp.)						
Plica plica	X	X	-	-	-	X
Plica umbra	X	X	-	-	X	X
Stenocercus roseiventris	X	X	-	-	X	X
Squamata: Serpentes						
Aniliidae (1 spp.)						
Anilius scytale	-	-	-	-	-	X
Boidae (2 spp.)						
Corallus hortulanus	X	-	-	-	-	X
Epicrates cenchria	X	X	-	-	-	X
Colubridae (35 spp.)						
Atractus badius	X	X	-	-	X	-
Atractus elaps	X	X	-	-	X	-
Atractus major	X	X	X	X	X	X
Chironius carinatus	-	-	-	-	X	-
Chironius fuscus	-	-	-	-	X	-
Chironius cf. *monticola*	X	-	-	-	-	-
Chironius multiventris	-	-	-	-	X	-
Chironius scurrulus	-	X	-	-	X	-
Clelia clelia	X	-	-	-	X	-
Dendrophidion dendrophis	-	X	-	-	X	-
Dipsas catesbyi	X	-	-	-	X	X
Dipsas indica	X	-	-	X	-	-
Dipsas cf. *peruana*	-	-	-	-	X	-
Drymobius rhombifer	-	X	-	X	-	X
Drymoluber dichrous	-	X	-	-	-	-
Imantodes cenchoa	X	X	-	-	X	X
Imantodes lentiferus	X	X	-	-	X	X
Leptodeira annulata	X	-	X	-	X	X
Leptophis ahaetulla	-	-	-	-	X	-
Leptophis cupreus	-	-	-	-	X	-
Liophis cobellus	X	-	-	-	X	X
Liophis epinephelus fraseri	-	X	-	-	-	-
Liophis reginae	X	X	-	-	X	-
Ninia hudsoni	-	X	-	-	X	-
Oxybelis argenteus	-	-	-	X	X	-
Oxyrhopus formosus	-	-	-	-	X	-
Oxyrhopus petola	X	X	X	-	X	X
Pseustes poecilonotus polylepis	-	X	X	-	-	-
Pseustes sulphureus	X	-	-	-	X	X
Rhadinaea brevirostris	X	-	-	-	-	X

Appendix 2. Continued

Species	San Martin-3	Cashiriari-2	Segakiato	Peruanita	Cashiriari-3	Pagoreni
Tantilla melanocephala	X	-	-	-	-	-
Tripanurgos compressus	X	-	-	-	X	X
Xenodon rabdocephalus	X	-	-	-	X	X
Xenodon severus	-	-	X	-	X	-
Xenopholis scalaris	X	-	-	-	X	-
Elapidae (5 spp.)						
Leptomicrurus narduccii	X	-	-	-	-	-
Micrurus lemniscatus	-	-	-	-	-	X
Micrurus spixii obscurus	-	-	-	-	X	X
Micrurus surinamensis	-	-	-	-	-	X
Micrurus sp.	-	X	-	-	-	X
Leptotyphlopidae (1 sp.)						
Leptotyphlops cf. *diaplocius*	X	-	X	-	X	X
Typhlopidae (1 sp.)						
Typhlops reticulatus	-	-	-	-	-	X
Viperidae (4 spp.)						
Bothriopsis bilineata	-	X	-	-	-	X
Bothrops atrox	-	-	X	-	X	X
Bothrops brazili	X	X	-	-	-	X
Lachesis muta	X	X	-	-	-	X
Total Crocodylia Species	1	1	0	2	0	0
Total Testudines Species	1	0	1	0	1	0
Total Amphisbaenia Species	0	1	0	0	1	0
Total Sauria Species	24	18	5	9	15	21
Total Serpentes Species	25	19	7	4	30	25
Total Species	51	39	13	15	47	46

Diversity and Conservation of Fish of the Lower Urubamba Region, Peru

Hernán Ortega, Max Hidalgo, Norma Salcedo,
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1 Introduction

The freshwater fish fauna in South America is amazingly diverse. Scientists list more than 5000 species from 60 families (Böhlke *et al*. 1978). Yet, many areas remain unexplored. The Lower Urubamba Region of southeastern Peru is one of those areas. There, only a few assessments have been conducted, including Eigenmann and Allen (1942), who examined the difference in the composition of species between cold and warm zones in the Upper Urubamba River; Salcedo (1998), who assessed the fish community in the Perené River — a tributary of the Upper Urubamba River; and the consulting firm Environmental Research Management (ERM), which conducted a rapid assessment of the Lower Urubamba River in 1995 (Environmental Research Management 1996). The ERM study listed 77 species of fish in the Lower Urubamba River. In addition to basic assessments, Ortega (1996) emphasized the need for research regarding the dynamics of fish communities throughout the area between the dry and wet seasons because many species of fish migrate as changes occur in water quality and quantity with the seasons.

Between 1996 and 1999, the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program coordinated a large-scale, multi-taxa assessment of the flora and fauna of the Lower Urubamba Region. This paper presents findings from the assessment of the fish community conducted as part of the project. We describe the aquatic habitat in the study area, compare the composition of fish species by site and season and list the species recorded at each site.

2 Study area

The southern boundary of the study area was marked by the indigenous community of Chocoriari (Convention Province, Department of Cusco), while the village of Atalaya (Atalaya Province, Department of Ucayali) defined the northern boundary. We selected a series of study sites throughout the drainage network formed by the Camisea, Urubamba and Sepahua rivers and their tributaries. Comiskey *et al.* (this volume) provide detailed descriptions of the forests surrounding the rivers.

3 Methods

We assessed the fish communities in the rivers and streams (both flooded and vaciante) of the Lower Urubamba Region from April through December 1998. Flooded refers to the condition when a river overflows its banks during the rainy season. Vaciante is the non-flooded state of a river, which normally prevails during the dry season. The three sites where we conducted the assessment were named after the villages that they surround — Atalaya, Camisea and Sepahua. We identified the samples as precisely as possible in the field based on recent classifications and studies of continental neotropical fish (Goulding *et al*. 1988, Malabarba *et al*. 1998).

We captured fish at all sites using three different sizes of sweep nets — 10.0 x 1.8 meters (m), 6.0 x 1.7 m and 2.0 x 1.2 m — all with 4.4-millimeter (mm) mesh size. Hand nets were also used to capture smaller fish. We fixed smaller specimens in a solution of 10% formaldehyde. Fish greater than 150 mm in length were injected with formaldehyde and fixed in a 70% alcohol solution. Vouchers were deposited in the Museum of Natural History at the University of San Marcos in Lima and in the Smithsonian Institution National Museum of Natural History in Washington, DC for further identification. We also observed fish species at markets in the native communities of Atalaya, Sepahua and Camisea. All species identified at the markets were photographed.

4 Results and Discussion

We sampled 12,628 specimens at the three sites, including those recorded at local markets, as follows: 765 specimens at Atalaya (12 sampling locations), 7188 specimens at Sepahua (20 sampling locations) and 2740 specimens at Camisea (12 sampling locations). We recorded 69 species at Atalaya, 116 species at Sepahua and 118 species at Camisea (Table 1).We also collected 1935 specimens fortuitously at other locations in the region. These individuals represented 156 species, 121 genera, 25 families and nine orders.

Nearly 90% of all species recorded were Characiformes (54%) or Siluriformes (35%). This pattern is common to other small river basins of the Amazon watershed (Lowe-McConnell 1987, Goulding *et al*. 1988, Ortega 1992). The Characidae (65 species), Pimelodidae (27 species) and Loricariidae (16 species) families contained the largest number of species. Most (65%) of the samples collected were relatively small individuals of the Characidae (*Astyanax*, *Bryconamericus*, *Cheirodontops*, *Creagrutus*, *Knodus*, *Moenkhausia*, *Odontostilbe* and *Phenacogaster*). Atalaya and Sepahua shared 61 species, Atalaya and Camisea shared 55 species and Sepahua and Camisea shared 87 species.

The people of the Lower Urubamba Region depend on fish for a substantial portion of their diet. Surveys of local markets show that the most commonly taken species are bottom feeding fish, typically catfish. The single most commonly taken species was *Prochilodus nigricans* (Prochilodontidae). Other common species include *Brachyplatystoma filamentosum*, *B. flavicans*, *B. juruense*, *Calophysus macropterus*, *Goslinia platynema*, *Pseudoplatystoma fasciatum*, *P. tigrinum*, *Sorubim lima*, *Sorubimichthys planiceps* and *Zungaro zungaro* (Pimelodidae); *Mylossoma duriventre* (Characidae); and *Leporinus trifasciatus* (Anostomidae).

The communities of Atalaya and Sepahua participate in an active commercial fishery that includes an export market. Fishermen use motorboats and other modern tools and techniques, and they tend to select the larger fish. Fishing is most active during the vaciante, but fish are sold year round in markets. The larger catfish are flown to commercial markets in Pucallpa and Satipo. The largest specimen we recorded was an individual of *P. tigrinum* that measured 140 centimeters in length. Local fishermen state that, recently, to maintain acceptable commercial production, they must continually move to new areas further away from the villages. Statistical registries of fish harvests in Iquitos and Pucallpa over the past 12 years show a preference for species of fast growth, short life and a bottom-feeding lifestyle. The most common fish in the markets have been *P. tigrinum* and large catfishes such as *B. flavicans* and *P. fasciatum* (Barthem *et al*. 1995).

In Camisea, fishing is primarily for subsistence — not commercial — purposes. The primary method is to use a canoe and catch the fish with hooks, arrows and natural chemicals from native plants. In June 1998, we recorded 35 species of food fish that the villagers consume. These included *Prochilodus nigricans*, *Calophysus macropterus* and *Zungaro zungaro* (one individual weighed 80 kilograms). In November 1998, we recorded several edible catfish species, including *Pseudoplatystoma fasciatum*, *Calophysus macropterus* and *Pimelodus blochii*.

A conservation concern in the Lower Urubamba region is the use of toxic plants called "barbasco" (*Lonchocarpus* spp.) to kill fish. The active ingredient in barbasco is a chemical called rotenone, which is a common piscicide in the United States where public agencies use it as a management tool. Rotenone is a non-selective chemical that inhibits a biochemical process at the cellular level and makes it impossible for fish to use oxygen in the release of energy needed for body processes. Although rotenone rapidly degrades to carbon dioxide and water, it can cause extensive die-off in a very short amount of time. In some cases, it can cause complete die-off of all fish in the application area. Fish populations are slow to recover because repopulation is mostly by way of immigration from other areas.

5 Conclusions

The Lower Urubamba Region contains a diverse array of commercial and noncommercial species of fish. The fish community has biological value, and it is also important to the people in the region who depend on the fish for food and for income. As the human population of the region continues to expand, many of these species may be threatened by overharvest, non-selective poisoning and clearing of forest near rivers, which deprives fish of the shelter and nutrients that the trees and foliage of the forests provide. Therefore, it is imperative that scientists monitor the populations of fish in the Lower Urubamba and obtain a better understanding of the ecology of the aquatic ecosystems in the region.

According to famed biologist and ecologist E.O. Wilson (1988), “We cannot hope to respond to important questions of ecology and other branches of evolutionary biology, much less to preserve diversity with some efficiency, by studying a single species.” Unless all fish of the Lower Urubamba Region are recorded and monitored, the area’s biodiversity cannot be successfully protected. Assessment and monitoring of the fish populations must continue if we are to discover which and how many species are at risk from forces such as development of land and the use of motorized boats and toxic plants.

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Appendix 1. Fish species recorded at three sites in the Lower Urubamba Region, southeastern Peru (total species = 156; fish sampled under both flood and vaciante conditions; the floods occur when the river overflows its banks during the rainy season; vaciante is the non-flooded state of the river prevalent during the dry season).

	Atalaya		Sepahua		Camisea	
Species	Flood	Vaciante	Flood	Vaciante	Flood	Vaciante
Rajiformes						
Potamotrygonidae (2 spp.)						
Paratrygon aieraba	-	X	-	-	X	X
Potamotrygon motoro	-	-	-	-	-	X
Clupeiformes						
Engraulidae (2 spp.)						
Anchoviella sp.	-	X	X	X	X	X
Lycengraulis sp.	-	-	-	X	-	-
Characiformes						
Anostomidae (5 spp.)						
Leporellus vittatus	-	-	-	-	-	X
Leporinus friderici *	-	-	-	X	-	-
Leporinus striatus	-	-	-	X	-	X
Leporinus trifasciatus *	-	-	-	X	-	-
Schizodon fasciatus *	-	-	-	X	X	X
Characidae (65 spp.)						
Aphyocharax alburnus	X	X	X	-	X	X
Aphyocharax pusillus	-	-	X	X	X	X
Astyanacinus multidens	-	-	X	X	X	X
Astyanax abramis	-	-	-	-	-	X
Astyanax bimaculatus	X	-	X	X	X	X
Astyanax fasciatus	-	-	-	X	X	X
Astyanax maximus	-	-	-	-	X	X
Brycon erythropterus *	-	X	-	X	-	X
Brycon melanopterus *	-	X	-	X	-	X
Bryconacidnus ellisi	-	-	-	X	X	X
Bryconamericus aff. *osgoodi*	-	-	-	-	-	X
Bryconamericus bolivianus	-	-	-	-	-	X
Bryconamericus pachacuti	-	-	-	-	-	X
Bryconamericus sp.	X	X	X	X	X	X
Ceratobranchia binghami	-	-	-	-	-	X
Characidium sp.	X	X	X	X	X	-
Characidium zebra	-	-	-	-	X	X
Charax tectifer	X	-	-	-	X	X
Cheirodontops sp.	-	X	X	X	X	X
Chryssobrycon sp. A	-	-	-	X	X	X
Chryssobrycon sp. B	-	-	-	-	-	X
Clupeacharax anchoveoides	-	X	X	-	X	X
Colossoma macropomum *	-	X	X	X	X	X
Creagrutus sp. A	X	X	X	X	X	X
Creagrutus sp. B	-	-	X	X	-	X

Appendix 1. Continued

	Atalaya		Sepahua		Camisea	
Species	Flood	Vaciante	Flood	Vaciante	Flood	Vaciante
Ctenobrycon hauxwellianus	-	-	X	-	-	X
Cynopotamus sp.	-	-	-	X	-	-
Engraulisoma taeniatum	-	X	X	-	X	X
Galeocharax gulo	-	X	X	X	-	X
Gymnocorymbus sp.	-	-	-	X	-	-
Hemibrycon jelskii	-	-	-	X	-	X
Hemigrammus marginatus	-	-	-	X	-	-
Hyphessobrycon sp.	-	-	X	-	X	X
Iguanodectes sp.	-	-	-	-	-	X
Knodus beta	-	-	-	-	X	X
Knodus breviceps	-	-	-	X	X	X
Knodus megalops	-	-	-	-	X	-
Knodus moenkhausii	-	-	-	-	X	X
Knodus septentrionalis	X	X	X	X	X	X
Michroschemobrycon sp.	-	-	-	-	-	X
Moenkahusia dichroura	X	X	X	X	X	X
Moenkhausia intermedia	-	-	-	-	-	X
Moenkhausia oligolepis	X	-	-	X	X	X
Moenkhausia sp.	-	X	-	-	-	X
Mylossoma duriventre *	X	X	X	X	X	X
Odontostilbe sp.	X	X	-	X	X	X
Paragoniates alburnus	-	X	X	X	X	X
Phenacogaster pectinatus	-	-	X	X	-	-
Poptella compressa	-	-	-	X	-	X
Prionobrama filigera	X	X	X	X	X	X
Prodontocharax melanotus	-	-	X	X	X	X
Pygocentrus nattereri	-	-	-	X	-	-
Rhinopetitia sp.	-	-	-	X	X	X
Roeboides myersii	-	-	X	-	-	-
Salminus affinis *	-	X	-	X	-	-
Scopaeocharax sp.	-	X	-	X	X	X
Serrasalmus rhombeus *	-	-	X	-	X	X
Serrasalmus sp. *	-	-	-	X	-	-
Tetragonopterus argenteus	-	X	-	X	-	X
Triportheus albus *	-	X	-	X	-	-
Triportheus angulatus *	-	X	-	X	-	-
Tyttobrycon sp.	-	X	X	X	-	X
Tyttocharax sp.	-	-	-	-	X	X
Unknown Characiform	X	X	-	-	-	X
Xenurobrycon polyancistrus	-	-	-	X	X	X
Curimatidae (6 spp.)						
Cyphocharax sp.	-	-	X	-	-	X
Potamorhina altamazonica *	-	X	-	X	-	X
Potamorhina latior *	-	-	-	X	-	-
Psectrogaster rutiloides *	-	-	X	-	-	-

Appendix 1. Continued

	Atalaya		Sepahua		Camisea	
Species	Flood	Vaciante	Flood	Vaciante	Flood	Vaciante
Steindachnerina guentheri	-	-	-	X	X	X
Steindachnerina hypostoma *	X	X	-	X	X	X
Cynodontidae (2 spp.)						
Hydrolicus scomberoides *	-	X	-	X	-	-
Rhaphiodon vulpinus *	-	X	-	X	-	X
Erythrinidae (1 sp.)						
Hoplias malabaricus *	X	X	X	-	X	X
Gasteropelecidae (2 spp.)						
Carnegiella myersii	X	-	-	X	X	X
Thoracocharax stellatus	X	X	X	X	X	X
Hemiodontidae (1 sp.)						
Anodus elongatus *	-	-	-	X	-	-
Parodontidae (2 spp.)						
Apareiodon sp. A	-	X	X	-	-	-
Apareiodon sp. B	-	-	X	X	-	X
Prochilodontidae (1 sp.)						
Prochilodus nigricans *	X	X	X	X	X	X
Gymnotiformes						
Sternopygidae (2 spp.)						
Eigenmannia virescens	-	X	-	X	-	X
Sternopygus macrurus	-	-	-	X	-	-
Siluriformes						
Ageneiosidae (1 sp.)						
Ageneiosus ucayalensis *	-	-	X	X	-	-
Aspredinidae (1 sp.)						
Bunocephalus sp.	-	-	X	X	-	-
Astroblepidae (1 sp.)						
Astroblepus sp.	-	-	-	-	-	X
Callichthyidae (1 sp.)						
Callichthys callichthys	-	-	-	-	-	X
Doradidae (4 spp.)						
Megalodoras irwini *	-	-	-	X	-	-
Opsodoras sp.	-	X	-	-	-	-
Pseudodoras niger *	-	X	-	X	-	X
Pterodoras granulosus *	-	-	X	X	-	-
Loricariidae (16 spp.)						
Ancistrus sp. *	-	X	X	-	X	X
Ancistrus aff. *tamboensis* *	-	-	-	-	-	X
Aphanotorulus unicolor	X	X	X	X	X	X
Chaetostoma lineopunctatum *	X	-	-	X	X	X
Cochliodon sp.	-	-	X	-	X	X
Crossoloricaria sp.	-	-	-	-	X	X
Farlowella sp.	-	-	-	X	X	X

