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INSTITUTIONAL PROFILES

The Field Museum

The Field Museum is a collections-based research and educational institution devoted to natural and cultural diversity. Combining the fields of Anthropology, Botany, Geology, Zoology, and Conservation Biology, museum scientists research issues in evolution, environmental biology, and cultural anthropology. Environmental and Conservation Programs (ECP) is the branch of the museum dedicated to translating science into action that creates and supports lasting conservation. Another branch, the Center for Cultural Understanding and Change, works closely with ECP to ensure that local communities are involved in conservation in positive ways that build on their existing strengths. With losses of natural diversity accelerating worldwide, ECP's mission is to direct the museum's resources—scientific expertise, worldwide collections, innovative education programs—to the immediate needs of conservation at local, national, and international levels.

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Gobierno Regional de Loreto (GOREL)

The Regional Government of Loreto (GOREL) is a judiciary entity representing the will of the public. It has political, economic and administrative autonomy and receives a designated budget as established in Article 191 of the Peruvian Constitution and Article 2 of Law 27867. The scope of its jurisdiction is delineated by the current boundaries of the department of Loreto and its headquarters are in the city of Iquitos.

GOREL's mission is to govern democratically and achieve an integrated development in the region, in agreement with national, sectorial, and regional policies. Together with other public institutions and private investments, GOREL implements and promotes programs, projects, and action towards the goal of generating economic well-being and to improve the living standards of the population.

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Organizacion Regional AIDESEP-Iquitos (ORAI)

The Regional Organization AIDESEP-Iquitos (ORAI) is registered publicly in Iquitos, Loreto. This institution consists of 13 indigenous federations, and represents 16 ethnic groups located along the Putumayo, Algodón, Ampiyacu, Amazonas, Nanay, Tigre, Corrientes, Marañón, Samiria, Ucayali, Yavarí, and Tapiche Rivers in the Loreto region.

The mission of ORAI is to ensure communal rights, to protect indigenous lands, and to promote an autonomous economic development based on the values and traditional knowledge that characterize indigenous society. In addition, ORAI works on gender issues, developing activities that promote more balanced roles and motivate the participation of women in the communal organization. ORAI actively participates in land titling of native communities, as well as in working groups with governmental institutions and the civil society for the development and conservation of the natural resources in the Loreto region.

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Herbario Amazonense de la Universidad Nacional de la Amazonía Peruana

The Herbario Amazonense (AMAZ) is situated in Iquitos, Peru, and forms part of the Universidad Nacional de la Amazonía Peruana (UNAP). It was founded in 1972 as an educational and research institution focused on the flora of the Peruvian Amazon. In addition to housing collections from several countries, the bulk of the collections showcase representative specimens of the Amazonian flora of Peru, considered one of the most diverse floras on the planet. These collections serve as a valuable resource for understanding the classification, distribution, phenology, and habitat preferences of plants in the Pteridophyta, Gymnospermae, and Angiospermae. Local and international students, docents, and researchers use these collections to teach, study, identify, and research the flora, and in this way the Herbario Amazonense contributes to the conservation of the diverse Amazonian flora.

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Museo de Historia Natural de la
Universidad Nacional Mayor de San Marcos

Founded in 1918, the Museo de Historia Natural is the principal source of information on the Peruvian flora and fauna. Its permanent exhibits are visited each year by 50,000 students, while its scientific collections—housing a million and a half plant, bird, mammal, fish, amphibian, reptile, fossil, and mineral specimens—are an invaluable resource for hundreds of Peruvian and foreign researchers. The museum's mission is to be a center of conservation, education and research on Peru's biodiversity, highlighting the fact that Peru is one of the most biologically diverse countries on the planet, and that its economic progress depends on the conservation and sustainable use of its natural riches.
The museum is part of the Universidad Nacional Mayor de San Marcos, founded in 1551.

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Our inventories are a massive collaborative effort, and we extend our deepest gratitude to everyone who helped us make the inventory in Nanay-Mazán-Arabela a great success. This was our fourth inventory in Loreto, and our first collaboration directly with Loreto's regional government (GOREL). We deeply thank Nélida Barbagelata for inviting us to do the inventory and for her profound commitment to conservation in Loreto. Similarly, we are extremely grateful to José "Pepe" Álvarez for his tireless conservation efforts in Peru, and his work in launching the regional conservation program in Loreto. Without Nélida, Pepe, and GOREL, this inventory would have been impossible.