Appendix 1. Continued

	Atalaya		Sepahua		Camisea	
Species	Flood	Vaciante	Flood	Vaciante	Flood	Vaciante
Hemiodontichthys acipenserinus	-	X	-	X	-	-
Hypostomus emarginatus *	-	X	-	-	-	X
Hypostomus sp. A	X	-	X	X	X	X
Hypostomus sp. B	-	-	X	-	X	X
Liposarcus sp. *	-	-	-	-	-	X
Loricaria sp.	-	X	X	X	X	X
Otocinclus sp.	-	-	-	X	-	X
Rineloricaria lanceolata	X	-	-	-	X	X
Sturisoma nigrirostrum	-	-	X	-	-	X
Pimelodidae (27 spp.)						
Brachyplatystoma filamentosum *	-	-	X	X	-	X
Brachyplatystoma flavicans *	X	X	X	X	X	X
Brachyplatystoma juruense *	X	X	X	X	-	-
Calophysus macropterus *	X	X	X	X	-	-
Cetopsorhamdia sp.	-	-	-	-	-	X
Cheirocerus eques *	X	X	-	-	-	-
Goslinia platynema *	X	X	X	X	X	X
Hemisorubim platyrhynchos *	-	-	X	X	-	X
Heptapterus sp.	-	-	X	-	-	X
Hypophthalmus sp. *	-	-	-	X	X	X
Imparfinis sp.	X	-	-	X	-	-
Leiarius marmoratus *	X	-	X	X	-	-
Megalonema sp.	X	-	X	-	-	-
Merodontotus tigrinus *	-	-	X	-	-	-
Phractocephalus hemioliopterus *	-	-	-	X	-	X
Pimelodella sp.	X	X	X	X	-	X
Pimelodus blochii	-	X	X	-	X	X
Pimelodus maculates *	-	X	X	-	-	X
Pimelodus ornatus	-	-	X	-	-	X
Pimelodus pictus	-	-	X	-	X	X
Platystomatichthys sturio *	-	-	-	X	-	-
Pseudoplatystoma fasciatum *	X	X	X	X	X	X
Pseudoplatystoma tigrinum *	X	X	X	X	X	X
Rhamdia quelen	-	-	X	X	-	X
Sorubim lima *	-	-	X	-	X	X
Sorubimichthys planiceps *	X	-	X	X	X	X
Zungaro zungaro *	-	-	X	X	-	X
Trichomycteridae (4 spp.)						
Henonemus punctatus	-	-	X	X	X	X
Stegophilus sp.	-	-	-	-	-	X
Trichomycterus barbouri	-	-	-	-	-	X
Vandellia plazaii	-	X	X	X	-	X

Appendix 1. Continued

Species	Atalaya		Sepahua		Camisea	
	Flood	Vaciante	Flood	Vaciante	Flood	Vaciante
Synbranchiformes						
Synbranchidae (1 spp.)						
Synbranchus marmoratus	-	-	-	-	X	-
Atheriniformes						
Belonidae (3 spp.)						
Potamorrhaphis eigenmanni	-	-	-	-	X	X
Pseudotylosurus angusticeps	-	-	-	-	-	X
Pseudotylosurus microps	-	-	-	-	-	X
Perciformes						
Cichlidae (3 spp.)						
Aequidens tetramerus	X	-	-	-	-	-
Bujurquina hophrys	X	-	X	X	X	-
Crenicichla sedentaria	-	X	X	X	X	X
Sciaenidae (1 spp.)						
Plagioscion sp. *	-	-	-	X	-	X
Pleuronectiformes						
Soleidae (2 spp.)						
Achirus achirus	X	-	-	-	-	-
Apionichthys finis	-	X	X	X	-	-
Total Rajimormes	0	1	0	0	1	2
Total Clupeiformes	0	1	1	2	1	1
Total Characiformes	18	33	32	55	42	66
Total Gymnotiformes	0	1	0	2	0	1
Total Siluriformes	16	18	33	31	20	41
Total Synbranchiformes	0	0	0	0	1	0
Total Atheriniformes	0	0	0	0	1	3
Total Perciformes	2	1	2	3	2	2
Total Pleuronectiformes	1	1	1	1	0	0
Total Species	37	56	69	94	68	116
Total Species by Site	69		116		118	

* Species recorded in local village markets.

Structure and Composition of the Bird Communities of the Lower Urubamba Region, Peru

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1 Introduction

Bird communities in Peru's Amazonian lowlands are among the most diverse in the world. However, ornithologists have surveyed relatively few sites within this vast area. In southeastern Peru, species lists have been published for several sites in Madre de Dios province, including Manu National Park (Terborgh *et al.* 1984, 1990; Servat 1996), the Tambopata Reserve (Parker *et al.* 1994) and the Reserva Cuzco Amazónico (Davis *et al.* 1991). In the lowlands of Cusco Province immediately to the west of Madre de Dios, the upper course of the Urubamba River has been surveyed (Chapman 1921, Parker and O'Neill 1980). However, the lower part of the river — the Lower Urubamba Region (LUR) — remained virtually unstudied until initiation of the Smithsonian Institution/Monitoring and Assessment of Biodiversity Program project.

We surveyed birds in the area of four exploratory natural gas well sites, operated by Shell Prospecting and Development Peru, in the watershed of the Camisea River, a tributary of the Lower Urubamba, and three other sites along the Urubamba and Camisea rivers. Our objective was to obtain preliminary bird species lists for the initial exploration sites and data needed to establish a long-term monitoring plan for birds in the vicinity of the sites. Preliminary reports about our work are found in Angehr and Aucca (1997), Angehr *et al.* (1998, 1999) and Aucca (1998).

2 Study area and methods

San Martin-3 well site (11º 47' 10'' S, 72º 42' 05'' W; 474 meters [m]). Numerous small streams dissect this area, with ridges about 50 to 70 m above the stream beds. A complex mosaic of forest and giant bamboo (*Guadua sarcocarpa*) dominates. The moister ravines have a higher percentage of trees than the drier ridges where bamboo is prevalent. We conducted our surveys from April 11 to May 7, 1997.

Cashiriari-2 well site, also known as Armihuari (11º 05' 51'' S, 72º 46' 16'' W; 579 m). The area is dissected by small drainages, but the relief is less than at the other three well sites. Cashiriari-2 is dominated by broad-leafed lowland forest, mostly primary, with no large areas of bamboo. Roads that were constructed to the site approximately 10 years before our surveys are now abandoned. The road margins, originally cleared to a distance of 10 to 15 m, now support dense second-growth forest dominated by *Cecropia* and other successional species. Surveys were conducted from May 7 to May 16, 1997.

Cashiriari-3 well site (11º 52' 57'' S, 72º 39' 02'' W; 694 m). This site, on a spur of a steep-sided ridge, is 200 m above a small swift-flowing seasonal stream about 10 m wide. Giant bamboo dominates, interspersed with small patches (often < one hectare) where broad-leafed trees are more common. More extensive patches of broad-leafed forest are found in the stream valley. Surveys were conducted from November 4 to November 23, 1997.

Pagoreni well site (11º 42' 22'' S, 72º 54' 10'' W; 465 m). The terrain is similar to that of San Martin-3. The area contains mostly primary broad-leafed lowland forest with the exception of the area near the Camisea River, which includes agricultural fields where crops such as cassava, cacao and bananas are grown as well as previously cultivated areas now dominated by young second growth, including *Gynerium* cane. An abandoned road constructed about 10 years ago parallels the river and is lined with older second growth. The indigenous villages of Shivankoreni and Camisea are nearby. We conducted surveys from May 11 to May 29, 1998.

River sites. We surveyed three river sites between September 15 and October 28, 1997, and visited the area more briefly from January 14 to January 30, 1998. The sites included Las Malvinas (11° 53' 37" S, 72° 56' 48" W; 360 m) and Shivankoreni-La Peruanita (11° 48' S, 73° 52' W; 320 m) along the Urubamba River and Segakiato (11° 48' 23" S, 72° 52' 51" W; 350 m) along the Camisea River. These sites included both broad-leafed lowland forest and bamboo-dominated areas. Bamboo-dominated areas were sampled at all three sites, but broad-leafed forest was sampled only at Shivankoreni-La Peruanita and Segakiato.

Some major habitat types, including lakes, swamps and seasonally flooded forest, that have been found to contribute to bird diversity in other parts of southeastern Peru (Remsen and Parker 1983, Robinson and Terborgh 1990, Terborgh *et al*. 1990, Servat 1996) were not present at the sites we surveyed and are regionally scarce in the Camisea area. Successional vegetation in the areas where we worked is primarily human induced and apparently lacks some species found in natural successional habitats at Manu and other areas.

We used mist nets (“ATX” type, 12 m long by 2.6 m high with a 36-millimeter mesh) and visual and auditory surveys to document bird communities in the area. We netted at several locations at each site and attempted to sample contrasting habitats or microhabitats at each site, including broad-leafed forest versus bamboo-dominated areas, ridgetops versus ravines and primary forest versus successional vegetation. At each netting location, we used between 11 and 20 nets and operated them for three to six days. When not netting, we walked trails and along streams at each site, usually in the morning and late afternoon.

We photographed at least the first individual of each species captured as a voucher for species occurrence. We also vouchered species occurrence by recording vocalizations with a Sony TCM-5000 portable tape recorder with a Sennheiser short shotgun microphone. Selected photographs have been deposited with VIREO at the Philadelphia Academy of Natural Sciences and selected recordings with the Library of Natural Sounds at the Laboratory of Ornithology, Cornell University, Ithaca, New York.

3 Results and Discussion

3.1 Species richness

We recorded a total of 420 species at the seven sites combined during 135 days of field work (Appendix 1). The number of species is comparable to species lists from several other localities in southeastern Peru; for example, 415 species have been recorded at Pakitza in Manu National Park (Servat 1996, recorded over a period of seven years) and 342 species at Cuzco Amazónico (Davis *et al.* 1991, during 87 days of field work). The number of species we recorded, however, is short of the 550-plus species recorded within 15 kilometers of Cocha Cashu in Manu National Park by Robinson and Terborgh (1990) between 1973 and 1989 and the 572 species recorded at the Tambopata Reserve since the late 1970s (Parker *et al*. 1994). The larger number of species recorded at the latter two sites results in part from the longer study periods. Additional field work in the LUR may well result in a significant number of additional species. Still, the LUR generally lacks important habitats such as oxbow lakes and swamps that contribute to species diversity at Cocha Cashu and Tambopata. Thus, the LUR species list will likely not reach the numbers found in those two areas. Of the 420 species in the LUR, 28 were associated with open-water habitats (not including species found only in small streams within closed canopy forest), and 14 were associated with aerial habitats (Black and Turkey Vultures, swifts, and most swallows). We recorded 22 migrants from the north or south temperate zones or from elsewhere in the tropics.

3.2 Mist net samples

Mist net samples provide a standardized means to compare species richness of understory bird communities at different sites. During 8311 net hours, we made 2381 captures (including recaptures) of 2118 individuals representing 168 species (Table 1).

3.2.1 Species richness and species accumulation curves

Although mist nets do not sample the entire bird community, Karr *et al.* (1990) found that overall differences in species richness at four sites in Costa Rica (La Selva), Panama (Pipeline Road), Brazil (Minimum Critical Size of Ecosystems Project north of Manaus) and Peru (Cocha Cashu, Manu National Park) were paralleled by differences in species richness in their understory bird communities, as shown by mist net studies. Of these four sites, the highest species richness was at Manu.

Figure 1 compares species accumulation curves for mist net samples in forests at the seven LUR sites with the curve for upland forest at Manu (based on data from Karr *et al.* 1990). We did not include data from very young agricultural second growth at Pagoreni. “Upland forest” at Manu, as described by Robinson and Terborgh (1990), contains large areas of bamboo and is dissected by steep ravines, similar to bamboo-dominated forest in the LUR. Of the eight sites, Segakiato has the highest species accumulation curve — 100 species recorded in 400 captures (including recaptures). The curve for San Martin-3 parallels that for Segakiato up to 170 captures, then levels off. The curves for Shivankoreni and Las Malvinas are also similar to the early portions of the Segakiato and San Martin-3 curves, but ultimately result in fewer than 200 captures each. The curves for Cashiriari-2 and Cashiriari-3 are somewhat lower and comparable to Manu, while Pagoreni has the lowest rate of species accumulation.

The exceptionally high species accumulation curves at most LUR sites may be due to the complex mix of bamboo-dominated and broad-leafed forest. Pagoreni, the most homogeneous site with broad-leafed forest only, shows the lowest rate of species accumulation. Although Cashiriari-3 is also fairly homogeneous, its accumulation curve is similar to some bamboo-dominated sites.

3.2.2 Capture rates

Capture rates can be compared on the basis of the number of captures (including recaptures) per 100 net hours. Net

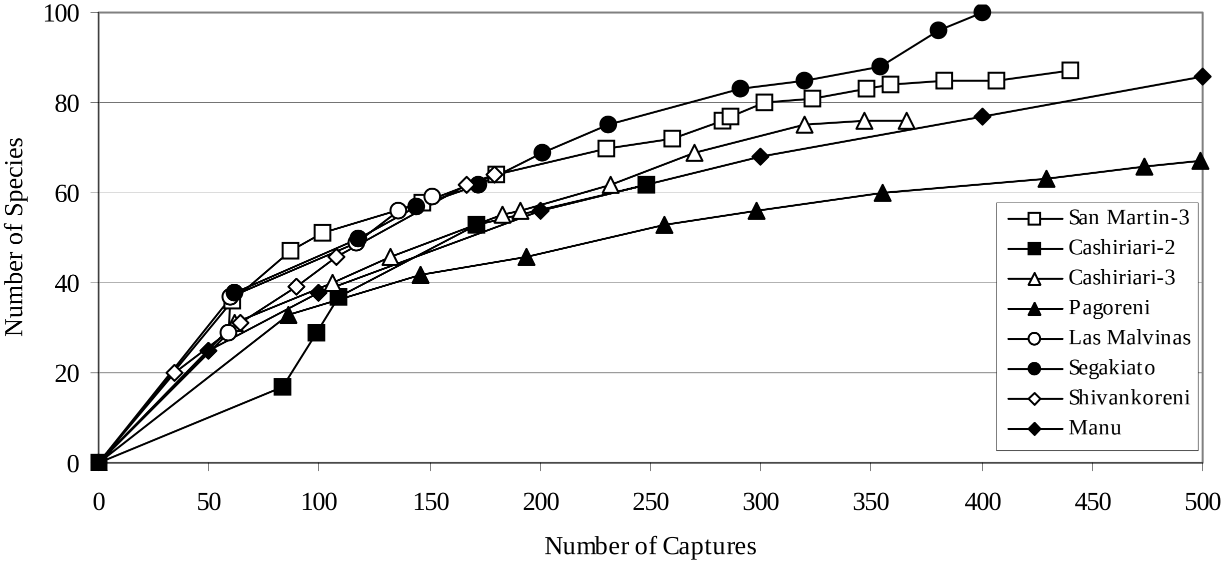

Figure 1. Species accumulation curves for mist net samples at sites in the Lower Urubamba Region compared with upland forest in Manu National Park; data from Manu National Park from Karr *et al.* (1990)).

Table 1. Mist net data for sites in the Lower Urubamba Region, Peru (net hours are calculated by multiplying the number of nets by the number of hours they are in operation; "captures" includes recaptures).

Site	Location	Habitat	net hours	individuals	captures	captures/ 100 net hours	species
San Martin-3	1	bamboo (ravine)	729	-	180	25	64
San Martin-3	2	bamboo (ridge)	392	-	122	31	42
San Martin-3	3	bamboo (ridge and ravine)	674	-	138	20	54
Total			**1795**	**360**	**440**	**-**	**87**
Cashiriari-2	1	broadleaf (primary)	402	-	109	27	37
Cashiriari-2	2	broadleaf (secondary)	263	-	139	53	45
Total			**665**	**224**	**228**	**-**	**62**
Cashiriari-3	1	mixed, mainly bamboo	586	-	191	33	56
Cashiriari-3	2	mixed, mainly broadleaf	568	-	175	31	54
Total			**1154**	**318**	**366**	**-**	**76**
Pagoreni	1	broadleaf (primary, ravine)	605	-	194	32	46
Pagoreni	2	broadleaf (primary, ridge)	569	-	161	28	45
Pagoreni	3	broadleaf (primary, edge)	567	-	144	25	42
Pagoreni	4	agricultural second growth	107	-	105	98	37
Pagoreni	5	treefall gap	10	-	13	-	11
Total			**1858**	**542**	**617**	**-**	**80**
Las Malvinas	1	bamboo (ravine)	632	-	151	24	59
Total			**632**	**141**	**151**	**-**	**59**
Segakiato	1	mixed broadleaf/bamboo	691	-	231	33	74
Segakiato	2	bamboo	596	-	169	28	58
Total			**1287**	**369**	**400**	**-**	**100**
Shivankoreni	1	bamboo	587	-	108	18	46
Shivankoreni	2	mixed broadleaf/bamboo	333	-	71	21	38
Total			**920**	**164**	**179**	**-**	**64**
Grand total			**8311**	**2118**	**2381**		**168**

hours are calculated by multiplying the number of nets in operation by the number of hours they are open. The capture rates for most locations fall within the range of 18 to 33 captures/100 net hours (Table 1). There are no obvious differences in capture rates among locations in bamboo-dominated and broad-leafed forest. The highest capture rates were found in secondary vegetation — 53/100 net hours in young secondary forest at Cashiriari-2 (location 2) and 98/100 net hours in very young agricultural second growth at Pagoreni (location 4).

Robinson and Terborgh (1990) provide mist net capture rates for a variety of habitats near Cocha Cashu in Manu National Park (Table 2). Capture rates in LUR forest sites were quite similar to those reported for Manu, which ranged from a low of 15 captures/100 net hours in high ground and ridgetop forest to a high of 36 captures/100 net hours in transition forest. As in the LUR, Robinson and Terborgh also recorded their highest capture rates in secondary vegetation — riverside *Tessaria* cane, which had 50 to 70 captures/100 net hours.

3.3 Breeding and molt

In the seasonal tropics, the greatest breeding activity usually takes place from the late dry season to the early part of the wet season. Molt typically takes place shortly after reproduction in the later part of the rainy season. In the LUR, the dry season extends from May to September and the wet season from October to April.

Data on breeding and molt from mist net samples in the LUR fit this pattern. At Cashiriari-3 in the early rainy season (November 1998), 50% of all birds examined showed some evidence of breeding, including active, recent or developing brood patches. The percentage was 31% at Pagoreni in mid-May 1998 (the early dry season) but less than 1% in April and early May 1997 at San Martin-3 and Cashiriari-2. (We did not evaluate breeding activity at Las Malvinas, Segakiato or Shivankoreni.) Conversely, the greatest percentage of individuals in molt, 56%, was found at San Martin-3 and Cashiriari-2, with 38% at Pagoreni, 40% at Las Malvinas, Segakiato and Shivankoreni (September through October 1998, representing the late dry season and early rainy season) and 31% at Cashiriari-3.

3.4 Avifaunal patterns

3.4.1 Bamboo specialists

A number of Amazonian bird species are found exclusively or mostly in thickets of *Guadua* bamboo. Such species are particularly characteristic of southeastern Peru where extensive areas of bamboo are common. In addition, several bird species that are found in other habitats elsewhere in their ranges show a preference for bamboo in southeastern Peru. These “bamboo specialists” have been the focus of studies by Kratter (1997) along the Tambopata River and by Servat (1996) at Pakitza on the Manu River.

Kratter found 32 species associated with bamboo at Tambopata. These included four “obligate bamboo specialists,” restricted to bamboo thickets throughout their geographic range; nine “near-obligate specialists,” which may use other habitats sparingly away from southeastern Peru; six “facultative bamboo specialists,” which frequently use non-bamboo habitats away from southeastern Peru; seven species, which were common in bamboo although they also used other habitats at that study site; and six that were apparent bamboo specialists but that were too uncommon to characterize definitely. Servat reported that 20 species were found exclusively in bamboo at Pakitza, although three were found in other habitats elsewhere in the region. Two other species were reported in bamboo in previous studies at Pakitza. Servat did not distinguish between obligate and facultative bamboo specialists. Stotz *et al.* (1996) list 29 indicator species for bamboo habitats in southern Amazonia, of which 24 occur in southeastern Peru. Taken together,

Table 2. Comparative data on mist net capture rates and numbers of species captured in different habitats in Manu National Park, from Robinson and Terborgh (1990); number after the habitat indicates the month and year of the sample.

Habitat	net hours	captures	captures/ 100 net hours	species
Tessaria /cane 8/83	325	194	60	58
Tessaria /cane 11/85	230	154	70	46
Tessaria /cane 8/86	144	73	50	39
Transition forest 9/80	1000	273	27	51
Transition forest 10/86	722	260	36	51
High ground forest 8/81	1064	189	18	55
High ground forest 11/82	593	152	26	44
High ground forest 7/81	1467	219	15	55
Upland bamboo 10/85	1223	252	21	66
Upland ravine 10/86	1165	306	26	68
Upland ridgetop 8/74	1672	250	15	49
Upland ridgetop 8/75	1672	251	15	55
Upland ridgetop 10/76	1782	294	16	65

Kratter, Servat and Stotz *et al.* list 41 species associated with bamboo in southeastern Peru (Table 3).

In the LUR, we recorded 35 of these 41 species. The species we did not record are *Dromococcyx pavoninus*, *Automolus melanopezus*, *Myrmotherula obscura*, *Lophotriccus eulophotes*, *Casiornis rufa* and *Capsiempis flaveola* (Table 3). More extended studies may detect these species as well. The presence of large areas of *Guadua* bamboo clearly has a major influence on the composition of the avifauna in the area. A few bamboo-associated species were recorded at the two broadleaf-dominated sites — four at Cashiriari-2 and 15 at Pagoreni. The majority of these were found in second growth in agricultural clearings or along abandoned roads. When bamboo-associated species occur outside of bamboo, they typically are found primarily in secondary or disturbed habitats (Kratter 1997). However, we encountered a few such species in treefall gaps within the forest or along edges, and *Leptopogon amaurocephalus* was netted and observed several times in apparently undisturbed forest at Pagoreni.

A mass flowering of *Guadua,* a monocarpic bamboo, was in progress at Cashiriari-3 during our survey. The nomadic bamboo specialist *Sporophila schistacea* was common there, and we observed it feeding on the stamens of bamboo flowers. The only other site at which this bird was recorded was Shivankoreni. Flocks of the generally rare *Conothraupis speculigera* were common at Cashiriari-3, and this was the most frequently captured species in mist net samples. It was also found at Shivankoreni. Possibly this species was attracted to the area by the bamboo flowering and fruiting event. The ecology of this species is poorly known, but it is thought to be nomadic (Ridgely and Tudor 1989).

3.4.2 Canopy flocks

Mixed-species canopy flocks composed of tanagers, flycatchers and vireos are a prominent feature of many neotropical forests. Munn (1985) studied their composition and ecology in detail at Manu National Park. Of the 35 species that Munn observed in more than half of the canopy flocks he studied, we found 23 at Pagoreni, compared to 15 at Cashiriari-3 and seven at San Martin-3. Among the three sites, the diversity of canopy flocks appears to be correlated with the relative amount of broad-leafed forest present — Pagoreni is dominated by broad-leafed forest, and Cashiriari-3, although bamboo dominated, has more extensive areas of broad-leafed forest than San Martin-3. But even at Pagoreni, the diversity of the flocks still appeared to be lower than at Manu. We were not at the other four LUR study sites long enough to observe canopy flocks in detail.

3.4.3 Exploited species

Large game birds such as tinamous, guans, curassows and trumpeters as well as species captured for the pet trade such as macaws and other large parrots are typically among the first species to disappear in response to human activity in an area, chiefly as a result of over-hunting.

At Cashiriari-3, the most remote of our study sites, many exploited species were both common and tame, indicating relatively low hunting pressure. Small groups of Razor-billed Curassow (*Mitu tuberosa*), Spix’s Guan (*Penelope jacquacu*) and Speckled Chachalaca (*Ortalis guttata*) were seen or heard regularly, and Blue-throated Piping-Guan (*Pipile cumanensis*) were also seen occasionally. We recorded the Pale-winged Trumpeter (*Psophia leucoptera*) twice and the Starred Wood-Quail (*Odontophorus stellatus*) on five days. We also recorded seven species of tinamou — Gray (*Tinamus tao*), Great (*T. major*), Cinereous (*Crypturellus cinereus*), Little (*C. soui*), Undulated (*C. undulatus*), Black-capped (*C. atrocapillus*) and Bartlett’s (*C. bartletti*). We observed seven species of macaw at Cashiriari-3, more macaw species than at any other site.

At San Martin-3, small groups of Spix’s Guan were noted regularly, and Common Piping-Guan was seen on three occasions. Razor-billed Curassow and Pale-winged Trumpeter were reported by other observers. We also recorded three species of tinamou — Great, Cinereous and Black-capped — as well as four species of macaw. Although San Martin-3 is somewhat less remote than Cashiriari-3, hunting pressure is evidently relatively low.

The frequency of encounters of such species at Pagoreni was much lower than at Cashiriari-3 and for

Table 3. Distribution of birds associated with *Guadua sarcocarpa* bamboo thickets in the Lower Urubamba Region (sites with extensive bamboo: SM-3 = San Martin-3, CS-3 = Cashiriari-3, LM = Las Malvinas, SE = Segakiato, SH = Shivankoreni-La Peruanita; broad-leafed dominated sites without extensive bamboo: CS-2 = Cashiriari-2, PG = Pagoreni [see text for explanation of terms used in “status” columns] Kratter (1997): O = obligate bamboo specialist, N = near-obligate bamboo specialist, F = facultative bamboo specialist, c = common in bamboo thickets, r = apparent bamboo specialist but too rare to determine exact status; Servat (1996): X = species found exclusively in bamboo at Pakitza, x = species found exclusively in bamboo at Pakitza but found in other habitats at other sites in the region; Stotz *et al.* (1996): X = indicator species for bamboo habitat in Southern Amazonia region with ranges that extend to southeastern Peru).

	Bamboo					Broad-leafed		Status		
Species	SM-3	CS-3	LM	SE	SH	CS-2	PG	Kratter	Servat	Stotz *et al.*
Crypturellus atrocapillus	X	X						c		
Dromococcyx pavoninus								r		X
Chlorostilbon mellisugus				X	X				x	
Bucco macrodactylus			X					r		
Malacoptila semicincta	X	X	X	X	X				x	
Nonnula ruficapilla	X	X	X	X				r	X	X
Monasa flavirostris	X	X	X	X				r		X
Picumnus rufiventris	X	X		X	X			F	X	
Celeus spectabilis	X	X			X			N		
Campylorhamphus trochilirostris	X	X	X	X	X		X	F	X	X
Synallaxis cabanisi	X		X	X	X			F		
Synallaxis cherriei	X	X								X
Simoxenops ucayalae	X	X			X			N	X	X
Automolus dorsalis	X	X		X				N	X	X
Automolus melanopezus								N	X	X
Automolus rufipileatus	X	X			X	X	X	c		
Automolus rubiginosus	X	X	X	X			X	r		
Cymbilaimus sanctaemariae	X	X					X	N	X	X
Myrmotherula ornata	X	X	X		X			F	X	X
Myrmotherula iheringi				X				F		X
Myrmotherula obscura									X	
Microrhopias quixensis	X	X					X	F	X	X
Drymophila devillei	X							O	X	X
Cercomacra manu	X	X	X	X	X			O	X	X
Cercomacra nigrescens					X		X	c		
Hypocnemis cantator	X	X	X	X	X		X	c		
Percnostola lophotes	X	X	X	X	X		X	N	X	X
Myrmeciza goeldii	X	X	X	X	X		X	N		X
Neopelma sulphureiventer	X	X	X		X	X	X		X	X
Leptopogon amaurocephalus	X	X	X	X	X	X	X		X	
Hemitriccus flammulatus	X	X	X	X	X		X	O	X	X
Lophotriccus eulophotes									X	X
Poecilotriccus albifacies	X							O		X
Ramphotrigon megacephala	X	X						N	X	X
Ramphotrigon fuscicauda		X						N		X
Myiophobus fasciatus	X						X	c		

Table 3. Continued

	Bamboo					Broad-leafed		Status		
Species	SM-3	CS-3	LM	SE	SH	CS-2	PG	Kratter	Servat	Stotz *et al.*
Lathrotriccus euleri	X	X	X		X	X	X	c		
Casiornis rufa									x	
Capsiempis flaveola									X	X
Machaeropterus pyrocephalus		X			X		X			X
Thryothorus genibarbis	X	X					X	c		

some species lower than that at San Martin-3 as well. We observed Razor-billed Curassow and Spix's Guan only one day each and Common Piping-Guan, Speckled Chachalaca and Starred Wood-Quail two days each at Pagoreni. We recorded only three species of tinamou — Great, Little and Variegated (*Crypturellus variegatus*) at that site and observed four species of macaw. The frequency of encounters of these species suggests that hunting pressure in the Pagoreni area is relatively high compared to Cashiriari-3, clearly because of the nearby villages of Shivankoreni and Camisea. However, hunting has not been sufficiently intense to extirpate game species from the area. Our stays at the other four sites were too brief to obtain any definite impression of the relative abundance of game species.

4 Conclusion

The avifauna of the Lower Urubamba Region is highly diverse. Species accumulation curves in mist net samples for several localities equal or exceed those for equivalent habitats in Manu National Park, one of the richest sites known for birds in the world (although the total species list may not equal that for Manu because of the absence of certain important habitats). At present, bird communities at the more remote sites such as Cashiriari-3 in this study appear to be in nearly pristine condition, with little evidence that human activity to date has had significant impact. Every effort should be made to see that this exceptional avifauna does not suffer degradation if natural resource development takes place in the area.

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Appendix 1. Species lists for sites in the Lower Urubamba Region ("bamboo" indicates sites where extensive areas of bamboo are present, "broad-leafed" indicates areas where extensive areas of bamboo are absent; SM-3 = San Martin-3, CS-3 = Cashiriari-3, LM = Las Malvinas, SE = Segakiato, SH = Shivankoreni-La Peruanita, CS-2 = Cashiriari-2, PG= Pagoreni, a = associated with open-water aquatic habitats, o = associated with terrestrial open habitats, g = generalist using aerial zone over both open and forest habitats, m = migrant, C = common, F = fairly common, U = uncommon, R = rare, x = present but abundance not determined because of limited time at the site.

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Tinamus tao	Gray Tinamou			R			x		
Tinamus major	Great Tinamou		R		x	x			U
Crypturellus cinereus	Cinereous Tinamou		R	F	x	x	x		
Crypturellus soui	Little Tinamou			F	x				U
Crypturellus undulatus	Undulated Tinamou			R					
Crypturellus atrocapillus	Black-capped Tinamou		R	R					
Crypturellus variegatus	Variegated Tinamou							x	R
Crypturellus bartletti	Bartlett's Tinamou			R					
Phalacrocorax brasilianus	Neotropic Cormorant	a				x			R
Egretta thula	Snowy Egret	a			x				
Ardea cocoi	Cocoi Heron	a			x	x			
Bubulcus ibis	Cattle Egret			R				x	
Butorides striatus	Striated Heron	a					x		
Agamia agami	Agami Heron		R						
Pilherodius pileatus	Capped Heron	a			x		x		
Tigrisoma lineatum	Rufescent Tiger-Heron			R	x				R
Tigrisoma fasciatum	Fasciated Tiger-Heron		R	R	x	x			
Coragyps atratus	Black Vulture	g			x	x	x		
Cathartes aura	Turkey Vulture	g			x				
Cathartes melambrotus	Greater Yellow-headed Vulture		R	R	x	x		x	C
Sarcoramphus papa	King Vulture			R	x		x		U
Pandion haliaetus	Osprey	am		R	x	x			
Leptodon cayanensis	Gray-headed Kite					x			
Elanoides forficatus	Swallow-tailed Kite				x				
Harpagus bidentatus	Double-toothed Kite			R					R
Ictinia plumbea	Plumbeous Kite			U	x	x			
Accipiter bicolor	Bicolored Hawk						x		
Leucopternis albicollis	White Hawk		R	U	x	x			U
Buteogallus urubitinga	Great Black-Hawk				x	x	x		
Busarellus nigricollis	Black-collared Hawk	a				x			
Buteo magnirostris	Roadside Hawk			R	x	x	x	x	U
Buteo platypterus	Broad-winged Hawk	m		R					
Buteo brachyurus	Short-tailed Hawk			R					R
Buteo albonotatus	Zone-tailed Hawk								R
Spizastur melanoleucus	Black-and-white Hawk-Eagle			R					
Spizaetus tyrannus	Black Hawk-Eagle		R	F	x		x		F
Daptrius ater	Black Caracara				x				R
Daptrius americanus	Red-throated Caracara		U	U	x	x	x		R

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Milvago chimachima	Yellow-headed Caracara	o			x		x		U
Herpetotheres cachinnans	Laughing Falcon		R	R					R
Micrastur ruficollis	Barred Forest-Falcon		F	R				x	C
Micrastur semitorquatus	Collared Forest-Falcon			R		x			R
Falco rufigularis	Bat Falcon							x	U
Ortalis guttata	Speckled Chachalaca			C	x	x	x		R
Penelope jacquacu	Spix's Guan		U	C	x	x		x	R
Pipile cumanensis	Blue-throated Piping-Guan		R	F		x			R
Mitu tuberosa	Razor-billed Curassow		R	F		x	x	x	R
Odontophorus stellatus	Starred Wood-Quail		R	U		x	x		R
Opisthocomus hoazin	Hoatzin	a					x		
Aramides cajanea	Gray-necked Wood-Rail			F					
Heliornis fulica	Sungrebe	a				x	x		
Psophia leucoptera	Pale-winged Trumpeter		R	U	x	x		x	
Jacana jacana	Wattled Jacana	a					x		
Tringa flavipes	Lesser Yellowlegs	am			x	x			
Tringa solitaria	Solitary Sandpiper	am			x	x	x		
Actitis macularia	Spotted Sandpiper	am		U	x	x	x		R
Himantopus mexicanus	Black-necked Stilt	am			x				
Pluvialis dominica	American Golden-Plover	am				x			
Charadrius collaris	Collared Plover	am			x		x		R
Vanellus cayanus	Pied Lapwing	a			x	x	x		
Sterna superciliaris	Yellow-billed Tern	a			x				
Rynchops niger	Black Skimmer	a			x				
Columba plumbea	Plumbeous Pigeon			C	x				F
Columba subvinacea	Ruddy Pigeon		C	C	x		x	x	C
Columbina talpacoti	Ruddy Ground-Dove						x		
Leptotila rufaxilla	Gray-fronted Dove		U	C	x	x	x	x	U
Geotrygon saphirina	Sapphire Quail-Dove								U
Geotrygon montana	Ruddy Quail-Dove			F	x	x	x		R
Ara militaris	Military Macaw			R					
Ara ararauna	Blue-and-yellow Macaw		R	C	x	x	x		U
Ara macao	Scarlet Macaw		U	C	x		x		C
Ara chloroptera	Red-and-green Macaw		R	C	x	x	x	x	C
Ara severa	Chestnut-fronted Macaw		U	F	x	x	x		F
Ara manilata	Red-bellied Macaw			R	x		x		
Ara couloni	Blue-headed Macaw			F	x		x		
Aratinga leucophthalmus	White-eyed Parakeet			R	x		x		R
Aratinga weddellii	Dusky-headed Parakeet				x		x		
Pyrrhura rupicola	Black-capped Parakeet			R	x				
Forpus sclateri	Dusky-billed Parrotlet								R
Brotogeris cyanoptera	Cobalt-winged Parakeet		U	C	x	x	x		C
Brotogeris sanctithomae	Tui Parakeet				x		x		
Touit huetii	Scarlet-shouldered Parrotlet								R

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Pionopsitta barrabandi	Orange-cheeked Parrot								R
Pionus menstruus	Blue-headed Parrot			C	x	x	x		C
Amazona ochrocephala	Yellow-crowned Parrot		R	U	x	x	x		U
Amazona farinosa	Mealy Parrot		F	C	x	x	x	x	U
Coccyzus americanus	Yellow-billed Cuckoo			U					
Piaya cayana	Squirrel Cuckoo		F	C	x	x	x	x	C
Piaya melanogaster	Black-bellied Cuckoo							x	
Piaya minuta	Little Cuckoo				x		x		
Crotophaga ani	Smooth-billed Ani			R	x	x	x		
Dromococcyx phasianellus	Pheasant Cuckoo			C			x		
Otus watsonii	Tawny-bellied Screech-Owl			R		x	x		U
Lophostrix cristata	Crested Owl				x		x		R
Pulsatrix perspicillata	Spectacled Owl			U		x			R
Nyctibius grandis	Great Potoo				x		x		R
Nyctibius griseus	Gray Potoo					x	x		R
Chordeiles rupestris	Sand-colored Nighthawk	a			x				R
Nyctidromus albicollis	Pauraque			R	x				U
Nyctiphrynus ocellatus	Ocellated Poorwill		R			x			
Hydropsalis climacocerca	Ladder-tailed Nightjar				x				
Hydropsalis brasiliana	Scissor-tailed Nightjar		R						
Streptoprocne zonaris	White-collared Swift	g	U	U	x	x		x	C
Chaetura egregia	Pale-rumped Swift	g		R					C
Chaetura brachyura	Short-tailed Swift	g		U	x				U
Tachornis squamata	Fork-tailed Palm-Swift	g			x				
Panyptila cayennensis	Lesser Swallow-tailed Swift	g		R					R
Glaucis hirsuta	Rufous-breasted Hermit				x	x	x		R
Threnetes leucurus	Pale-tailed Barbthroat		F	F	x	x	x	x	F
Phaethornis superciliosus	Long-tailed Hermit		F	C				x	C
Phaethornis hispidus	White-bearded Hermit		F	U	x	x	x	x	U
Phaethornis koepckeae	Koepcke’s Hermit			C	x	x	x	x	
Phaethornis philippi	Needle-billed Hermit					x			
Phaethornis stuarti	White-browed Hermit		R	U					R
Eutoxeres condamini	Buff-tailed Sicklebill		F	U	x	x	x	x	U
Campylopterus largipennis	Gray-breasted Sabrewing		F	F	x	x	x	x	C
Florisuga mellivora	White-necked Jacobin			R				x	C
Klais guimeti	Violet-headed Hummingbird							x	
Chlorostilbon mellisugus	Blue-tailed Emerald					x	x		
Thalurania furcata	Fork-tailed Woodnymph		F	C	x	x	x	x	C
Hylocharis cyanus	White-chinned Sapphire				x				
Chrysuronia oenone	Golden-tailed Sapphire			R		x			R
Heliodoxa aurescens	Gould's Jewelfront		U	F		x	x	x	C
Heliothryx aurita	Black-eared Fairy			R					U
Heliomaster longirostris	Long-billed Starthroat			R					
Trogon melanurus	Black-tailed Trogon		R	F	x	x			C