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Logistically, this inventory was an enormous challenge. Our deepest gratitude goes to the Peruvian National Police (PNP), and especially Coronel Dario "Apache" Hurtado, Suboficial Roger "Checoni" Conislla, and Comandante Oscar "Orca" Roca. Over the last five years, the PNP has been instrumental in our inventories in Peru, getting us to remote corners in their helicopters. We also received generous help from the Ejército Peruano. We extend our deepest thanks to General Miranda and Mayor Pimentel from Lima, and Comandante Alva and Mayor Nacarino in Curaray, who went above and beyond to help us in our transportation needs.

Our advance team had to overcome several obstacles. Ítalo Mesones, Álvaro del Campo, and Marcos Ramírez led different teams into the field and established three campsites and trail systems. The teams rallied hard to pull the inventory together, and it is thanks to their dedication and hard work that the biological and social teams were able to be effective in the field. Ítalo Mesones deserves special recognition for persevering against incredible odds and establishing not one, but two full campsites and getting us exactly where we needed to be to visit the drainage divide and explore the highest reaches of the headwaters.

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First and foremost, the social inventory team is grateful to the residents of the eleven communities we visited for their generous hospitality and willingness to share their knowledge and experiences with us. We also thank the members of the sub-sector of the Regional Government in Santa Clotilde for their logistical support during the inventory, including the use of their motor boat.
We thank the Fathers of the Santa Clotilde Vicariate for their warm hospitality and their insights on the region's economic and political context. We are grateful to the Parroquia of Santa Rosa de Mazán for housing us at the parrish, for accompanying us on our visits to the Mazán communities, and for facilitating contacts with members of AIDEPEMPROFORMA. Abel and Norma Chávez of AIDEPEMPROFORMA accompanied us on our visits and patiently shared the history of their organization's efforts. In Iquitos we received great assistance from the Regional Government's technical departments as well as the Defensoría del Pueblo, the National Statistics Institute, and the Ministry of Agriculture.

Everyone on the inventory team is grateful to Dr. Vicente Vásquez. When we came out of the field, several members of the team came down with dengue and malaria, and he helped diagnose their illnesses and reassured us all with his bedside manner. Tyana Wachter served as an endlessly giving nurse to all who needed help.

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Finally, we extend our gratitude to the Gordon and Betty Moore Foundation for financial support of the inventory.

The goal of rapid biological and social inventories is to catalyze effective action for conservation in threatened regions of high biological diversity and uniqueness.

Approach

During rapid biological inventories, scientific teams focus primarily on groups of organisms that indicate habitat type and condition and that can be surveyed quickly and accurately. These inventories do not attempt to produce an exhaustive list of species or higher taxa. Rather, the rapid surveys (1) identify the important biological communities in the site or region of interest, and (2) determine whether these communities are of outstanding quality and significance in a regional or global context.

During social asset inventories, scientists and local communities collaborate to identify patterns of social organization and opportunities for capacity building. The teams use participant observation and semi-structured interviews to evaluate quickly the assets of these communities that can serve as points of engagement for long-term participation in conservation.

In-country scientists are central to the field teams. The experience of local experts is crucial for understanding areas with little or no history of scientific exploration. After the inventories, protection of natural communities and engagement of social networks rely on initiatives from host-country scientists and conservationists.

Once these rapid inventories have been completed (typically within a month), the teams relay the survey information to local and international decisionmakers who set priorities and guide conservation action in the host country.

REPORT AT A GLANCE

Dates of Field Work

Biological Team: 15–30 August 2006
Social Team: 15–29 August 2006

Region

Province of Loreto, northwestern Peruvian Amazon, near the border with Ecuador. Nanay-Mazán-Arabela (N-M-A) Headwaters lie south of the Curaray and Arabela rivers and north of the Tigre and Pucacuro rivers. A mosaic of land-uses surrounds the area: the Pucacuro Reserve Zone to the south and southwest, the proposed Territorial Reserve Napo-Tigre to the west, the proposed Comunal Reserve Napo-Curaray to the north, and forestry concessions to the east.