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Trogon viridis	White-tailed Trogon				x				
Trogon collaris	Collared Trogon			F					C
Trogon curucui	Blue-crowned Trogon			U					F
Trogon violaceus	Violaceous Trogon			R			x		R
Pharomachrus pavoninus	Pavonine Quetzal								R
Megaceryle torquata	Ringed Kingfisher	a			x	x			R
Chloroceryle amazona	Amazon Kingfisher	a		U	x	x			
Chloroceryle americana	Green Kingfisher	a	R	U	x	x	x		U
Chloroceryle inda	Green-and-rufous Kingfisher		R	R	x	x	x		U
Chloroceryle aenea	American Pygmy Kingfisher			R			x		
Electron platyrhynchum	Broad-billed Motmot			R	x	x	x		R
Baryphthengus martii	Rufous Motmot		U	C	x			x	R
Momotus momota	Blue-crowned Motmot				x				
Brachygalba albogularis	White-throated Jacamar	o	R		x				
Galbula cyanescens	Bluish-fronted Jacamar		F	C	x	x	x	x	U
Jacamerops aureus	Great Jacamar								U
Notharchus macrorhynchos	White-necked Puffbird			U					R
Notharchus tectus	Pied Puffbird				x				
Bucco macrodactylus	Chestnut-capped Puffbird				x				
Nystalus striolatus	Striolated Puffbird		U	U					F
Malacoptila semicincta	Semicollared Puffbird		U	U	x	x	x	x	U
Nonnula ruficapilla	Rufous-capped Nunlet		R	U	x	x			
Monasa nigrifrons	Black-fronted Nunbird			F	x	x	x		U
Monasa morphoeus	White-fronted Nunbird								F
Monasa flavirostris	Yellow-billed Nunbird		U	F	x	x			
Chelidoptera tenebrosa	Swallow-wing	o			x	x	x		R
Capito niger	Black-spotted Barbet				x	x		x	C
Eubucco richardsoni	Lemon-throated Barbet		R	R			x		F
Aulacorhynchus prasinus	Emerald Toucanet		R	F	x	x	x		R
Pteroglossus mariae	Brown-mandibled Aracari								R
Pteroglossus castanotis	Chestnut-eared Aracari		R	R	x		x		
Pteroglossus beauharnaesii	Curl-crested Aracari					x			R
Selenidera reinwardtii	Golden-collared Toucanet							x	C
Ramphastos cuvieri	Cuvier's Toucan		C	C	x	x	x	x	C
Ramphastos ambiguus	Black-mandibled Toucan						x		
Picumnus aurifrons	Bar-breasted Piculet							x	U
Picumnus rufiventris	Rufous-breasted Piculet		U	R		x	x		
Melanerpes cruentatus	Yellow-tufted Woodpecker		U	C	x	x	x		U
Veniliornis passerinus	Little Woodpecker		U	F	x		x	x	U
Veniliornis affinis	Red-stained Woodpecker			R					R
Piculus leucolaemus	White-throated Woodpecker			R			x		
Piculus chrysochloros	Golden-green Woodpecker								U
Piculus rivolii	Crimson-mantled Woodpecker				x		x		

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Celeus grammicus	Scaly-breasted Woodpecker								U
Celeus spectabilis	Rufous-headed Woodpecker		R	R			x		
Dryocopus lineatus	Lineated Woodpecker		R						U
Campephilus rubricollis	Red-necked Woodpecker								U
Campephilus melanoleucos	Crimson-crested Woodpecker		F	F		x	x		R
Dendrocincla fuliginosa	Plain-brown Woodcreeper		U	U	x		x		U
Dendrocincla merula	White-chinned Woodcreeper				x				
Deconychura longicauda	Long-tailed Woodcreeper		R					x	R
Sittasomus griseicapillus	Olivaceous Woodcreeper			U			x		U
Glyphorynchus spirurus	Wedge-billed Woodcreeper		U	U			x	x	C
Dendrexetastes rufigula	Cinnamon-throated Woodcreeper			R					
Xiphocolaptes promeropirhynchus	Strong-billed Woodcreeper		R		x	x		x	
Dendrocolaptes picumnus	Black-banded Woodcreeper		R	U					R
Xiphorhynchus ocellatus	Ocellated Woodcreeper		F	C	x	x	x	x	
Xiphorhynchus spixii	Spix's Woodcreeper				x	x		x	C
Xiphorhynchus guttatus	Buff-throated Woodcreeper			U					C
Campylorhamphus trochilirostris	Red-billed Scythebill		C	C	x	x	x		R
Furnarius leucopus	Pale-legged Hornero	a		R	x		x		
Synallaxis cabanisi	Cabanis' Spinetail		U		x	x	x		
Synallaxis gujanensis	Plain-crowned Spinetail			R	x	x	x		C
Synallaxis cherriei	Chestnut-throated Spinetail		R	R					
Cranioleuca gutturata	Speckled Spinetail							x	U
Premnoplex brunnescens	Spotted Barbtail				x				
Ancistrops strigilatus	Chestnut-winged Hookbill			U	x				F
Hyloctistes subulatus	Striped Woodhaunter		R			x			F
Philydor ruficaudatus	Rufous-tailed Foliage-gleaner				x	x	x		
Philydor pyrrhodes	Cinnamon-rumped Foliage-gleaner								U
Simoxenops ucayalae	Peruvian Recurvebill		F	R			x		
Automolus ochrolaemus	Buff-throated Foliage-gleaner		F	C		x	x	x	F
Automolus dorsalis	Crested Foliage-gleaner		F	C		x			
Automolus infuscatus	Olive-backed Foliage-gleaner					x	x	x	C
Automolus rubiginosus	Ruddy Foliage-gleaner		U	U	x	x			U
Automolus rufipileatus	Chestnut-crowned Foliage-gleaner		F	R			x	x	R
Sclerurus mexicanus	Tawny-throated Leaftosser		U	R					U
Sclerurus albigularis	Gray-throated Leaftosser		R						
Sclerurus caudacutus	Black-tailed Leaftosser		U			x		x	C
Xenops minutus	Plain Xenops		F	F		x		x	C
Cymbilaimus lineatus	Fasciated Antshrike							x	C
Cymbilaimus sanctaemariae	Bamboo Antshrike		R	C			x		

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Frederickena unduligera	Undulated Antshrike		R						U
Taraba major	Great Antshrike		R	F	x	x	x		U
Thamnophilus doliatus	Barred Antshrike				x				
Thamnophilus aethiops	White-shouldered Antshrike		R	U					R
Thamnophilus murinus	Mouse-colored Antshrike				x		x		
Thamnophilus schistaceus	Plain-winged Antshrike		F	C	x	x	x	x	C
Pygiptila stellaris	Spot-winged Antshrike								R
Dysithamnus mentalis	Plain Antvireo					x			R
Thamnomanes ardesiacus	Dusky-throated Antshrike		U		x	x	x	x	C
Thamnomanes schistogynus	Bluish-slate Antshrike		U	C	x	x	x		F
Myrmotherula brachyura	Pygmy Antwren		R	U				x	C
Myrmotherula hauxwelli	Plain-throated Antwren			R		x		x	
Myrmotherula leucophthalma	White-eyed Antwren		F	U	x	x	x		
Myrmotherula ornata	Ornate Antwren		F	C	x		x		
Myrmotherula axillaris	White-flanked Antwren		F	U	x	x	x	x	C
Myrmotherula longipennis	Long-winged Antwren		U	R		x	x	x	C
Myrmotherula iheringi	Ihering's Antwren					x			
Myrmotherula menetriesii	Gray Antwren					x	x	x	
Myrmotherula erythrura	Rufous-tailed Antwren			R		x			C
Herpsilochmus rufimarginatus	Rufous-winged Antwren			R					
Microrhopias quixensis	Dot-winged Antwren		R	F					R
Drymophila devillei	Striated Antbird		U						
Cercomacra cinerascens	Gray Antbird			U				x	C
Cercomacra nigrescens	Blackish Antbird				x				C
Cercomacra serva	Black Antbird		F	F	x	x	x		R
Cercomacra manu	Manu Antbird		F	C	x	x	x		
Myrmoborus leucophrys	White-browed Antbird		C	C	x	x	x	x	F
Myrmoborus myotherinus	Black-faced Antbird			U		x	x	x	C
Hypocnemis cantator	Warbling Antbird		U	C	x	x	x		U
Sclateria naevia	Silvered Antbird		R						
Schistocicla leucostigma	Spot-winged Antbird		R	R		x			C
Percnostola lophotes	White-lined Antbird		C	C	x	x	x		F
Myrmeciza hemimelaena	Chestnut-tailed Antbird		C	C	x	x	x	x	C
Myrmeciza goeldii	Goeldi's Antbird		C	C	x	x	x		R
Myrmeciza fortis	Sooty Antbird		R	R		x		x	C
Myrmeciza atrothorax	Black-throated Antbird			U	x				U
Rhegmatorhina melanosticta	Hairy-crested Antbird		R					x	F
Hylophylax naevia	Spot-backed Antbird		C	C	x	x	x	x	C
Hylophylax poecilonota	Scale-backed Antbird					x	x	x	F
Phlegopsis nigromaculata	Black-spotted Bare-eye		F	C	x	x	x		U
Formicarius analis	Black-faced Antthrush		U	C	x	x	x	x	F
Formicarius rufifrons	Rufous-fronted Antthrush					x			

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Hylopezus berlepschi	Amazonian Antpitta		R		x				
Myrmothera campanisona	Thrush-like Antpitta		U	F					C
Conopophaga peruviana	Ash-throated Gnateater		R	U	x	x		x	R
Liosceles thoracicus	Rusty-belted Tapaculo		U	C		x	x	x	C
Laniocera hypopyrra	Cinereous Mourner								U
Iodopleura isabellae	White-browed Purpletuft		R	R					R
Lipaugus vociferans	Screaming Piha				x		x	x	C
Porphyrolaema porphyrolaema	Purple-throated Cotinga			U					
Cotinga maynana	Plum-throated Cotinga		R						U
Cotinga cayana	Spangled Cotinga				x				R
Conioptilon mcilhennyi	Black-faced Cotinga			U					
Querula purpurata	Purple-throated Fruitcrow		R						R
Chloropipo holochlora	Green Manakin		U	F		x		x	C
Pipra fasciicauda	Band-tailed Manakin		C	C	x	x	x		U
Pipra chloromeros	Round-tailed Manakin		U	U		x	x	x	C
Pipra coronata	Blue-crowned Manakin					x	x	x	C
Machaeropterus pyrocephalus	Fiery-capped Manakin			R			x		C
Neopelma sulphureiventer	Sulphur-bellied Tyrant-Manakin		R	R	x		x	x	R
Tyranneutes stolzmanni	Dwarf Tyrant-Manakin				x	x			C
Piprites chloris	Wing-barred Piprites								U
Mionectes olivaceus	Olive-striped Flycatcher		R	F		x		x	F
Mionectes oleagineus	Ochre-bellied Flycatcher			F		x	x	x	C
Mionectes macconnelli	McConnell's Flycatcher		R	F	x		x		R
Leptopogon amaurocephalus	Sepia-capped Flycatcher		U	R	x	x	x	x	F
Poecilotriccus albifacies	White-cheeked Tody-Tyrant		U						
Phylloscartes orbitalis	Spectacled Bristle-Tyrant			R					
Hemitriccus flammulatus	Flammulated Bamboo-Tyrant		U	U	x	x	x		U
Hemitriccus zosterops	White-eyed Tody-Tyrant				x				R
Hemitriccus rufigularis	Buff-throated Tody-Tyrant					x			
Todirostrum latirostre	Rusty-fronted Tody-Flycatcher								C
Todirostrum maculatum	Spotted Tody-Flycatcher			R			x		
Todirostrum chrysocrotaphum	Yellow-browed Tody-Flycatcher			F					U
Todirostrum pulchellum	Black-backed Tody-Flycatcher								R
Todirostrum plumbeiceps	Ochre-faced Tody-Flycatcher					x			
Corythopis torquata	Ringed Antpipit		U		x	x	x	x	U
Zimmerius gracilipes	Slender-footed Tyrannulet		U	U		x			C
Ornithion inerme	White-lored Tyrannulet								R

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Camptostoma obsoletum	Southern Beardless-Tyrannulet			U					
Phaeomyias murina	Mouse-colored Tyrannulet						x		R
Tyrannulus elatus	Yellow-crowned Tyrannulet			R	x				U
Myiopagis gaimardii	Forest Elaenia								C
Myiopagis caniceps	Gray Elaenia						x		
Elaenia gigas	Mottle-backed Elaenia					x			
Serpophaga cinerea	Torrent Tyrannulet	a		R					
Myiornis ecaudatus	Short-tailed Pygmy-Tyrant			R					F
Ramphotrigon megacephala	Large-headed Flatbill		R	C					
Ramphotrigon fuscicauda	Dusky-tailed Flatbill			R					
Tolmomyias assimilis	Yellow-margined Flycatcher								U
Tolmomyias poliocephalus	Gray-crowned Flycatcher								U
Tolmomyias flaviventris	Yellow-breasted Flycatcher			C					
Platyrinchus coronatus	Golden-crowned Spadebill					x	x	x	U
Platyrinchus platyrhynchos	White-crested Spadebill						x	x	U
Onychorhynchus coronatus	Royal Flycatcher					x			
Myiophobus fasciatus	Bran-colored Flycatcher		F	U					R
Myiobius erythrurus	Ruddy-tailed Flycatcher		F	F		x	x	x	C
Myiobius atricaudus	Black-tailed Flycatcher		F						
Myiobius barbatus	Sulphur-rumped Flycatcher		F			x		x	F
Lathrotriccus euleri	Euler's Flycatcher		F	R	x		x	x	U
Contopus cooperi	Olive-sided Flycatcher	m	R	U					
Contopus virens	Eastern Wood-Pewee	m		C					
Empidonax alnorum	Alder Flycatcher	m		C					
Pyrocephalus rubinus	Vermilion Flycatcher	m	R	R	x	x			R
Ochthornis littoralis	Drab Water-Tyrant	a			x	x	x		U
Muscisaxicola fluviatilis	Little Ground-Tyrant	o	R	R					R
Colonia colonus	Long-tailed Tyrant		R	F	x		x		
Attila bolivianus	Dull-capped Attila				x	x			
Attila spadiceus	Bright-rumped Attila		R					x	U
Sirystes sibilator	Sirystes			R					
Myiarchus tuberculifer	Dusky-capped Flycatcher				x		x		R
Tyrannus melancholicus	Tropical Kingbird			U	x	x	x		U
Tyrannus savana	Fork-tailed Flycatcher	o							
Tyrannus tyrannus	Eastern Kingbird	m			x	x	x		
Griseotyrannus aurantioatrocristatus	Crowned Slaty-Flycatcher	m	R	U					R
Megarhynchus pitangua	Boat-billed Flycatcher			U	x	x	x		
Myiodynastes maculatus	Streaked Flycatcher			R	x	x	x		
Myiodynastes luteiventris	Sulphur-bellied Flycatcher	m		R		x			
Myiozetetes similis	Social Flycatcher			U			x		U
Myiozetetes granadensis	Gray-capped Flycatcher		R	U					U
Legatus leucophaius	Piratic Flycatcher			C					

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Philohydor lictor	Lesser Kiskadee	a			x	x	x		
Pitangus sulphuratus	Great Kiskadee					x			
Pachyramphus polychopterus	White-winged Becard			U					U
Pachyramphus minor	Pink-throated Becard			R					R
Tityra cayana	Black-tailed Tityra			R					
Tityra semifasciata	Masked Tityra		U	U					R
Cyanocorax violaceus	Violaceous Jay			U	x	x	x		U
Cyanocorax cyanomelas	Purplish Jay					x			
Vireo olivaceus	Red-eyed Vireo			U					U
Hylophilus thoracicus	Lemon-chested Greenlet			U					U
Hylophilus hypoxanthus	Dusky-capped Greenlet								C
Hylophilus ochraceiceps	Tawny-crowned Greenlet		U	F				x	C
Catharus ustulatus	Swainson's Thrush	m		C			x		
Catharus minimus	Gray-cheeked Thrush	m		R					
Turdus ignobilis	Black-billed Thrush				x				
Turdus lawrencii	Lawrence's Thrush			U					
Turdus hauxwelli	Hauxwell's Thrush			R	x	x	x		R
Turdus albicollis	White-necked Thrush		U	C		x		x	C
Donacobius atricapillus	Black-capped Donacobius	a					x		
Campylorhynchus turdinus	Thrush-like Wren		U	C					
Thryothorus coraya	Coraya Wren				x	x			
Thryothorus genibarbis	Moustached Wren		C	C					C
Troglodytes aedon	House Wren				x		x		
Microcerculus marginatus	Southern Nightingale-Wren		C	C	x	x	x	x	C
Cyphorhinus aradus	Musician Wren				x	x	x		
Ramphocaenus melanurus	Long-billed Gnatwren		U	F					U
Tachycineta albiventer	White-winged Swallow	g			x	x			U
Progne tapera	Brown-chested Martin	mg			x	x	x		
Neochelidon tibialis	White-thighed Swallow			U					
Notiochelidon cyanoleuca	Blue-and-white Swallow	g				x	x		U
Atticora fasciata	White-banded Swallow	g			x	x	x		U
Stelgidopteryx ruficollis	Southern Rough-winged Swallow	g		R					U
Hirundo rustica	Barn Swallow	mg					x		
Coereba flaveola	Bananaquit			U	x		x		U
Oporornis agilis	Connecticut Warbler	m		R					
Basileuterus chrysogaster	Golden-bellied Warbler			C	x		x		
Basileuterus fulvicauda	Buff-rumped Warbler		F	F	x	x	x		F
Ammodramus humeralis	Grassland Sparrow				x				
Ammodramus aurifrons	Yellow-browed Sparrow				x		x		U
Arremon taciturnus	Pectoral Sparrow		R	U	x	x			U
Paroaria gularis	Red-capped Cardinal				x				
Conothraupis speculigera	Black-and-white Tanager	m		C			x		

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Cissopis leveriana	Magpie Tanager		U	C	x		x		R
Hemithraupis guira	Guira Tanager			R					
Hemithraupis flavicollis	Yellow-backed Tanager								R
Eucometis penicillata	Gray-headed Tanager								R
Lanio versicolor	White-winged Shrike-Tanager		F	F	x	x	x	x	C
Tachyphonus rufiventer	Yellow-crested Tanager		U	F					F
Chlorothraupis carmioli	Olive Tanager			F	x	x	x	x	C
Habia rubica	Red-crowned Ant-Tanager		U	F					
Piranga olivacea	Scarlet Tanager	m		F					
Ramphocelus nigrogularis	Masked Crimson Tanager				x				R
Ramphocelus carbo	Silver-beaked Tanager		R	C	x	x	x		F
Thraupis episcopus	Blue-gray Tanager			C	x	x	x		U
Thraupis palmarum	Palm Tanager		R	U	x		x		U
Euphonia xanthogaster	Orange-bellied Euphonia		F	C	x	x	x	x	C
Euphonia rufiventris	Rufous-bellied Euphonia			R					F
Tangara cyanicollis	Blue-necked Tanager			U	x		x		
Tangara mexicana	Turquoise Tanager		R	F	x		x	x	F
Tangara chilensis	Paradise Tanager		F	F			x	x	C
Tangara schrankii	Green-and-gold Tanager			C		x	x	x	C
Tangara xanthogastra	Yellow-bellied Tanager			U				x	F
Tangara gyrola	Bay-headed Tanager			F					U
Tangara nigrocincta	Masked Tanager			F				x	U
Tangara velia	Opal-rumped Tanager			F					
Tangara callophrys	Opal-crowned Tanager								R
Dacnis lineata	Black-faced Dacnis		R	U				x	U
Dacnis flaviventer	Yellow-bellied Dacnis		R	U	x		x		U
Dacnis cayana	Blue Dacnis		R	F				x	F
Chlorophanes spiza	Green Honeycreeper			C			x		U
Cyanerpes caeruleus	Purple Honeycreeper			F	x				U
Tersina viridis	Swallow-Tanager			F	x				
Volatinia jacarina	Blue-black Grassquit						x		
Sporophila schistacea	Slate-colored Seedeater			C			x		
Sporophila lineola	Lined Seedeater					x			
Sporophila caerulescens	Double-collared Seedeater					x			
Sporophila castaneiventris	Chestnut-bellied Seedeater				x	x	x		R
Sporophila luctuosa	Black-and-white Seedeater				x		x		
Tiaris obscura	Dull-colored Grassquit				x	x			
Saltator grossus	Slate-colored Grosbeak		F	C		x	x		C
Saltator maximus	Buff-throated Saltator		U	C	x	x	x	x	C
Saltator coerulescens	Grayish Saltator				x		x		
Cyanocompsa cyanoides	Blue-black Grosbeak		F	F		x	x	x	C
Psarocolius decumanus	Crested Oropendola		U	U	x	x	x		
Psarocolius angustifrons	Russet-backed Oropendola			F	x	x	x	x	F
Psarocolius yuracares	Olive Oropendola		U	F	x	x	x	x	F

Appendix 1. Continued

			Site and Habitat Type						
			Bamboo					Broad-leafed	
Species	Common Name	Code	SM-3	CS-3	LM	SE	SH	CS-2	PG
Cacicus cela	Yellow-rumped Cacique		U	U	x	x	x		U
Cacicus solitarius	Solitary Cacique			R	x	x	x		
Agelaius xanthophthalmus	Pale-eyed Blackbird				x	x			
Icterus cayanensis	Epaulet Oriole		U	U			x		
Icterus icterus	Troupial		U	F	x		x		
Molothrus oryzivorus	Giant Cowbird				x	x	x		U
Totals			165	257	196	178	190	99	257

The Small Mammal Community of the Lower Urubamba Region, Peru

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1 Introduction

Small mammals are a primary component of neotropical rainforests (Voss and Emmons 1996). Through seed dispersal (Brewer and Rejmanek 1999), pollination (Fleming and Sosa 1994), mycorrhizal dispersal (Janos *et al*. 1995), control of insect populations (Cook *et al*. 1995) and as prey for carnivorous animals (Redford and Eisenberg 1992), small mammals contribute in many ways to the natural functions of ecosystems.

Although there is no true taxonomic division between small and large mammals, for the purposes of this study we consider the following orders to be small mammals: Didelphimorphia, Chiroptera and Rodentia (the last including only the families Muridae and Echimyidae). These three orders account for nearly 3000 of the 4600 known species of mammals (Wilson and Reeder 1993, Nowak 1999).

Like many taxa, the diversity of small mammals reaches its maximum in tropical regions (Cole *et al*. 1994), and the neotropical forests of western Amazonia are no exception (Voss and Emmons 1996). Emmons and Feer (1997) recognize 560 species of mammals from the neotropics, including 420 species of small mammals under our definition. Emmons (1984) suggests that the rainforest mammal fauna may be the richest in the western subregion of Amazonia, where more than 200 species could occur sympatrically — including more than 160 species of small mammals (Voss and Emmons 1996).

The Lower Urubamba Region (LUR) is of great ecological importance because of its biodiversity (Dallmeier and Alonso 1997; Alonso and Dallmeier 1998, 1999). Until recently, this unexplored region remained mostly unaffected by human exploitation. In 1996, Shell Prospecting and Development Peru (SPDP) reestablished a natural gas exploration project in the LUR. The plans included construction of four well sites, a gas processing plant and two pipelines to carry the gas to the Pacific Coast. The Smithsonian Institution’s Monitoring and Assessment of Biodiversity Program collaborated with SPDP in an effort to integrate science and conservation with development of the natural gas resource. Both parties cooperated in creating a plan for wise development (Dallmeier and Alonso 1997), agreeing that management decisions would incorporate the findings of a multi-taxa biodiversity assessment of the LUR’s forests.

We describe the procedures, results and significance of the small mammal assessment, which was aimed at obtaining baseline information regarding the status and distribution of small mammals in the LUR, compare our findings to those from other neotropical forests and examine the potential effects of the natural gas development project on small mammal communities.

2 Study area

The study area, approximately 20 x 30 kilometers (km) in size at 12° south latitude, 73° west longitude, is located in southeastern Peru’s Lower Urubamba River Valley between Manu National Park and the Apurimac Reserve Zone at the base of the eastern foothills of the Andes Mountains. The area includes the Urubamba, Camisea and Cashiriari rivers.

We sampled small mammals at seven sites covering approximately 4 km^2 within the larger area. The sites

Table 1. Time of year and effort expended at each of seven sampling sites in the Lower Urubamba Region, Peru (trap nights and net nights equal the total number of traps or nets set multiplied by the total number of nights spent sampling).

Site	First Assessment	Trap nights	Net nights	Second Assessment	Trap nights	Net nights
Well sites						
San Martin-3	May, 1997	1651	58	November, 1998	2050	65
Cashiriari-2	May, 1997	1065	95	November, 1998	2220	65
Cashiriari-3	October, 1997	2000	88	November, 1998	2400	78
Pagoreni	April, 1998	2898	80	November, 1998	2400	75
River sites						
Las Malvinas	September, 1997	560	50			
Segakiato	October, 1997	1200	50			
Peruanita	October, 1997	860	50			

included four natural gas wells, San Martin-3 (Sanm3), Cashiriari-2 (Cash-2), Cashiriari-3 (Cash-3) and Pagoreni (Pag) as well as three additional sites along the Urubamba and Camisea rivers — Las Malvinas (Lasm), Segakiato (Sega) and Peruanita (Perua). The sampling sites represented three habitat types: *terra firme* forest (Sanm-3, Cash-2 and Pag), secondary forest (Lasm, Sega) and mixed-upland forest (Cash-3 and Perua). Comiskey *et al.* (this volume) provide detailed descriptions of the vegetation at each site.

Temperatures across the study area are typically warm and show little annual variation. They range from 23.5^0 C to 24.5^0 C, and the relative humidity normally exceeds 80%. The region experiences distinct wet and dry seasons. Mean annual rainfall averages 3000 to 3500 millimeters and occurs mostly from October through April (Alonso and Dallmeier 1999).

3 Methods

We assessed the small mammal community between May 1997 and November 1998, sampling twice at each of the well sites and once at each of the riverside sites for a total of 11 sampling periods (Table 1). The sampling time periods averaged two weeks.

We collected a representative sample of each species recorded. All samples were prepared for use as study specimens, either as a standard museum study skin and skeleton or preserved whole in 10% formalin. We deposited museum specimens at the Museo de Historia Natural, Universidad Nacional Mayor de San Marcos in Lima, Peru, and at the National Museum of Natural History, Washington, DC, USA.

3.1 Non-volant mammals

To sample non-volant mammals, we established multiple trap lines at each site. To maximize the potential number of species encountered, we set trap lines in a large section of all microhabitats — such as cultivated areas, transitional forests, streamsides, patches of bamboo, logs, rocky outcrops, etc. — occurring at each site.

We set trap stations approximately every 10 meters along each trap line. Each station was the location for several types of traps, including snap-traps (Victor rat traps) and live traps (Sherman and Tomahawk traps). We baited traps every day or every two days, depending on how quickly animals removed the bait. Bait consisted of oats, peanut butter, vanilla, fruits or vegetables. Total trapping effort, based on trap nights, varied (Table 1).

3.2 Bats

At all sites, we sampled bats using mist nets. Each night, we placed one to 15 mist nets — with a mean of six —

across trails, streams and forest edges and left the nets open between four and 12 hours. We varied effort (Table 1) and net location to maximize the diversity of species captured.

4 Results and Discussion

We recorded 103 species of small mammals in the LUR, which makes this area among the most species-rich small mammal communities in the neotropics (Appendix 1). Bats were by far the most speciose group with 68 species, followed by rodents (18 species) and marsupials (17 species). Boddicker *et al.* (this volume) provide additional data regarding the rodent families Dasyproctidae, Dinomyidae, Erethizontidae and Sciuridae.

The number of species recorded at each of the sites was highly variable and depended upon the sampling effort. There was a tendency toward higher diversity at the well sites, where the total exceeded 60 species at each site, except Pag (52 species). In contrast, none of the riverside sites exceeded 40 species (Appendix 1).

Among the well sites, there appeared to be a relationship between non-volant mammal diversity and the presence of bamboo. At the two sites — Sanm3 and Cash-3 — where bamboo was present, we recorded high opossum (10 and 11 species, respectively), and rodent (15 and 14 species, respectively) diversity. At the sites — Pag and Cash-2 — where bamboo was absent, we recorded six opossum and eight rodent species and five opossum and six rodent species, respectively. Because trapping effort was similar at the four well sites, a possible explanation for the difference might be that the dense tangle of bamboo culms produced a more complex habitat, both horizontally and vertically, which provided more habitat niches that can produce increased species richness (August 1983). The bat fauna at the well sites does not appear to have a relationship to bamboo. Cash-2, a non-bamboo site, recorded the highest richness (53 species), while Sanm-3, Cash-3 and Pag exhibited lower richness (38 to 39 species).

Species richness was lowest at the three sites along the river. At Lasm, we recorded the fewest non-volant mammals of all sites — two rodent species and no marsupials, while at Sega and Perua, we recorded eight and nine species, respectively. Of the species recorded, only one, the spiny tree rat *Mesomys hispidus* recorded at Sega, was unique to riverside forests. Bat species richness was also lowest at the three sites along the river: Lasm recorded the fewest bat species (14), while Sega and Perua recorded 29 and 26 species, respectively. Three bats — *Rhynchonycteris naso, Noctilio* cf. *leporinus* and *Myotis albescens* — were unique to the riverside habitats. The lower species richness values recorded at the river sites are most likely a result of lower sampling effort, which totaled 2620 trap nights and 150 net nights. In comparison, we sampled for 16,684 trap nights and 604 net nights at the four well sites (Table 1). The lower richness may also be associated with human disturbance. The secondary forest sites at Lasm and Sega are located along rivers and hence are more accessible to humans than the other sites. Agrarian communities exist in this area, and there is evidence of small-scale clearing of the forest for agriculture as well as abandoned agricultural plots.

Several findings are worth special mention. The recording of *Marmosa andersoni* was only the second record of this rare and endemic species since it was first described more than 25 years ago (Pine 1972). The original record was based on a single individual collected in 1954, and our specimens, two adults and four juveniles, constitute a geographic extension of more than 100 km to the north from the first recording at Cosñipata (Pine 1972). The most distinctive characteristics of the species are the well-developed postorbital processes (Pine 1972), but some external characteristics do not correspond with its assignment to the genus *Marmosa.* It is possible that this animal deserves a formal generic status, possibly *Stegomarmosa*.

We recorded three species of the genus *Monodelphis* — *M. adusta*, *M. brevicaudata*, and the extremely rare *M. emiliae* — occurring sympatrically, which is the first known case of such an event. Our record of *M. adusta*, a montane mammal species (Emmons and Feer 1997) identified at Cash-3 where several montane plant species are also found, represents the first record of this species for the Department of Cusco. *M. adusta* was previously known only from Loreto and Madre de Dios. We also recorded another rare marsupial, *Caluromysiops irrupta*, which is known from less than 30 specimens.

High sympatry of Marmosine genera (sensu Hershkovitz 1992) is not common in the neotropics (Voss and Emmons 1996, Emmons and Feer 1997). Nevertheless, we recorded five species at Cash-3. Similar to other rainforest localities, *Marmosops noctivagus* was the most common species in LUR forests.

Notable rodents included *Oxymycterus inca* (Muridae). The genus *Oxymycterus* of the Akodontine tribe is a common group in the Andes region at higher altitudes, with just a few species of this genus inhabiting the lowland tropics (Reig 1987, Hershkovitz 1994). One of these lowland species was recorded at Cash-3, providing further evidence of an association between the lowland tropical and montane forests in the LUR (Comiskey *et al*. this volume). Among the Oryzomyine tribe, we found up to four species in each of the genera *Oecomys* and *Oryzomys*, although some of the species were too difficult to identify because current taxonomic revisions are lacking. We list just three names within *Oecomys*, but at least another two taxa could be present among our specimens, representing either new geographic records or new species.

There were also several noteworthy aspects of the bat fauna in the LUR forests. Among the subfamilies of Phyllostomidae, the Stenodermatines were the best represented group. The 25 species recorded include all of the expected genera from western Amazonia and possibly all of the expected species (see Voss and Emmons 1996). A well-represented Stenodermatine fauna is typical in western Amazonia. Voss and Emmons (1996) state that the number of Stenodermatines at a site often approaches geographic expectations (19 to 21 species) in western Amazonia, while most other bat taxa are typically underrepresented. This is indeed the case in the LUR. Among the less represented groups in our assessment were the Emballonurids, Vespertilionids and Molossids. Patterson *et al*. (1996) suggest that this phenomenon is a result of the insectivorous feeding habits of the latter groups; insectivorous bats tend to have a greater development of their echolocation capabilities, hence a greater ability to detect and avoid mist nets. The LUR study also found a southward extension of the known latitudinal range for three species of bat, *Centronycteris centrali* (Emballonuridae), *Thyroptera lavali* (Thyropteridae) and *Lonchophylla handleyi* (Glossophaginae) (Pine 1993, Pacheco *et al*. 1995, Emmons and Feer 1997, Solari *et al*. In press).

Among Stenodermatines, we found the highest records of sympatric species in the genera *Dermanura* and *Platyrrhinus*, with four species each. This may be an indication of great resource availability or high habitat heterogeneity. Another important record was the short-faced fruit bat, *Sphaeronycteris toxophyllum*, which is one of just a few bat species displaying sexual dimorphism.

Bats in the LUR region feed on a variety of food items, but most of those we recorded were frugivores, comprising 44% of the overall bat community, and they represented the largest trophic guild at all sites. Insectivores were the next most common group overall (26%), but the proportion of insectivores by site varied greatly. Frugivores were also the most abundant group in a bat community at Loreto, Peru, followed by the insectivores (Ascorra and Wilson 1992). As noted, however, lower diversity values for insectivores could be a result of their ability to detect and avoid mist nets (Voss and Emmons 1996).

4.1 Geographic patterns of diversity and distribution

Few studies have been conducted in the neotropics that examine the entire mammal community. Voss and Emmons (1996) reviewed 10 such studies, and Table 2 summarizes results that pertain to small mammals. The data in Table 2 and additional records from the region (Ascorra *et al*. 1996, Pacheco and Vivar 1996, Voss and Emmons 1996) clearly show that small mammal communities, including that of the LUR, in southeastern Peru are among the richest in the neotropics and on Earth (Emmons 1984). Overall, the LUR claims the richest marsupial and bat faunas, and the area's rodent fauna rivals that of other sites in southern Peru.

Table 2. Number of small mammal species by order recorded at 11 neotropical sites (data modified from Voss and Emmons 1996).

Site	Sampling period (yrs.)	Marsupials	Bats	Rodents: Muridae	Rodents: Echimyidae	Total
Central America						
Barro Colorado, Panama	71	6	64	5	2	77
La Selva, Costa Rica	34	5	65	6	2	78
Northern South America						
Arataye, French Guiana	17	9	61	9	5	84
Cunucunuma, Venezuela	< 1	8	50	4	2	64
Kartabo, Guyana	5	7	-	11	2	-
Central Amazonia						
BDFF Reserves, Brazil	6	9	-	7	5	-
Xingu, Brazil	< 1	8	47	10	7	78
Southwest Amazonia						
Balta, Peru	3	11	56	10	6	91
Cocha Cashu/Pakitza, Peru	21	12	60	11	7	99
Cuzco Amazonica, Peru	2	9	44	11	5	75
Lower Urubamba Region, Peru	2	16	68	12	6	102

4.2 Effects of natural gas exploration and development

Some human activities, such as agriculture and forestry, can have dramatic effects on the distribution, abundance and diversity of small mammals, primarily because of the influence of habitat fragmentation. Habitat fragmentation can lead to lower diversity (Adler *et al*. 1997, Stevens and Husband 1998), lower abundance (Granjon *et al*. 1996, Nupp and Swihart 1998) and fluctuating populations (Adler *et al*. 1997). Fragmentation has also been shown to increase diversity (Gascon and Lovejoy 1998) and abundance (Yahner 1992, Adler *et al*. 1997, Nupp and Swihart 1998), while still other studies indicate fragmentation has no effects on small mammal populations (Heske 1995, Bayne and Hobson 1998, Mahan and Yahner 1998). These conflicting reports present a challenge when it comes to the task of interpreting the results of small mammal assessments. For a full assessment of the impacts of fragmentation or other means of habitat alteration, researchers may have to rely on intensive field studies. Our initial determination is that the development of the gas exploration project is having little to no effect on the small mammal populations throughout the LUR. We base this impression on the high diversity of the small mammal community and comparisons to other protected areas in the region. Ultimately, because responses by small mammal populations to human-induced habitat alteration are often contradictory, scientists should critically evaluate the potential values of assessing and monitoring small mammals as an indicator of ecosystem health.

5 Conclusions

The overall diversity of small mammals in the LUR is impressive and attests to the global importance of the region as a center for biodiversity. Several theories attempt to explain the remarkable variety of plants and animals in the region. Haffer (1969) postulated that Amazonian diversity is a result of large changes in vegetation cover and distribution of species because of expansion and contraction of the polar ice caps during the Pleistocene (the Pleistocene refugia theory). Although, those changes influenced the flora (Prance 1987) and fauna (Haffer 1987), Brown (1987) argues that ecological and not evolutionary factors determine community — or alpha — level diversity. Fine-scale habitat heterogeneity and intermediate levels of natural disturbance, such as that seen in the LUR (Comiskey *et al*. this volume), create many niches, which in turn lead to higher diversity of organisms (Connell 1978, Fox 1979, August 1983).

In addition to the complex habitat mosaic in the region, an important factor affecting diversity of small mammals in the LUR may be the temporal stability of primary production and asynchronous peaks of fruiting and masting that provide a year-round food supply (Janson and Emmons 1990, Voss and Emmons 1996). Finally, the location of the LUR in southwestern Amazonia means the area will be influenced by the flora and fauna of the Amazon Basin, the Andes mountains and the savannas of Bolivia. Ultimately, some combination of these factors creates the amazingly rich forests we see in the LUR.

The establishment of a baseline study allowed us to build a base of knowledge in regard to the ecology of the small mammal community in the Lower Urubamba River Valley. As a next step, we recommend studies that focus more on identifying specific habitat preferences for all species and on obtaining abundance data. Each step we take in this process will bring us closer to an understanding of how this complex ecosystem functions and will alert us to any potential negative impacts that may occur because of the activities of natural gas exploration and development.

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Appendix 1. List of the small mammals recorded in the Lower Urubamba Region, Peru. Total of 103 species. Nomenclature based on Nowak (1999) except where noted. SM-3 = San Martin-3, Cash-2 = Cashiriari-2, Cash-3 = Cashiriari-3, Pag = Pagoreni, LM = Las Malvinas, Sega = Segakiato and Peru = Peruanita.