Fig. i. Map of the region showing original and current proposals for Nanay-Mazán-Arabela Headwaters.

All of the data and summaries for the biological inventory reflect the original proposal of 136,005 ha (Fig. 2A, i); therefore, the biological results represent a conservative measure of the diversity in the current proposal of 747,855 ha (Fig. 2A). The social inventory results are relevant for both proposals, irrespective of their size.

Inventories

Biological focus: Geology, hydrology, vascular plants, fishes, reptiles and amphibians, birds, large mammals, and bats.

The biological team visited 3 sites, one in each watershed (Mazán, Nanay, Arabela).

- Mazán: Alto Mazán, 15–20 August 2006
- Nanay: Alto Nanay, 21–24 August 2006
- Arabela: Panguana, 25–30 August 2006

Social focus: Cultural and social assets including organizational strengths and resource use and management.

The social team visited 11 communities in three watersheds (Arabela, Curaray, Mazán).

- Arabela (2 communities): Flor de Coco and Buena Vista, 18–19 August 2006
- Curaray (5 communities): Bolivar, San Rafael, Santa Clotilde, Shapajal, and Soledad, 16–17 and 20–24 August 2006
- Mazán (4 communities): Puerto Alegre, Santa Cruz, Libertad, and Mazán, 29 August 2006

Principal biological results

N-M-A Headwaters are spectacularly diverse (Table 1). Habitats vary broadly across the landscape, and range from white sand patches to hilly areas that represent the eastern most extension of the Ecuadorian Andes. The highest of these hills (270 m) is a drainage divide for three regionally important rivers: Nanay, Mazán, and Arabela. Below we summarize the biological highlights.

Table 1. Species richness in each inventory site for all organisms surveyed; total richness across inventory sites; and richness estimates for the Nanay-Mazán-Arabela Headwaters region.

Organismal group	Alto Mazán	Alto Nanay	Panguana	Inventory total	Regional richness
Plants	600	800	1000	1200	3000–3500
Fishes	92	78	56	154	240
Amphibians	25	26	31	53	80–100
Reptiles	20	12	26	36	60–80
Birds	271	221	297	372	500
Large Mammals*	29	17	31	35	59

* Bats (20 species found during the inventory) not included.

REPORT AT A GLANCE

Principal biological results (continued)

Geology and Hydrology: Three formations (Pevas, Unit B, Unit C) meet in the N-M-A Headwaters region, creating a rich geological mosaic. Natural erosion is extensive along river and stream edges. Any artificial increase in erosion (deforestation, mining, intensive agriculture, oil extraction) would result in a catastrophic impact with heavy sedimentation throughout the watershed.

Vegetation: Vegetation varies broadly across the region, from stunted trees growing on white sands to tall forests growing on clay hills. In the Arabela headwaters, we found floodplain species growing on hilltops (Fig. 5E), an odd locale for species that colonize open areas. We speculate that these pioneer species may have colonized hilltops after agriculture was abandoned 400–500 years ago. Natural disturbances (tree-fall gaps, erosion) appear to be more common here than elsewhere in Amazonia.

Plants: Botanists found ~1,200 species, including 3 new plant species for Peru, and 5 species almost certainly new to science. Valuable timber species are nearly absent from the region. However, lesser-known timber species are abundant, and if markets for these species expand, the resulting deforestation would be immense (60% of forest cover).

Fishes: The region's 154 species include fishes that are new to science or new for Peru (13), rare or range-restricted (6), valuable as ornamentals (10), or important in local food markets (5). Headwater areas are a critical source of nutrients for downstream aquatic communities; any disturbance upstream will cascade through the food web.

Amphibians and Reptiles: Herpetologists registered 53 species of amphibians, including 2 species new to science, 3 rare species, and an abundant population of an *Atelopus* frog (Fig. 7C) critically threatened elsewhere. Reptiles were similarly diverse (36 species) and included a new record for Loreto and a species potentially new to science. Local drought and sedimentation, provoked by deforestation, would reduce stream quality and availability and severely impact the majority of the herpetofauna.

Birds: The region's diverse bird community (372 species) is dominated by terra firme species. Highlights include a specialist avifauna (12 species) associated with rare, white-sand habitats, and 6 foothill species typically associated with the Andes. Guans (*Penelope* and *Crax*) are abundant, suggesting the area provides an important refuge for game birds.

Mammals: Regional primate diversity (11 species) is high, and includes a range-restricted species of monk-saki (*Pithecia*, Fig. 9C). Currently, commercial hunting threatens mammal populations in the upper Mazán River, as evidenced by hunting parties traveling along the river (Fig. 4C), lower mammal densities at this site, and apprehensive behavior in observed animals. In contrast, the upper reaches of the Nanay and Arabela rivers appear to provide an important refuge for local fauna. Human settlements along the Mazán, Arabela, and Curaray rivers are small communities (70–300 inhabitants) with a subsistence lifestyle that relies on forest resources, small-scale agriculture, and local commerce (Fig.10D). We found great social strengths and responsible natural resource use within these human communities, providing promising avenues for local management and conservation (Table 2).

Table 2. Overview of social assets and natural resource use in 11 communities visited during the social inventory in the Mazán, Arabela, and Curaray watersheds.

Watersheds	Mazán	Arabela	Curaray
Communities	Puerto Alegre Libertad Santa Cruz Mazán	CN* Buena Vista CN Flor de Coco CN Soledad CN San Rafael Santa Clotilde	CN Shapajal CN Bolívar
Overview	▪ A self-sufficient lifestyle predominates, largely compatible with environmental conservation. ▪ However, the last decade has seen greatly increased integration into commercial markets (timber as well as others) by native communities in the Arabela and Curaray rivers as well as the *ribereño* (riverine) communities along the Mazán River.		
Social assets	▪ A work ethic based on communal values ▪ Barter economy ▪ Organizations dedicated to management of natural resources ▪ Links between parish and communities that facilitate communication and management ▪ Family networks that support social cohesion ▪ River-based flows of information, commerce, and health care among communities ▪ Revitalization of cultural identity (including indigenous languages)		
Natural resource use	▪ Subsistence economy with relatively low levels of extraction ▪ Small semi-diversified agricultural plots (on average, 0.5–1 ha) ▪ Medicinal plant knowledge and use ▪ Some communities regulate commercial extractive use by outsiders		

Note: Communities on the Nanay River, although not visited during the social inventory, are involved in integrated management efforts in collaboration with the Instituto de Investigaciones de la Amazonía Peruana (IIAP) in Iquitos. The collaborative work along the Nanay would provide a model for working with local communities in the rest of the region.

*CN = Comunidad Nativa

REPORT AT A GLANCE

Principal threats

Although N-M-A Headwaters is in a remote corner of Peru, rivers provide access to the entire area. Without a coherent plan for local conservation and management of the area, the biological and human communities will become increasingly threatened (Figs. 4A–C).

Biological communities are threatened by:

01 **Commercial activities that increase erosion.** Deforestation created by extractive industries (timber, oil, mining), coupled with the already high natural levels of erosion in N-M-A Headwaters, would drastically increase river sedimentation within the entire watershed.

02 **Intensive commercial hunting and fishing.** Unregulated, large-scale hunting and fishing is not sustainable in the long term. Demand in Iquitos overwhelmingly drives the bushmeat trade.

03 **Contamination.** Mining and oil operations pose an enormous threat to water quality for local residents and local fauna, especially fishes.

Human communities are threatened by:

01 **Commercial activities that create social upheaval.** Historically, commercial resource extraction in Amazonia (e.g., rubber, gold, oil) follows a boom and bust cycle. These cycles destabilize local social networks and accelerate cultural erosion.

02 **Incomplete information during negotiations with commercial interests.** Communities are uninformed about their rights vis-à-vis commercial industries interested in extracting resources from their territories. Often, this leads to skewed decision-making. Moreover, commercial industries will negotiate directly with individuals in rural and indigenous communities, creating internal conflict and division.

03 **Excessive extraction.** Commercial hunting and fishing deplete game species that local people depend on for subsistence.