	Site						
Scientific Name	SM-3	Cash-2	Cash-3	Pag	LM	Sega	Peru
Didelphimorphia							
Marmosidae (12 spp.)							
Gracilinanus cf. *agilis*	X	X		X			
Gracilinanus kalinowskii			X				
Marmosa murina			X	X			
Marmosops noctivagus	X	X	X	X			X
Marmosops parvidens		X					X
Metachirus nudicaudatus	X	X		X		X	X
Micoureus demerarae		X					
Micoureus regina	X		X	X			X
Monodelphis adusta			X				
Monodelphis brevicaudata	X						
Monodelphis emiliae	X		X				
Stegomarmosa andersoni [a]	X		X				
Caluromyidae (2 spp.)							
Caluromys lanatus			X				
Caluromysiops irrupta			X				
Didelphidae (3 spp.)							
Chironectes minimus	X		X				X
Didelphis marsupialis	X			X		X	
Philander opossum	X		X				
Chiroptera							
Emballonuridae (6 spp.)							
Centronycteris centralis [b]			X				
Peropteryx macrotis		X					
Peropteryx kappleri				X			
Rhynchonycteris naso							X
Saccopteryx bilineata	X	X	X				
Saccopteryx leptura	X	X	X				X
Noctilionidae (1 sp.)							
Noctilio cf. *leporinus*						X	
Phyllostomidae (51 spp.)							
Carolliinae (5 spp.)							
Carollia brevicauda	X	X	X	X	X	X	X
Carollia castanea	X	X	X	X	X	X	X
Carollia perspicillata	X	X	X	X	X	X	X
Rhinophylla fischerae	X	X	X	X			
Rhinophylla pumilio	X	X		X		X	X
Desmodontinae (2 spp.)							
Desmodus rotundus	X	X		X	X	X	
Diphylla ecaudata	X						

Appendix 1. Continued

	Site						
Scientific Name	SM-3	Cash-2	Cash-3	Pag	LM	Sega	Peru
Glossophaginae (8 spp.)							
Anoura caudifer	X	X	X	X	X	X	X
Anoura geoffroyi		X					
Choeroniscus intermedius	X	X					X
Choeroniscus minor			X				
Glossophaga soricina		X					
Lionycteris spurrelli		X					
Lonchophylla handleyi				X			
Lonchophylla thomasi	X	X	X	X		X	X
Phyllostominae (11 spp.)							
Chrotopterus auritus		X		X			
Micronycteris megalotis		X	X			X	
Micronycteris minuta		X					
Mimon crenulatum	X	X				X	
Phylloderma stenops	X						
Phyllostomus elongatus			X	X		X	
Phyllostomus hastatus		X	X				X
Tonatia brasiliense		X					
Tonatia saurophila	X			X			
Tonatia silvicola	X	X					
Vampyrum spectrum				X			
Stenodermatinae (25 spp.)							
Artibeus lituratus	X	X	X	X	X	X	X
Artibeus obscurus	X	X	X	X	X		X
Artibeus planirostris	X	X	X	X	X	X	X
Chiroderma salvini	X	X	X	X		X	
Chiroderma trinitatum	X	X		X			
Chiroderma villosum	X	X	X	X		X	X
Dermanura anderseni		X		X	X	X	X
Dermanura cinerea	X	X	X	X	X	X	X
Dermanura glauca		X	X	X			
Dermanura gnoma		X		X		X	
Enchistenes hartii	X	X	X	X			
Platyrrhinus brachycephalus	X	X	X	X	X	X	X
Platyrrhinus infuscus	X	X	X	X		X	X
Platyrrhinus nigellus [c]			X				
Platyrrhinus helleri	X	X	X	X	X	X	X
Sphaeronycteris toxophyllum	X	X	X	X		X	X
Sturnira lilium	X	X	X	X		X	
Sturnira magna		X	X				
Sturnira tildae		X	X	X			X
Uroderma bilobatum	X	X	X	X	X	X	X
Uroderma magnirostrum	X	X	X	X		X	X
Vampyressa bidens		X	X	X		X	
Vampyressa macconnelli [d]	X	X	X	X			X

Appendix 1. Continued

Scientific Name	Site SM-3	Cash-2	Cash-3	Pag	LM	Sega	Peru
Vampyressa pusilla		X	X	X		X	
Vampyrodes caraccioli	X	X		X			X
Thyropteridae (2spp.)							
Thyroptera lavali			X				
Thyroptera tricolor	X	X	X				
Vespertilionidae (5 spp.)							
Eptesicus brasiliensis		X					
Myotis albescens						X	X
Myotis nigricans	X	X	X		X		
Myotis riparius	X	X	X	X		X	
Myotis simus		X					
Molossidae (3 spp.)							
Molossus ater	X	X					
Molossus molossus	X						
Promops centralis	X	X					
Rodentia							
Muridae (12 spp.)							
Neacomys spinosus	X	X	X	X			
Nectomys squamipes	X		X			X	
Oecomys bicolor	X	X	X	X			
Oecomys cf. *superans*	X		X				X
Oecomys cf. *roberti*			X	X			
Oligoryzomys microtis	X						
Oryzomys macconnelli	X	X	X	X			
Oryzomys megacephalus [e]	X	X	X	X		X	X
Oryzomys nitidus	X	X	X	X		X	
Oryzomys yunganus			X				
Oxymycterus cf. *inca*	X		X				
Rhipidomys cf. *couesi*	X		X	X			
Echimyidae (6 spp.)							
Dactylomys dactylinus	X		X		X		X
Mesomys hispidus						X	
Proechimys aff. *cuvieri*	X						
Proechimys cuvieri	X		X				
Proechimys longicaudatus	X					X	
Proechimys simonsi	X	X	X	X	X	X	X
Total Didelphimorphia Species	10	5	11	6	0	2	5
Total Chiroptera Species	39	53	38	38	14	29	26
Total Rodentia Species	15	6	14	8	2	6	4
Total Species	64	64	63	52	16	37	35

[a] listed as subgenera of *Marmosa* in Nowak (1999)

[b] see Simmons and Handley (1998)

[c] listed as *Platyrrhinus lineatus* by Nowak (1999)

[d] included in *Mesophylla* by Nowak (1999)

[e] see Musser et al. (1998)

Assessment of the Large Mammals of the Lower Urubamba Region, Peru

Major Boddicker, Juan José Rodríguez and Jessica Amanzo

1 Introduction

Throughout history, curiosity and a quest for knowledge have motivated naturalists to explore the globe and seek out the unusual. Certainly over the past two centuries, Charles Darwin's first voyage in 1831, Alfred Russel Wallace and Henry Walter Bates' 1000-mile trek up the Amazon river in 1848 and Paul Belloni du Chaillu's discovery of the gorilla in the jungles of western Africa in 1856 (Jenkins 1978) rank among the most adventurous and fruitful. They resulted in the cataloging of many species of flora and fauna, including large mammals that pervade the folklore of nearly all cultures. As symbols of strength and power, large mammals both evoke worship as dieties and instill fear and frustration as pests. They also play a vital role in the functioning of ecosystems around the world.

The global list of large mammal species is nearly complete (but see Dung *et al*. 1994, Giao *et al*. 1998), although places exist where the composition of the mammal community remains virtually unknown. In the neotropics for example, Voss and Emmons (1996) list only 10 comprehensive, published studies that purport to assess the entire community of mammals in a region even as exploitation of neotropical forests is at an all-time high (FAO 1997), and their biodiversity is being lost at alarming rates (Wilson 1992, Whitmore 1997).

Because large mammals affect the functioning of ecosystems, losses of large mammal populations may have detrimental effects (Howe 1984). These animals distribute seeds (Fragoso 1997, Julliot 1997, Voysey *et al*. 1999), aid seed germination (Traveset 1998, Cypher and Cypher 1999), act as both predator and prey, interact with insect guilds (Feer 1999) and alter the structure and composition of vegetation (McInnes *et al*. 1992), plant productivity (Frank and McNaughton 1993) and nutrient cycling (Pastor *et al*. 1993). Large mammals are also a source of clothing, food, tools and spiritual values for people (Deb and Malhotra 1997). Many of the most familiar of these animals, along with many that are less well known, are experiencing rapid population declines (Jackson 1997, Rylands *et al*. 1997) because of reduction, fragmentation and degradation of their habitat (Hanski *et al*. 1995) and because of hunting (Bodmer *et al*. 1997). Population declines are threatening the existence of some large mammals (IUCN 1996).

Faced with these potential losses, conservationists and resource managers have begun to concentrate on assessing the entire community of large mammals within sites of conservation concern. Western Amazonia, with its biologically rich forests, is such a place (Myers *et al*. 2000). Nearly 25%, or 1096 species, of the world's mammal species reside in the neotropics (Wilson *et al*. 1996), and approximately 200 of these likely occur in western Amazonia (Emmons 1984), making this region among the most species rich in the world (Voss and Emmons 1996). But it appears that increasing human activity in the region will result in significant impacts on mammal populations.

In the lowland rainforests of the Lower Urubamba Region (LUR) in southeastern Peru, the Smithsonian Institution's Monitoring and Assessment of Biodiversity Program cooperated with Shell Prospecting and Development Peru in a landmark, multi-taxa biodiversity assessment and monitoring project (Dallmeier and Alonso 1997; Alonso and Dallmeier 1998, 1999). The goal was to assess the biodiversity of the LUR and incorporate the findings into the management decision-making process, with the intent of minimizing or eliminating negative impacts on biodiversity caused by development of natural gas and condensates.

The objectives of the large mammal assessment program were to: (1) create a list of the potential and actual large mammal species present in the LUR and (2) examine the effects of the natural gas drilling project on the composition of large mammals. For this assessment, we defined large mammals as all members of the Orders Didelphimorphia, Xenarthra, Primates, Carnivora, Perissodactyla, Artiodactyla and Lagomorpha and the families Sciuridae, Erethizontidae, Dinomyidae and Dasyproctidae of the Order Rodentia.

2 Study area

We conducted the assessment in the Lower Urubamba River Valley of southeastern Peru. We focused on an area approximately 20 x 30 kilometers (km) near the junction of the Urubamba, Camisea and Cashiriari rivers, which are part of the Amazon watershed. This region lies between Manu National Park and the Apurimac Reserve Zone at 12° south latitude and 73° west longitude. Comiskey *et al*. (this volume) provide a detailed description of the study area, which is a relatively unspoiled region of lowland tropical rainforest. Mature *terra firme* forest dominates the steep, sloping terrain. Temperatures are warm and stable, with an annual mean of 24° C. The relative humidity typically exceeds 80%. Rainfall averages between 3000 and 3500 millimeters per year and occurs mostly in the wet season (October through April; Dallmeier and Alonso 1997). All research sites were located in non-flooded forests with few signs of human disturbance.

3 Methods

We assessed mammals at four sites: San Martin-3 (Sanm-3), Cashiriari-2 (Cash-2), Cashiriari-3 (Cash-3) and Pagoreni (Pag). We conducted the study during the dry season at Sanm-3 (May 1997), Cash-2 (June 1997) and Pag (April 1998) and during the rainy season at Cash-3 (November 1997), spending four weeks at each site. We established transects across a variety of microhabitats (hill tops, valleys, streams, etc.) to assure that we would encounter a high proportion of the diversity present throughout the area. Transect length totaled 6.0 km at Sanm-3, 8.5 km at Cash-2, 5.0 km at Cash-3 and 4.5 km at Pag.

We used a combination of five standard mammal survey methods (Wilson *et al.* 1996) to gather evidence and document the presence of large mammals along the transects. The methods included direct observation, identification of vocalizations, scent-post surveys (Linhart and Knowlton 1975), mammal-sign surveys (Wemmer *et al.* 1996) and trapping.

We called each piece of recorded evidence a “mammal event,” which represented both direct data (collections and observations) and indirect data (tracks, feces, hair, bone, feeding characteristics, bed, dens, nests, trails, vocalizations, odors and identification by local residents). We also gathered qualitative data by questioning local people about the species present in the area.

From the data, we generated an occurrence indicator value (OI; Boddicker *et al*. In press) consisting of accumulated mammal events from various survey methods to develop a confirmed species list. We based the OI on a point system that assigned values to different types of evidence (Table 1). The point system reflected our ability to relate the evidence to the species that produced it. We separated types of evidence into three classes — unambiguous evidence, high-quality evidence and low-quality evidence (Table 1). Unambiguous evidence was defined as a species observed or collected and included any part of the individual such as a complete skull that would lead to certain identification. High-quality evidence is characteristic of a species, but may be easily distorted or difficult to discern and, thus, difficult to interpret. For example, tracks of ocelot (*Leopardus pardalis*) and margay (*L. wiedii*) are definitive, but substrate, age or other factors can lead to distortions that make the tracks difficult to distinguish. Low-quality evidence is suggestive but not characteristic of a species.

Table 1. Point values for various types of evidence used to calculate the occurrence indicator value (OI).

Type of Evidence	Point Value
Unambiguous evidence	
Species collected	10
Species observed	10
High quality evidence	
Bone [1]	5
Hair	5
Identification by local residents [2]	5
Tracks	5
Vocalizations and odors	5
Low quality evidence	
Beds, dens, nest, trails	4
Feces (scat)	4
Feeding characteristics	4

[1] Does not include a complete skull or other skeletal evidence that would permit unambiguous identification.

[2] We questioned local people about the species present by showing them photographs of neotropical mammals.

It is typically indicative of a group of species such as small cats, but does not permit verification at the species level.

We totaled the accumulated points for each species at a site to calculate the OI. When the points reached 10, we concluded that the species was present in the surveyed area. Any one type of evidence was counted just once at each location, even though that evidence may have been observed more than one time. Only unambiguous data qualified as a verification with no additional support. Therefore, we assigned unambiguous data a value of 10. Verification of presence based on high-quality evidence required at least two mammal events of different types for the same species (Table 1). Verification of presence based on low-quality evidence required at least three mammal events of different types (Table 1).

An example of the occurrence index, based on data for the Brazilian tapir (*Tapirus terrestris*), shows the various types of evidence collected, the associated point values and how this data led to a positive listing of presence at Sanm-3 (Table 2). The value for the Brazilian tapir (32) far exceeded the threshold value of 10, so we concluded that tapirs were present. In this case, tapir presence would have been confirmed because an individual was actually observed — unambiguous evidence that required no additional support. However, if we had not observed a tapir, we would have still concluded that they were present based on other evidence (for example, finding tracks and claims by local residents that the species was present led to the following equation: 5 + 5 = 10).

It is often possible, and probable, that some types of evidence we valued at less than 10 may be unambiguous verification of a species presence and should rate at least 10. The call of a howler monkey (*Alouatta seniculus*) or the track of a jaguar (*Panthera onca*) are examples. The scale we chose reflects our skills and confidence at the time of the study. Other researchers will have different skills, experiences and abilities and may consider a species as present based on index values that we rated less than 10.

4 Results and Discussion

We confirmed the presence of 45 species as follows: 26 species at Sanm-3, 25 species at Cash-2, 28 at Cash-3 and 26 at Pag (Appendix 1). Rodríguez (unpublished data) confirmed eight additional species during a second assessment in 1998, and Solari *et al*. (this volume) confirmed an additional 11 marsupials during a small mammal assessment in the same region for a total of 64 species of large mammals (Appendix 1).

We compiled a list of species that may inhabit the LUR from range maps and distribution descriptions found in Pacheco *et al*. (1993), Pacheco and Vivar (1996), Guerrero and Zeballos (1996) and Emmons and Feer (1997). We also asked local inhabitants to examine drawings in the Emmons and Feer (1997) field guide and identify species that they believed occurred in the area. In all, more than 80 species of large mammals were considered potentially present at the four sites.

The number of large mammals species recorded in the LUR rivals that of the most diverse sites in the neotropics (Table 3). Many studies at other neotropical sites that contain high diversity have been underway for decades, covering many different habitat types. The LUR project represents only two years' worth of evidence from just *terra firme* forest habitat. Therefore, we expect that the species list in the LUR will grow as assessment and monitoring in the region continues.

In addition to the large mammal assessment, we began to investigate the effects of the gas drilling operations on the distribution of large mammals. We found that large mammals were active throughout the study area and that the noise and other aspects of the operations did not appear to have any severe impacts other than at the drilling pads. Red brocket deer (*Mazama americana*) and Brazilian rabbit (*Sylvilagus brasiliensis*) tracks were present at both well sites. Ocelot (*Felis pardalis*), tapir and peccary (*Tayassu tajacu*) tracks, beds and other signs were found within 100 m of the drilling pads. Big cats such as pumas (*Felis concolor*) and jaguars, which are often considered the first to flee human development, were also active to within 100 m of the pad at Cash-2. In fact, a major loafing and toilet area for jaguars and pumas was found at a location where the engines could be heard clearly approximately 2.5 km from the well site. Sightings and signs of large mammals did not appear to be any less numerous near the drilling activity than 2.5 km away.

Table 2. An example of the occurrence index (data are for the Brazilian tapir (*Tapirus terrestris*)).

Type of evidence	Occurrence index
Species collected	0
Species observed	10
Tracks	5
Feces (scat)	4
Hair	0
Bone	0
Feeding characteristics	4
Beds, Dens, Nest, Trails	4
Vocalizations and odors	0
Questioning of local residents [1]	5
Index value	32

[1] We questioned local people about the species present by showing them photographs of neotropical mammals.

Table 3. Number of large mammal species from select Orders recorded in 11 neotropical forests (data modified from Voss and Emmons (1996) except for Lower Urubamba Region, Peru).

	Sampling period (yrs.)	Carnivora	Lagomorpha	Marsupialia	Primates	Rodentia[a]	Ungulates[b]	Xenarthra	Total
Central America									
Barro Colorado, Panama	71	13	1	6	4	5	5	6	40
La Selva, Costa Rica	34	14	1	5	4	6	5	7	42
Northern South America									
Kartabo, Guyana	5	13	0	7	6	6	5	9	46
Arataye, French Guiana	17	11	0	9	7	6	5	8	46
Cunucunuma, Venezuela	< 1	7	0	8	7	5	3	7	37
Central Amazonia									
MCSE Reserves, Brazil	6	8	0	9	6	5	5	8	41
Xingu, Brazil	< 1	2	1	8	7	5	3	4	30
Southwestern Amazonia									
Balta, Peru	3	15	1	11	10	7	4	9	57
Cocha Cashu/Pakitza, Peru	21	14	1	12	13	8	5	7	60
Cuzco Amazonica, Peru	2	11	1	9	7	6	4	5	43
Lower Urubamba Region, Peru	2	13	1	16	12	10	5	7	64
Potentially present[c]		18	1	-	14	-	6	12	-

[a] Includes only the families Dasyproctidae, Dinomyidae, Erethizontidae and Sciuridae.
[b] Perissodactyla and Artiodactyla
[c] Refers to the lowland forests of southeastern Peru (Emmons and Feer 1997, Voss and Emmons 1996).

5 Conclusion

In only two years, we verified the presence of 80% of the potential large mammal species in the LUR. We also laid the groundwork for a monitoring program that will oversee the effects of natural resource development projects in the area. Currently, initial reports suggest that these development projects are having little impact on the distribution and abundance of large mammals. Hunting of large mammals is minimal in the LUR, as is true of neighboring areas (Pacheco and Vivar 1996). Unlike other parts of the country (Bodmer *et al.* 1997), large mammal populations in southern Peru are still intact.

This is not the case in many areas of the neotropics where large mammal populations and other species are rapidly declining, primarily because of habitat destruction (Hanski *et al.* 1995) and over-hunting (Redford 1993). These losses will inevitably affect other aspects of the forests. Many of the large mammals are frugivores (Emmons and Feer 1997), and their loss would impact seed dispersal and germination rates, which may further accelerate the changes in both the flora and fauna of the forests (Gilbert 1980, Terborgh 1986, Levey *et al.* 1994).

As a center of rich biodiversity, the relatively undisturbed forests of southern Peru are of particular conservation concern. They claim the highest worldwide diversity for birds (Terborgh 1985, Robinson and Terborgh 1990), frogs (Duellman 1978), butterflies (Lamas 1994), mammals (Voss and Emmons 1996), trees (Gentry 1988, Valencia *et al.* 1994) and many other taxa. Careful, persistent monitoring is necessary to devise proactive adaptive management strategies and mitigate any negative impacts on this natural system and the species it supports.

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Appendix 1. List of actual and potential large mammal species at four sites in the Lower Urubamba Region, Peru (includes all species expected to occur based on range maps and distribution descriptions (Emmons and Feer 1990, Pacheco and Vivar 1996 and Guerrero and Zaballos 1996) and from interviews with local inhabitants; values represent the Occurrence Index value (OI); only values that confirm presence (>=10) are shown; "NC" = not confirmed; "C" = species confirmed as present at the site based on data obtained in other studies; evidence type (ET) = the types of evidence that led to confirmation of occurrence [a = species collected, b = species observed, c = bones, d = hair, e = identification by local residents, f = foot prints (tracks), g = vocalization or odor, h = bed, den, nest or trail, i = feces, j = feeding sign, blank space = no evidence collected; 45 species were confirmed in this study and an additional 18 species were confirmed in other studies; "Manu" = species that were also recorded in Manu National Park, Peru (Pacheco *et al.* 1993, Voss and Emmons 1996); nomenclature based on Nowak (1991), except for the ordinal name Didelphimorphia (Wilson and Reeder 1993)).