04 **Lack of a regional land-use plan.** N-M-A Headwaters harbor great biological diversity and are surrounded by communities motivated to conserve this diversity and their own livelihoods. However, oil concessions cover most of Loreto, including N-M-A Headwaters. A land-use plan would balance the importance of preserving biological and cultural diversity with the demand for large-scale resource extraction. These issues must be resolved at a regional scale.

Antecedents and current status	In March 2004, Loreto's regional government (Gobierno Regional de Loreto, GOREL) excluded 24 timber concessions from the Mazán headwaters (Regional Ordinance 003-2004-CR/GRL; 136,005 ha, Fig. 2A). In March 2006, GOREL invited The Field Museum to lead a rapid biological and social inventory to provide technical support for protecting this fragile region. All of the biological results reflect the original proposal of 136,005 ha (Fig. i). After the inventory in August 2006, the team presented preliminary results to GOREL in Iquitos. Based on the inventory results, GOREL proposed to protect the entire N-M-A Headwaters—including the Nanay headwaters—within the new regional conservation system managed by a new program (Programa de Conservación, Gestión, y Uso Sostenible de la Biodiversidad Biológica de la Región Loreto, PROCREL). The proposal (747,855 ha, Fig. 2A) is now awaiting review and approval by the Board of Ministers (Consejo de Ministros).
Principal recommendations for protection and management	01 **Establish a Regional Conservation Area (Área de Conservación Regional) of 747,855 ha that includes the upper Nanay River (Fig. 2A).** The area should be implemented and managed by PROCREL, and coordinated with the adjacent protected area (Zona Reservada Pucacuro) and adjacent, proposed protected areas (Reserva Territorial Napo-Tigre, Reserva Comunal Napo-Curaray). 02 **Restrict intensive commercial use in the fragile N-M-A Headwaters.** 03 **Support the proposed Nanay-Pucacuro Corridor.** The proposed Regional Conservation Area Nanay-Mazán-Arabela is a key piece of this corridor. 04 **Fully integrate local residents and appropriate local organizations in the protection of the area.** 05 **Create a buffer zone for the proposed Regional Conservation Area.** 06 **Create a zoning plan for the proposed Regional Conservation Area and its buffer zone.** 07 **Implement capacity-building, environmental education, and communication programs for local residents.**
Long-term conservation benefits	01 **Guaranteed water quality and supply** for rural and urban populations (including Iquitos) 02 **Integrity of the river network** (Nanay, Mazán, Napo) that supports regional transit and commerce 03 **Protection of fundamental resources** (waterways, forests) that are critical to maintaining stable fish populations (including economically valuable species)

REPORT AT A GLANCE

Long-term conservation benefits (continued)

04 **Established refuge** in Loreto, to mitigate fauna and flora depletion elsewhere

05 **Ensured well-being of communities** along the Nanay, Mazán, Arabela, and Curaray rivers in their subsistence lifestyles

Why Nanay-Mazán-Arabela Headwaters?

Close to the border with Ecuador, a group of headwater streams originate along a small divide in the lowlands. These headwaters give rise to three of the most important rivers in Loreto—the Arabela, Mazán, and Nanay—and provide clean water for the more than 400,000 residents of the capital city of Iquitos. This is the area (747,855 ha) we call "Nanay-Mazán-Arabela Headwaters."

The three watersheds are characterized by distinct geologies, with elements of the ancient Pevas formation occurring alongside Andean formations. The geological diversity begets a tremendous biological diversity that ranges from stunted forest growing on white sands to tall, rich forests growing on clay hills, and includes rare and range-restricted species as well as species better known from the Andes.

The headwaters form part of the proposed biological corridor Nanay-Pucacuro, an area harboring spectacular biodiversity and rich in endemic species. In its entirety, this corridor protects a representative sample of Loreto's diversity, ensures habitat connectivity for migratory species or species with large home ranges, provides a refuge for flora and fauna threatened in areas with more intensive use in Loreto, and engenders source populations of flora and fauna for adjacent areas where resources are used more intensively by local residents.

Local indigenous and riverine populations rely on a barter economy with small-scale extraction of natural resources. Several organizations already exist that promote sustainability and limit excessive extraction by outsiders. With appropriate guidelines, current levels of use could be compatible with conservation of the area.