	San Martin-3		Cashiriari-2		Cashiriari-3		Pagoreni		Manu
Species	OI	ET	OI	ET	OI	ET	OI	ET	
Didelphimorphia									
Didelphidae									
Caluromys lanatus	NC	e	NC	e	C[a]	e	NC	e	X
Caluromys philander	NC	e	NC	e	NC	e	NC	e	
Caluromysiops irrupta	NC	e	NC	e	C[a]	e	NC		X
Chironectes minimus	24	b, e, f, j	NC	e	10	e, f	NC	e	
Didelphis albiventris	NC		NC		NC		NC	e	
Didelphis marsupialis	35	a, b, e, f, j	10	e, g	10	e, f	20	a, e, g	X
Gracilinanus kalinowskii	NC		NC		C[a]		NC		
Marmosa cf. *agilis*	C[a]		C[a]		C[a]		C[a]		X
Marmosa andersoni	C[a]		NC		C[a]		NC		
Marmosa demerarae	NC		C[a]		NC		NC		
Marmosa murina	NC		NC		C[a]		C[a]		X
Marmosa noctivaga	C[a]		C[a]		C[a]		C[a]		X
Marmosa parvidens	NC		C[a]		NC		NC		X
Marmosa regina	C[a]		NC		C[a]		C[a]		X
Metachirus nudicaudatus	C[a, b]	e	C[a]	e	NC	e	C[a]	e	X
Monodelphis adusta	NC		NC		C[a]		NC		
Monodelphis brevicaudata	C[a]		NC		NC		NC		X
Monodelphis emiliae	C[a]		NC		C[a]		NC		
Philander opossum	C[a]	e	NC	e	C[a]	e	15	b, e	X
Xenarthra									
Bradypodidae									
Bradypus variegatus	15	b, e	NC	e	NC	e	NC	e	X
Dasypodidae									
Cabassous unicinctus	NC	e	NC	e	NC	e	NC	e	
Dasypus kappleri	NC	e	NC	e	NC	e	NC	e	
Dasypus novemcinctus	13	e, h, j	18	e, f, h, i	14	e, f, h	28	b, e, f, h, j	X
Dasypus septemcinctus	NC	e	NC	e	NC	e	NC	e	
Euphractus sexcinctus	NC	e	NC	e	NC	e	13	e, h, j	
Priodontes maximus	NC	e	NC	e	10	e, f	13	e, h, j	X
Megalonychidae									
Choloepus didactylus	NC	e	15	c, d, e	NC	e	NC	e	
Choloepus hoffmanni	NC	e	NC	e	15	a, e	NC	e	X

Appendix 1. Continued

	San Martin-3		Cashiriari-2		Cashiriari-3		Pagoreni		Manu
Species	OI	ET	OI	ET	OI	ET	OI	ET	
Myrmecophagidae									
Cyclopes didactylus	NC	e	NC	e	NC	e	NC	e	X
Myrmecophaga tridactyla	NC	e, j	NC	e	NC	e	13	e, h, j	X
Tamandua tetradactyla	NC	e, j	NC	e	10	e, f	NC	e	X
Primates									
Callitrichidae									
Cebuella pygmaea	NC	e	NC	e	NC	e	NC	e	X
Saguinus mystax	NC	e	20	b, e, g	NC	e	NC	e	
Saguinus fuscicollis	NC	e	20	b, e, g	NC	e	NC	e	X
Saguinus imperator	15	b, e	NC	e	15	b, e	NC	e	X
Cebidae									
Alouatta seniculus	20	b, e, g	15	b, e	20	b, e, g	20	b, e, g	X
Aotus sp.	NC	e	NC	e	15	b, e	20	b, e, g	
Ateles paniscus chemek	20	b, e, g	NC	e	NC	e	10	e, g	X
Cacajao calvus	NC	e	NC	e	NC	e	NC	e	
Callicebus moloch brunneus	NC	e	NC	e	15	b, e	NC	e	X
Cebus albifrons	20	b, e, g	20	b, e, g	15	b, e	15	b, g	X
Cebus apella	20	b, e, g	20	b, e, g	15	b, e	NC	e	X
Lagothrix lagotricha	NC	e	NC	e	15	b, e	NC	e	X
Pithecia monachus	NC	e	NC	e	NC	e	15	b, e	
Saimiri sciureus boliviensis	20	b, e, g	NC	e	15	b, e	NC	e	X
Carnivora									
Canidae									
Atelocynus microtis	NC	e	14	e, f, h	NC	e	NC	e	X
Speothos venaticus	20	b, e, f	NC	e	NC	e	10	e, f	
Felidae									
Felis concolor	NC	e	23	e, f, g, h, i	NC	e	NC	e	X
Felis pardalis	18	e, f, h, i	24	b, e, f, h	18	e, f, i, j	14	e, f, i	X
Felis tigrina	C[b]	e	NC	e	C[b]	e	NC	e	
Felis wiedii	10	e, f	10	e, f	NC	e	NC	e	X
Felis yagouaroundi	NC	e	NC	e	NC	e	NC	e	X
Panthera onca	NC	e, h	23	e, f, g, h, i	14	e, f, h	14	e, f, h	X
Mustelidae									
Eira barbara	14	e, f, h	18	c, e, i, j, h	24	b, e, f, j	NC	e	X
Galictis vittata	NC		NC		C[b]		NC		X
Lutra longicaudis	NC	e	NC	e	NC	e	14	e, f, h	X
Mustela africana	NC	e	NC	e	NC	e	NC	e	
Mustela frenata	NC	e	NC	e	NC	e	NC	e	
Pteronura brasiliensis	NC	e	NC	e	NC	e	NC	e	X
Procyonidae									
Bassaricyon gabbii	NC	e	NC	e	NC	e	NC	e	X
Nasua nasua	14	e, f, j	10	e, f	NC	e	14	e, f, j	X

Appendix 1. Continued

	San Martin-3		Cashiriari-2		Cashiriari-3		Pagoreni		Manu
Species	OI	ET	OI	ET	OI	ET	OI	ET	
Potos flavus	NC	e	10	c, e	NC	e	NC	e	X
Procyon cancrivorus	10	e, f	14	e, f, j	14	e, f, j	14	e, f, h	X
Perissodactyla									
Tapiridae									
Tapirus terrestris	32	b, e, f, h, i, j	14	e, f, h	22	e, f, h, i, j	14	e, f, h	X
Artiodactyla									
Cervidae									
Mazama americana	29	b, e, f, g, h	29	b, d, e, f, h	24	b, e, f, h	15	e, f, g	X
Mazama gouazoubira	NC	e	NC	e	NC	e	NC	e	X
Odocoileus virginianus	NC	e	C[b]		C[b]	e	NC	e	
Tayassuidae									
Tayassu pecari	10	e, f	NC	e	NC	e	NC	e	X
Tayassu tajacu	33	b, e, f, g, h, j	29	c, d, e, f, g, j	33	b, e, f, g, h, j	18	e, f, h, j	X
Rodentia									
Dinomyidae									
Dinomys branickii	NC	e	NC	e	NC	e	14	e, f, j	X
Dasyproctidae									
Agouti paca	14	e, f, h	14	e, f, h	18	e, f, h, j	18	e, f, h, j	X
Dasyprocta punctata variegata	28	a, e, f, h, j	34	b, c, e, f, g, j	18	e, f, h, j	14	e, f, h	X
Myoprocta acouchy	14	e, f, j	14	e, f, j	24	b, e, f, h	14	e, f, j	X
Erethizontidae									
Coendou cf. *bicolor*	NC		NC		NC		C[b]		X
Coendou prehensilis	NC	e, j	NC	e, j	13	e, h, j	NC	e	
Hydrochaeridae									
Hydrochaeris hydrochaeris	NC	e	NC	e	NC	e	NC	e	X
Sciuridae									
Microsciurus flaviventer	20	b, e, g	20	b, e, g	15	b, e	19	b, e, j	X
Sciurus cf. *sanborni*	NC		NC		C[b]		NC		
Sciurus sp.	NC		NC		NC		C[b]		
Sciurus spadiceus	10	e, g	20	b, e, g	15	b, e	15	b, e	X
Lagomorpha									
Leporidae									
Sylvilagus brasiliensis	24	b, e, f, j	24	b, e, f, j	24	b, e, f, i	10	e, f	X
Total Species (this study)	26		25		28		26		
Total Species from all Studies	36		31		43		34		

Ectoparasites of Small Mammals of the Lower Urubamba Region, Peru

John Chavez

1 Introduction

Peru, similar to other neotropical countries, has a great diversity of mammals, particularly bats, rodents and marsupials. Bats, as pollinators and seed dispersers, play an important role in ecosystem functions, and some are known in medical epidemiology for their ability to transmit disease. Rodents spread mycorrhiza-ridden fungi, furthering the crucial association between the roots of vascular plants and specialized fungi. Rodents also help control certain species of insects that serve as a baseline of the vertebrate nutritional chain. Marsupials fill a unique niche. They are omnivores and do not compete with small rodents, which are generally herbivores, nor with medium-sized frugivorous, herbivorous and canopy rodents.

All of these mammals host a large parasite entomofauna, primarily a diverse group of arthropods that have adapted to their hosts. Many of these parasites (fleas, ticks and mites) are important as vectors of certain pathological entities that produce diseases (Gorirrossi 1950; Parker *et al*. 1954; Kohls 1955; Philip 1961; Hoogstraal 1961, 1967; Horsfall 1962; Marshall 1982).

Systematic studies of ectoparasites of these mammals in Peru are scarce. Generally, ectoparasites are described only as an aside when new species are recorded. However, there is an exciting opportunity to study these organisms and thus to increase knowledge of tropical parasite entomofauna.

This paper presents an assessment of ectoparasites identified for the Lower Urubamba Region, as well as their hosts, from the San Martin-3 and Cashiriari-2 and -3 well sites (Comiskey *et al*. this volume). Characteristics of the groups are noted, with the intention of contributing to Peruvian entomological fauna catalogs.

2 Methods

The San Martin-3 well site is located at 11°47’10" S, 72°42’05" W (elevation of 480 meters [m]) above sea level. Cashiriari-2 (11°51’51" S, 72°46’46" W) is at an elevation of 560 m. Cashiriari -3 is located at 11°52’57" S, 72°39’02" W (690 m above sea level). The sites are found in the Convencion Province of the Department of Cusco, Peru. The sites are characterized by primary forest with dense vegetation, tall trees, and an abundance of bamboo. Some samples were collected in areas of secondary forest with little bamboo and an abundance of large trees. Areas of mixed forest were also sampled.

2.1 Comparative study areas

Three areas were chosen for comparative analyses. All have been well studied with respect to certain families of ectoparasites of bats. At each, the results were obtained after a minimum of one year’s work. The areas are:

***** Tambopata National Reserve (12°51' S, 69°18' W), elevation 250 m, Department of Madre de Dios;

***** Panguana National Reserve (93°37' S, 74°65' W), elevation 220 m to 260 m, Department of Ucayali (study of the ecology of the bat community and review of the Diptera parasites); and

***** Pakitza, Manu National Park (11°56’47" S, 71°17’00" W), elevation 356 m, Department of Madre de Dios (study resulted in a preliminary list of ectoparasites of bats).

The principal materials obtained for this analysis of parasites were mammalian hosts (rodents, bats and marsupials) captured between May and June and November and December 1997 by the small mammal teams during this project. The hosts were identified at the field camps for the most part (see Dallmeier and Alonso 1997, Solari *et. al*. this volume).

The small mammal teams set traps and mist nets at each of the well sites (Solari *et al*. this volume). This ensured a broad spectrum of habitats, including bamboo forest, primary forest, transitions zones between bamboo and primary forests, large trees with small streams and terraced forest.

Once the hosts were captured, they were placed in cloth bags (bats) or plastic bags (marsupials and rodents). They remained in the bags until the following morning when they were sacrificed to facilitate sampling of parasites. The bags and traps were also checked for parasites. Parasites were removed with fine tweezers, then placed in vials of 70% alcohol. The vials were labeled with the sampling date.

3 Results and Discussion

A total of 144 rodents (16 species), 25 marsupials (nine species) and 530 chiropterans (62 species) were reviewed for ectoparasites. Of those specimens, 32.3% were infested by some type of parasite, making it possible to note qualitative and quantitative differences with respect to the capture sites (Table 1).

The most abundant hosts were bats within the Stenodermatinae and Carolliinae. *Oryzomys* spp. were the most frequent rodent hosts, while the Marmosidae were the most abundant marsupial hosts. Some species such as *Sphaeronycteris toxophyllum, Centronycteris maximiliani, Rhinophylla fischerae, Marmosa murina, Micoureus regina* and *Caluromysiops irrupta* had abundant ectoparasites with a net infestation rate of 36.9%.

In all, 209 samples of parasites were sampled and classified. They are described below (see also Appendix 1). The accumulation curve for the sampled parasites is shown in Figure 1.

Table 1. Ectoparasite families encountered in the Lower Urubamba at three sites. (+ = family recorded, **-** = family not recorded; STR = Streblidae, NYC = Nycteribiidae, SPI = Spinturnicidae, MAC = Macronyssidae, TRO = Trombiculidae, LAB = Labidocarpidae, LAE = Laelapidae, IXO = Ixodidae, ARG = Argasidae, SPE = Spelaeorhynchidae, HOP = Hoplopleuridae, STA = Staphyllinidae).

Host Orders/Site	STR	NYC	SPI	MAC	TRO	LAB	LAE	IXO	ARG	SPE	HOP	STA
Didelphimorphia												
San Martin-3	-	-	-	-	-	-	-	-	-	-	-	-
Cashiriari-2	-	-	-	-	-	-	-	-	-	-	-	-
Cashiriari-3	-	-	-	-	+	-	+	-	-	-	-	-
Rodentia												
San Martin-3	-	-	-	-	-	-	-	+	-	-	+	-
Cashiriari-2	-	-	-	-	+	-	+	-	+	-	-	-
Cashiriari-3	-	-	-	+	+	-	+	+	+	-	+	+
Chiroptera												
San Martin-3	+	+	+	+	+	+	-	+	+	-	+	-
Cashiriari-2	+	+	+	+	+	+	-	-	+	+	-	-
Cashiriari-3	+	+	+	+	+	+	-	-	+	+	-	-

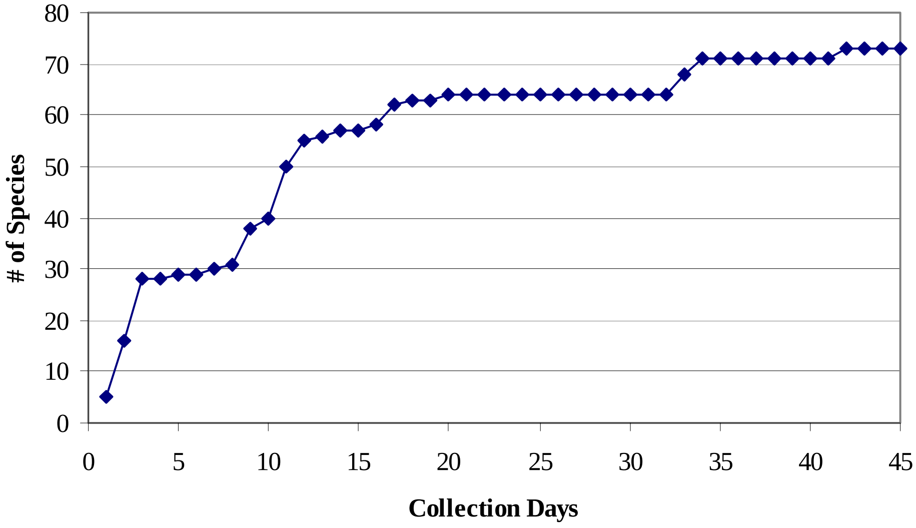

Figure 1. Species accumulation curve for ectoparasites sampled in the Lower Urubamba Region, Peru.

3.1 Class Insecta; Order Diptera

The Diptera have a pan-tropical distribution, but they can also be found in the hottest parts of temperate regions and in cold mountain zones of the tropics. There are 223 known species in five subfamilies; three of those families (147 species) are found exclusively in the New World (Guerrero 1993, 1994).

The Diptera are well known in Peru. Wenzel (1970) discussed various species in distinct localities of Peru, and Koepcke (1987) briefly referred to the group in a study on bat communities, finding that 276 of the 659 captured bats were infested, for a rate of 41.9%. Guerrero (1996a) analyzed the group, identifying many species from Pakitza, one of the richest biological zones in Peru, finding 33 species on 206 individual bats for a 48.5% rate of infestation (total of 425 captured bats).

To compare, we have captured 530 bats to date. Of those, 163 were parasitized for an infestation rate of 30.5%.

3.1.1 Family Streblidae (Kolenati 1863)

The family Streblidae contains a large group of pupiparas (blood-feeding flies) that are parasites obligated to bats. All are ectoparasites except the females of the Old World genus *Ascodipteron*; these organisms are found pinned so tightly to the skin of their hosts that they are practically endoparasites (Wenzel 1970).

This section provides some details about species in this family. For a comparison of Streblidae among four Peruvian research sites, see Figure 2.

* *Trichobius diphyllae*: Wenzel *et al.* (1966) and Guerrero (1996a) sampled this species from the bat *Diphylla ecaudata*. In the present study, only two samples were taken, initially registered as *Trichobius* sp. 1. Later analysis confirmed identification as *Trichobius diphylla* sampled from the vampire *Diphylla ecaudata*.

* *Trichobius lonchophyllae*: We sampled this species from bat *Lonchophylla thomasi* as did Guerrero (1996a).

* *Trichobius dugesii*: Orozco (1992) registered the species from the bat *Glossophaga* sp. in the Tambopata National Reserve. Guerrero (1996a) registered the species from the bat *Glossophaga soricina*. We also recorded it from *Glossophaga soricina*.

* *Trichobius longipes*: Koepcke (1987) registered the species in Panguana, having sampled it from the bats

Phyllostomus hastatus and *Phyllostomus elongatus*. Orozco (1992) registered it for the Tambopata National Reserve from the bats *Phyllostomus elongatus* and *Phyllostomus hastatus*. We recorded it from *Phyllostomus hastatus*.

* *Trichobius joblingi*: Koepcke (1987) registered it from the bats *Carollia castanea, Carollia perspicillata, Phyllostomus elongatus* and *Micronycteris megalotis*. Orozco (1992) referred to the species as a parasite from the bat *Phyllostomus elongatus* in the Tambopata zone. Guerrero (1996a) registered the species in Pakitza from the bats *Carollia brevicauda, Carollia castanea, Carollia perspicillata* and *Phyllostomus elongatus* (the material from the bat *C. castanea* is probably a new species). In this study, we registered the species from the bats *Carollia perspicillata, Carollia castanea* and *Carollia brevicauda*.

* *Trichobius* sp. 1: We registered this species three times, one of which was in a poor state, from the bat *Rhinophylla pumilio*.

* *Trichobius* sp. 2: We recorded one example of this species from the bat *Platyrrhinus brachycephalus*. It may be a new species.