In the Arabela River and its tributaries, there is substantial evidence of indigenous people living in voluntary isolation. These people represent essential elements of the cultural patrimony of Peru, and their populations are extremely sensitive to disturbance and disease.

N-M-A Headwaters is highly susceptible to disturbances, with its soils currently experiencing nearly continuous natural erosion. Any activity that increases erosion rates would drastically increase river sedimentation, destroying aquatic habitats and fisheries, and damaging water quality within the entire watershed.

The headwaters of nearly all other important rivers in Loreto originate in Ecuador or Colombia, such that decisions in these countries dictate the fate of most of Loreto's watersheds. In contrast, the headwaters of the Nanay, Mazán, and Arabela rivers originate in Peru, creating a singular opportunity for the *Gobierno Regional de Loreto* (GOREL) to manage the area in an integrated manner, ensuring the sustainability of water, timber, and fish resources in the watershed, and the well-being of the region.

Conservation Targets

The following species, forest types, and ecosystems are of particular conservation concern in Nanay-Mazán-Arabela Headwaters. Some are important because they are threatened or rare elsewhere in Peru or in Amazonia; others are unique to this area of Amazonia, key to ecosystem function, important to the local economy, or important for effective long-term management.

Biological and Geological Communities	▪ Complex geology and associated poor-to-rich soils developed within the only large headwater region north of the Amazon and outside of the Andes ▪ A unique combination of soils and elevations over 200 m that resemble Andean foothills, but are isolated from the Andes by intervening valleys and at least 300 km ▪ A mosaic of poor, intermediate, and rich soils that span a nearly complete gradient of soil fertilities and that represent habitats not protected within national (SINANPE) or regional protected areas ▪ Aquatic habitats, especially streams including the headwaters themselves, that provide reproductive sites and food resources for fauna (e.g., frogs and fishes)
Vascular Plants	▪ The westernmost extent of the poor-soil Central Amazonian flora ▪ Tiny populations of valuable timber species (e.g., *Cedrela fissilis* and *C. odorata*, Meliaceae; *Cedrelinga cateniformis*, Fabaceae) logged at unsustainable levels elsewhere in Amazonia ▪ Large populations of timber species of lesser value (*Virola* spp., Myristicaceae; various species of Lecythidaceae, Lauraceae, and Fabaceae; *Calophyllum brasiliense*, Clusiaceae; *Simarouba amara*,

Vascular Plants (continued)	Simaroubaceae) that are increasingly exploited as higher value timber species become extinct ▪ 5–10 plant species potentially new to science
Fishes	▪ Communities of species adapted to the headwaters, sensitive to the effects of deforestation, and probably endemic to the region (*Creagrutus, Imparfinis, Characidium, Hemibrycon, Bujurquina*) ▪ Species that are probably new to science (*Imparfinis, Cetopsorhamdia, Bujurquina*) ▪ Species of high value in the ornamental fish trade (*Monocirrhus, Nannostomus, Hemigrammus, Hyphessobrycon, Otocinclus, Apistogramma, Crenicara*)
Reptiles and Amphibians	▪ An abundant population of *Atelopus* sp. (Fig. 7C), a new species within the harlequin frog genus, a genus considered threatened by extinction throughout its geographic range ▪ Two frogs that are new to science, the *Atelopus* sp. and an *Eleutherodactylus* sp. (Fig. 7A). ▪ Species with commercial value such as turtles (*Geochelone denticulata*) and caimans (*Caiman crocodilus*), especially in riparian forests and oxbow lakes along the upper reaches of the Arabela and Mazan rivers
Birds	▪ A dozen bird species restricted to white-sand forests, which are rare habitats within Peru and Amazonia ▪ Game birds, e.g., Salvin's Curassow (*Crax salvini*), under considerable hunting pressure in other parts of their range, especially in Loreto ▪ Populations of foothill species, isolated from the Andes