* *Neotrichobius bisetosus*: Koepcke (1987) registered this species for the Panguana zone from the bat *Artibeus fuliginosus*. Guerrero (1996a) registered the species for Pakitza from the bats *Artibeus obscurus* and *Artibeus jamaicensis*. We registered the species from the bats *Artibeus obscurus* and *Artibeus planirostris.*

* *Neotrichobius delicatus*: Koepcke (1987) registered it in Panguana parasitizing the bats *Rhinophylla pumilio, Uroderma bilobatum* and *Artibeus anderseni*. Orozco (1992) recorded it from the bat *Uruderma bilobatum*. We found it on the bats *Vampyressa pusilla, Artibeus planirostris* and *Artibeus lituratus*.

* *Asidoptera falcata*: Koepcke (1987) refers to the parasite *Asidoptera delatorrei* as the most abundant on the bat *Sturnira lilium*. According to Guerrero (1994), the species *Asidoptera delatorrei* is found in the northeastern part of Venezuela and Panama, not in the Amazon. Orozco (1992) confused the register with *Asidoptera delatorrei* as a parasite from the bat *Sturnira lilium* in the Tambopata zone. Guerrero (1996a) registered the species correctly as *A. falcata* from the bat *Sturnira lilium.*

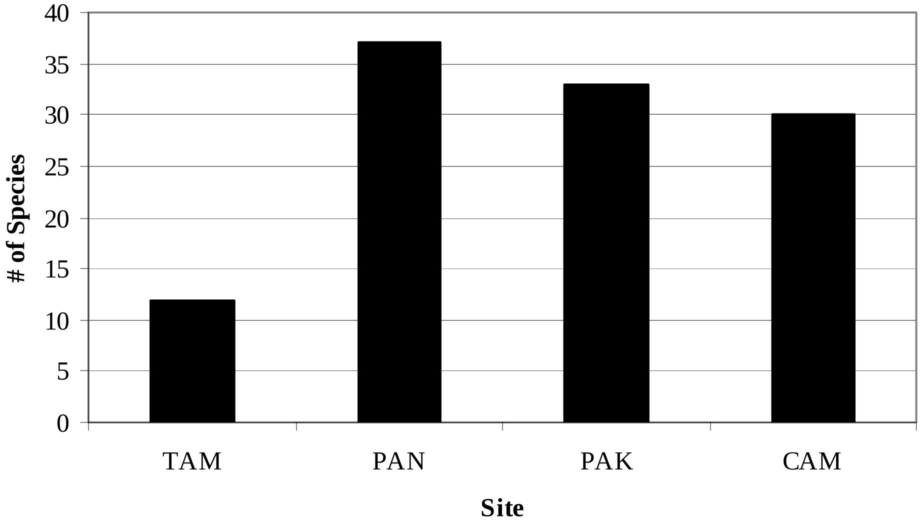

Figure 2. Comparison of Streblidae species richness among four Peruvian research sites (TAM = Tambopata National Reserve; PAN = Panguana National Reserve; PAK = Pakitza, Manu National Park; AM = Camisea).

***** *Asidoptera phyllostomatis*: Koepcke (1987) cited it as a parasite from the bats *Artibeus lituratus, Artibeus planirostris, Artibeus fuliginosus* and *Micronycteris schmidtorum*. Orozco (1992) registered it in Tambopata as a parasite from the bat *Artibeus jamaicensis*. Guerrero (1996a) registered the species in Pakitza from the bats *Artibeus jamaicensis* and *Artibeus obscurus*. This species is registered in this study from the bat *Artibeus planirostris*.

***** *Exatinion* sp. 1: We recorded one specimen from the bat *Anoura caudifer*.

***** *Megistopoda aranea*: Koepcke (1987) registered the species parasitizing the bats *Artibeus fuliginosus, Artibeus literatus* and *Artibeus planirostris* at Panguana. Guerrero (1996a) referred to the species as parasites from the bats *Artibeus jamaicensis* and *Uroderma bilobatum*. We registered it from the bats *Artibeus lituratus, Artibeus planirostris* and *Artibeus obscurus*.

***** *Megistopoda proxima*: Koepcke (1987) registered the species in Panguana from the bats *Sturnira lilium* and *Sturnira tildae*. Orozco (1992) referred to it as a parasite from the bat *Sturnira lilium* in the Tambopata National Reserve. Guerrero (1996a) registered it in Pakitza parasitzing the bat *Sturnira lilium*. We found it from the bats *Sturnira lilium, Sturnira tildae, Artibeus lituratus* and *Phyllostomus hastatus*.

***** *Paratrichobius salvini*: Koepcke (1987) uncertainly referred to it from the bat *Vampyrops helleri* (*Platyrrhinus helleri*) in Panguana. We registered it from the bat *Artibeus planirostris*.

***** *Paratrichobius dunni*: Koepcke (1987) registered the species in Panguana parasitizing the bats *Sturnira lilium* and *Uroderma bilobatum*. Guerrero (1996a) mentioned it from the bat *Uroderma bilobatum*. We recorded it from *Uroderma bilobatum* and *Artibeus planirostris*.

***** *Paratrichobius longicrus*: Koepcke (1987) in Panguana registered the species from the bat *Artibeus lituratus*, although with doubts. That is understandable given the ample distribution and range of the hosts. We recorded it from the bats *Artibeus planirostris* and *Artibeus lituratus*.

***** *Mastoptera minuta*: Koepcke (1987) registered the species in Panguana coming from the bats *Tonatia brasiliense* and *Phyllotomus hastatus*. Orozco (1992) registered the species as a parasite from the bats *Phyllostomus hastatus, Phyllostomus elongatus, Tonatia silvicola* and *Carollia brevicauda*. We found it from *Phyllostomus hastatus*.

***** *Anatrichobius scorzai*: We found this species on *Myotis riparius* and *Myotis* sp. 1.

***** *Speiseris ambigua*: Koepcke (1987) registered the species for Panguana on the bat *Carollia perspicillata*. Guerrero (1996a) registered the species in Pakitza as a parasite from the bats *Carollia perspicillata, Carollia brevicauda* and *Trachops cirrhosus*. We recorded it on the bats *Carollia perspicillata* and *Carollia brevicuada*.

***** *Speiseria peytonae*: Guerrero (1996a) registered it in Peru for the first time at Pakitza parasitizing the bat *Carollia brevicauda*. We also found it on *Carollia brevicauda.*

***** *Speiseria* sp. 1: We recorded two samples of this species from the vampire *Diphylla ecaudata*. Morphological characteristics made it possible to catalog the samples in this genera.

***** *Paradyschiria* sp. 1: We recorded one example from the skin of a *Promops centralis* bat.

***** *Pseudostrebla riberoi*: Guerrero (1996a) registered the species in Pakitza from the bat *Tonatia silvicola*; we also found it on that host.

***** *Metelasmus pseudopterus*: Koepcke registered the species in Panguana from the bats *Artibeus literatus* and *Artibeus planirostris*. Guerrero (1996a) found it at Pakitza parasitizing the bat *Artibeus jamaicensis*. We recorded it on *Artibeus lituratus* and *Platyrrhinus brachycephalus*.

***** *Strebla kohlsi*: Guerrero (1996a) registered the species in Pakitza as a parasite from the bats *Tonatia silvicola* and *Phylloderma stenops*. We found it parasitizing the *Tonatia silvicola* bat.

***** *Strebla guajiro*: Koepcke (1987) registered the species on the bats *Carollia perspicillata* and *Carollia castanea*. Guerrero (1996a) registered it in Pakitza on *Carollia brevicauda* and *Carollia perspicillata* bats. We also found it on those two bats.

***** *Strebla alvarezi*: Guerrero (1996a) registered it for the first time in Peru at Pakitza on the *Lonchophylla thomasi*. We also sampled it from that host.

***** *Strebla* cf. *consocia*: Koepcke registered it on *Phyllostomus hastatus* and *Phyllostomus elongatus* in Panguana. Orozco (1992) registered it in Tambopata on *Phyllostomus elongatus*. Guerrero (1996a) registered it in Pakitza from *Phyllostomus hastatus* and *Phyllostomus elongatus*. We obtained four samples from *Phyllostomus hastatus*; more sampling is needed for final determination.

***** *Strebla mirabilis*: Koepcke (1987) registered the species in Panguana on *Trachops cirrhosus* and *Phyllostomus hastatus*. Orozco (1992) recorded it in Tambopata from the bat *Phyllostomus elongatus*. Guerrero (1996a) sampled it in Pakitza from the bats *Trachops cirrhosus* and *Phyllostomus elongatus*. It is registered in the study area from *Phyllostomus hastatus* and *Diphylla ecaudata*.

3.1.2 Family Nycteribiidae (Samouelle 1819)

This family of hematophagous dipterans primarily parasitizes insectivorous bats, although they can also parasitize certain species of frugivorous bats (Phyllostomidae). These dipterans are less frequent than the streblids (Guerrero 1996b). In Peru, the Nycteribiidae have been known since the revision of taxa done by Guimaraes and D'andretta (1956). But only a few works refer to them, most notably Koepcke's study (1987) of bat communities; the chapter on parasites touches on various species of this family. Guerrero (1996c) also cited this group in his study of parasites of bats in Pakitza, although he registered no samples, implying a preliminary study.

We recorded the following species:

***** *Basilia myotis*: It was registered in the study area parasitizing the insectivorous bat *Myotis riparius*.

***** *Basilia* cf. *peruvia*: Koepcke (1987) refers to the species at Panguana as a parasite of the bat *Myotis nigricans*. We registered it as a parasite of the same host, although we need to gather more data for confirmation.

***** *Basilia* cf. *anceps*: Koepcke (1987) registered the species on *Myotis nigricans* at Panguana. We took it from the bat *Myotis* sp. 1. More material is needed for final determination.

***** *Basilia* cf. *manu*: Guerrero (1994) found this species at Pakitza parasitizing the insectivorous bat *Myotis riparius*. We sampled the same host, but additional material is needed for a final determination.

***** *Basilia* sp. 1. We sampled two examples from the insectivorous bat *Myotis* sp 1. Sufficient evidence does not exist to classify the species.

***** *Hershkovitzia* sp. 1. Of the three examples we gathered (from the rare bat *Thyroptera lavali*), one was in poor condition. This circumstance leads to the possibility of a new species. Additional sampling is required.

3.2 Class Acarina; Order Acarina

This worldwide order contains a large variety of parasites exclusive to bats. In the neotropics, the genus *Periglischrus* is closely associated with bats of the Phyllostomidae family. Two additional genera in the neotropics are *Cameronieta* and *Spinturnix*.

Guerrero (1996c) cites this group, but contains no references to registered species. There are no other studies for this group, so it is not possible to do a comparative analysis.

3.2.1 Family Spinturnicidae (Oudemans 1902)

We registered the following species of this family: *Periglischrus iheringi, Periglischrus caligus, Periglischrus ojastii, Periglischrus* cf. *tonatii, Periglischrus acutisternus, Periglischrus* cf. *torrealbai, Periglischrus* cf. *iheringi* and *Spinturnix* sp. 1.

3.2.2 Family Argasidae (Canestrini 1890)

This family encompasses soft-bodied ticks that infect diverse vertebrates, including humans and other primates, rodents, bats, canines, felines, birds and some reptiles. This tick is frequently found on bats. Guerrero (1996c) cites the family as a bat parasite at Pakitza where he obtained about 300 species, primarily from the bat *Noctilio albiventris*.

We sampled *Ornithodoros* sp. 1, from the bats *Artibeus lituratus* and *A. obscurus*. Additional material must be gathered for a final determination.

3.2.3 Family Ixodidae (Murray 1877)

This broad group of ticks is characterized by a dorsal shield that covers the surface of the male but only the anterior part of the dorsal surface of the female. Most of these ticks live on their hosts from the immature stage through the mature stage. They have a broad range of hosts, including rodents, primates, canines, felines, marsupials and, to a lesser degree, bats.

In this study, we sampled the following species:

***** *Amblyomma* sp. 1: Adults, nymphs and larva of this genus were sampled from diverse hosts such as the rodents *Proechimys semispinosus, Oryzomys macconnelli* and *Oryzomys nitidus* and the bat *Phyllostomus hastatus*.

***** *Ixodes* cf. *luciae*: We sampled 18 examples, primarily nymphs, from the rodents *Oryzomys nitidus* and *Proechimys* sp. 1.

***** *Ixodes* sp. 1: We sampled adults and nymphs from the rodents, *Nectomys squamipes, Proechimys* sp. 1 and *Rhipidomys* sp. 1.

3.2.4 Family Spelaeorhynchidae (Oudemans 1902)

This group contains exclusively bat parasites. Individuals of the group can be confused with ticks as happened in the original description. Known distribution includes Puerto Rico, Cuba, Mexico, Dominican Republic, Guatemala, Colombia, Venezuela and Brazil.

We sampled two examples of *Spelaeorhynchus* sp. 1 from the bat *Carollia perspicillata*, although additional samples are necessary for precise determination. This appears to be the first register for the species in Peru.

3.2.5 Family Laelapidae

A total of 21 of these mites were sampled from the rodents *Oryzomys nitidus, Oryzomys* sp. 1, *Oecomys* sp. 1, *Nectomys squamipes* and *Rhipidomys* sp. 1. The three species recorded have not yet been identified.

3.3 Class Insecta; Order Siphnaptera

The Siphnaptera are ticks that are well known around the world. They can act as vectors of microorganisms (bacteria, virus, etc.) or can transmit immature-stage worms to the host. While these parasites have a wide range of hosts, they are found principally on mammals.

3.3.1 Family Rhopallopsyllidae

We sampled the following species from this family: *Rhopallopsyllus* sp. 1, *Polygenis* cf. *roberti, Polygenis* cf. *occidentalis* and *Polygenis* sp. 1.

3.3.2 Family Pulicidae

We sampled *Xenopsylla cheopis* from the rodents *Oryzomys* sp. 1,*Proechimys semispinosus, Proechimys* sp. 1 and *Oryzomys nitidus*. This species is very important in that it is a vector of the bubonic plague in many areas where it is found.

3.4 Class Insecta; Order Anoplura

These parasites are known as bloodsuckers. Like fleas, they are apterous (wingless) insects. They are vectors for diseases such as typhus, recurring fevers, bacterial infections and, often, irritated skin. They suck blood and cutaneous fluids from their hosts, which are primarily mammals, including humans.

3.4.1 Family Hoplopleuridae (Ewing 1929)

We registered the following species from this family (all samples were taken from the rodents (*Proechimys* sp. 1, *Nectomys squamipes,* and *Rhipidomis* sp. 1): *Hoplopleura* cf. *splendida, Hoplopleura* cf. *quadridentata* and *Hoplopleura* sp. 1.

3.5 Class Insecta; Order Coleoptera

3.5.1 Family Staphyllinidae

This family contains unusual species that can live freely or parasitically, as is the case for the samples taken in this study. Staphyllinid parasites of rodents have life cycles that are influenced by ecological factors. For the most part, it is believed these parasites are restricted to mountain zones and habitats with cold temperatures and climates. Only a few species seem to have adapted to dry, warmer climates. *Amblyopinus gahani* is the only species found in subaquatic habitats.

In this study, just one example was taken (Genus unknown). It did not conform to all rules of this special group, being rare and peculiar with respect to its host. This is a good example for additional research of the parasites in the study region.

3.6 Recommendations

In general, we recommend that the considerable value of parasitic systems in the study area be taken into account. Parasites are extremely useful for establishing phylogenetic relations of their hosts. In many cases, they also permit confirmation or refutation of registers and records of distribution.

For these reasons, we recommend that parasitologists be part of the field teams. They can sample and maintain parasitological material for later analysis in the laboratory.

We also recommend that the mammal teams find a means other than rat traps for sampling rodents. Often, the captured individuals are left (dead) overnight, which causes the loss of parasitic material because the parasites will abandon dead hosts.

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Appendix1. Ectoparasites recorded in the Lower Urubamba Region, Peru.

Family Streblidae
- *Trichobius diphyllae* Wenzel *et al*. 1966
- *Trichobius lonchophyllae* Wenzel *et al*. 1966
- *Trichobius dugesii* Townsend 1891
- *Trichobius longipes* Rudow 1871
- *Trichobius joblingi* Wenzel *et al*. 1966
- *Trichobius* sp.1
- *Trichobius* sp. 2
- *Neotrichobius bisetosus* Wenzel 1976
- *Neotrichobius delicatus* Machado-Allison 1966
- *Asidoptera falcata* Wenzel 1976
- *Asidoptera phyllostomatis* Perty 1833
- *Exatinion* sp. 1
- *Megistopoda aranea* Coquillet 1899
- *Megistopoda proxima* Seguy 1926
- *Paratrichobius salvini* Wenzel *et al*. 1966
- *Paratrichobius dunni* Curran 1935
- *Paratrichobius longicrus* Miranda-Ribeiro 1907
- *Mastoptera minuta* Costa- Lima 1921
- *Anatrichobius scorzai* Wenzel *et al*. 1966
- *Speiseria ambigua* Kessel 1925
- *Speiseria peytonae* Wenzel 1976
- *Speiseria* sp. 1
- *Paradyschiria* sp. 1
- *Pseudostrebla riberoi* Costa- Lima 1921
- *Metelasmus pseudopterus* Coquillet 1907
- *Strebla kohlsi* Wenzel *et al*. 1966
- *Strebla guajiro* Garcia and Casal 1965
- *Strebla alvarezi* Wenzel *et al*. 1996
- *Strebla* cf. *consocia* Wenzel *et al*. 1966
- *Strebla mirabilis* Waterhouse 1879

Family Nycteribiidae
- *Basilia myotis* Curran 1935
- *Basilia* cf. *peruvia* Guimaraes and D’andretta 1956
- *Basilia* cf. *anceps* Guimaraes and D’andretta 1956
- *Basilia* cf. *manu* Guerrero 1994
- *Basilia* sp. 1
- *Hershkovitzia* sp. 1

Family Spinturnicidae
- *Periglischrus iheringi* Oudemans 1902
- *Periglischrus caligus* Kolenati 1857
- *Periglischrus ojastii* Machado-Allison 1964
- *Periglischrus* cf. *tonatii* Herrin and Tipton 1975
- *Periglischrus acutisternus* Machado-Allison 1964
- *Periglischrus* cf. *torrealbai* Machado-Allison 1964
- *Periglischrus* cf. *iheringi* Oudeman 1902
- *Spinturnix* sp. 1

Family Staphyllinidae
- Genus unknown 1

Family Macronyssidae
- *Macronyssoides* sp. 1
- *Steatonyssus* sp. 1
- *Parichoronyssus* sp. 1
- Genus unknown 1
- Genus unknown 2

Family Labidocarpidae
- Genus unknown 1
- Genus unknown 2
- Genus unknown 3

Family Trombiculidae
- *Odontacarus* sp. 1
- *Hooperella* sp. 1
- *Paracesia* sp. 1
- *Eutrombicula* cf. *alfreddugesi*
- *Eutrombicula* sp.
- *Eutrombicula geoldii*
- *Eutrombicula* cf. *geoldii*
- *Odontocarus* sp. 1

Family Argasidae
- *Ornithodoros* sp. 1

Family Ixodidae
- *Ixodes cf. luciae* Senevet (1940)
- *Ixodes* sp. 1
- *Amblyomma* sp. 1

Family Spelaeorhynchidae
- *Spelaeorhynchus* sp. 1

Family Rhopallopsyllidae
- *Rhopallopsyllus* sp. 1
- *Polygenis* cf. *roberti* Machiavello 1948
- *Polygenis* cf. *occidentalis* Johnson 1957
- *Polygenis* sp. 1

Family Pulicidae
- *Xenopsylla cheopis* Rothschild 1903

Family Hoplopleuridae
- *Hoplopleura* cf. *splendida* Johnson 1972
- *Hoplopleura* cf. *quadridentata* Ferris 1916
- *Hoplopleura* sp. 1

Family Laelapidae
- Genus unknown 1
- Genus unknown 2
- Genus unknown 3