Mammals	▪ Abundant, intact populations of mammals, especially in the Arabela headwaters, threatened elsewhere in Amazonia ▪ Substantial populations of equatorial saki monkey (*Pithecia aequatorialis*, Fig. 9C), a range-restricted primate occurring in Peru only on the left bank of the Marañón River between the Napo and Tigre rivers ▪ Populations of primates that are important seed dispersers but threatened by commercial hunting, especially the white-bellied spider monkey (*Ateles belzebuth*) listed as Vulnerable (IUCN), the red howler monkey (*Alouatta seniculus*), and the common woolly monkey (*Lagothrix poeppigii*) ▪ Populations of giant armadillo (*Priodontes maximus*), listed as Vulnerable (IUCN) and Threatened (CITES) ▪ Top predators, e.g., jaguar (*Panthera onca*) and puma (*Puma concolor*), that are important in regulating prey populations ▪ Populations of Brazilian tapir (*Tapirus terrestris*), an important dispersal agent, especially of large seeds, listed as Vulnerable (CITES, IUCN) ▪ Three bat species (*Artibeus obscurus, Vampyriscus bidens*, and *Diphylla ecaudata*, Fig. 9B) considered Lower Risk/Near Threatened (IUCN)
Human Communities	▪ Indigenous populations living in voluntarily isolation in the headwaters of the Arabela River ▪ Social behaviors and patterns (e.g., communal work, barter economy) that can buffer villagers from the uncertainties inherent in living in isolated parts of the Amazon ▪ Villagers practicing a self-sufficient lifestyle that is compatible with environmental conservation

RECOMMENDATIONS

Below we highlight a series of recommendations to secure effective conservation of the area and ensure the integrity of the watersheds in the long-term.

Protection and management

01 **Establish a Regional Conservation Area of 747,855 ha that includes the upper Nanay drainage (Fig.2A).** The Nanay is an important river for Loreto, especially Iquitos, and like other key rivers in Loreto, it provides a source of food, water, and transport. Currently, the Nanay headwaters have no formal protection. The Regional Government of Loreto achieved tremendous success with two ordinances—prohibiting dredging machinery and restricting commercial fishing. A similarly successful project was led by the Instituto de Investigación de la Amazonía Peruana (IIAP) in the mid- and lower Nanay where, with legal and technical support, the local residents are organized and recuperating their natural resources. The headwaters of the Nanay should be protected to ensure the continued success of existing projects and the quality of life of residents in the entire watershed. The regional conservation proposal captures the intent of an earlier initiative by IIAP to create a Communal Reserve in the mid- and upper Nanay, now reformulated to protect the headwaters.

02 **Categorize the Regional Conservation Area as "Área de Protección Ambiental Cabeceras Nanay-Mazán-Arabela," managed by PROCREL.** In Loreto, PROCREL represents a tremendous opportunity for regional conservation and is likely the most appropriate entity to manage the area. To guarantee the long-term benefits of these watersheds for Loreto, activities in the region should be carefully zoned and limited to subsistence practices by adjacent communities and uncontacted indigenous people. Management of this new conservation area should be coordinated with neighboring areas: the Zona Reservada Pucacuro, the proposed Reserva Territorial Napo-Tigre, and the proposed Reserva Comunal Napo-Curaray.

03 **Restrict intensive commercial use in Nanay-Mazán-Arabela Headwaters.** The headwaters, which provide essential ecosystem services to a large part of Loreto and supply water to Iquitos, are extremely fragile. The area's soft substrates and steep gradients are subjected to an almost continuous natural erosion, making the headwaters extremely vulnerable to any activity that increases the rate of erosion—timber extraction, oil extraction, mining, or large-scale agriculture. Excluding the timber concessions from the region is critical; however, this alone is not sufficient to protect the headwaters. If other intensive use is permitted in the area, the increase in erosion will trigger heavy sedimentation in the three watersheds, resulting in economic, biological, and social losses for Loreto.

RECOMMENDATIONS

Protection and Management (continued)

04 **Strengthen the proposed corridor Nanay-Pucacuro. The "Nanay-Mazán-Arabela Headwaters Area of Environmental Protection" is part of this corridor.** The corridor will protect the richest biological communities on Earth, unite the megadiverse forests of Peru and Ecuador, and conserve the characteristic richness of Loreto.

05 **Determine the roles of the principal actors in each of the three watersheds, once the Regional Conservation Area is established and under management by PROCREL.** Successful protection of the area will depend on a concerted and united effort by everyone, and should play to existing strengths found in neighboring communities, local authorities, and the national and regional institutions protecting the area. The key actors include GOREL, via PROCREL; local communities, via their management committees and their relevant organizations and representatives in each watershed; local governments, via the relevant legal norms; indigenous federations and *campesino* organizations; and other supporting entities (e.g., forest management committees, NGOs, state institutions).

06 **Involve local people in protection of the area, and strengthen and regulate existing initiatives in the region.** Managing a protected area is much more effective when local residents are integral participants. In Nanay-Mazán-Arabela Headwaters, the role of local people is even more critical because rivers provide such easy access to the region. In the Nanay and Arabela rivers, there are successful local initiatives to control entry into the area by outsiders. We recommend strengthening and regulating these activities and exporting these initiatives to all of the vulnerable entry points in the region. In addition, we recommend empowering local communities in the three watersheds by training voluntary park guards to eradicate illegal hunting, fishing, and logging in their watersheds, and by creating entry fees for outsiders visiting the region.

07 **Establish zoning for uses of varying intensitites in the Regional Conservation Area and its buffer zone, in accordance with the fragility of the soils and ecosystems.** Sustainable use of the area will ensure the well-being of both the uncontacted indigenous people living within N-M-A Headwaters and the communities that live outside of its borders. To ensure successful integrated management and sustainable use of the area, the buffer zone should include part of the Curaray watershed.

08 **Design and implement training, environmental education, and awareness programs.** In the region there is a lack of information about various topics, including the environmental impact of resource extraction in such a fragile area, and how to mitigate these impacts to restore the area. Technical assistance, training,

environmental education, and awareness are key elements in allowing local communities to make informed management decisions about their watersheds.

09 **Avoid promoting agricultural and livestock programs and prevent invasion by exotic species, as the headwaters are incredibly fragile.** In particular, buffaloes cause enormous damage, destroying habitats and disrupting watersheds.

Further inventory

01 **Map the geology of the region.** There are no previous descriptions of the area's geology. We recommend conducting additional inventories that measure stream water chemistry, describe major landforms, characterize soils, and evaluate water quality. The results can be integrated into a preliminary geological map.

02 **Continue basic plant and animal surveys, focusing on other seasons and other sites.** Survey priorities include the hills inland from the Mazan River, the high terraces and low hills dominated by dead Tachigali trees (easily visible from the air, Fig. 3D), the Arabela River and associated lakes, and the flat region in the Tigre basin, south of Panguana and to the west of the Nanay. For amphibians, reptiles, and fishes, it will be important to do additional surveys during the wet season from October to March.

03 **Conduct longer inventories that can focus on small mammals and bats.** Mammal diversity is highest in smaller-bodied taxa such as rodents and bats, and our inventory was not long enough to adequately sample these groups.

04 **Inventory white-sand areas in the upper Nanay basin.** White-sand areas are rare habitats with low diversity overall, but high levels of endemism. Additional surveys should focus on plant and bird communities. One priority is searching for populations of *Polioptila clementsii*, an endemic bird known only from several dozen breeding pairs in white-sand habitats in the Reserva Nacional Allpahuayo-Mishana near Iquitos.

Research

01 **Evaluate the impact of local fishing and hunting on game populations (fish, birds, mammals).** Use participatory research methods to work with community members and determine which species are most commonly captured, the relative abundances of these species, and the sites most often used for hunting. These data will provide a baseline for long-term monitoring and local management decisions.

02 **Investigate whether large catfishes spawning in the headwaters.** These data will be critical elements in any regional plans for conserving and managing the most important fish resources.

03 **Conduct studies on *Pithecia* monkeys in N-M-A Headwaters.** We are not certain whether we observed one species with great variation in pelage, or two

RECOMMENDATIONS

Research (continued)	species (Fig. 9C). We recommend a revision of the genus, based on the collection of new specimens, behavioral observations, molecular analyses, and a detailed revision of existing museum specimens. 04 **Investigate the archeology of the Panguana region.** Floodplain trees growing on hilltops in Panguana (Fig. 5E) suggest that people may have cleared the rich-soil hills for small-scale agriculture in the last 400-500 years. There may be ceramics or other evidence corroborating past human presence.
Monitor and/or Survey	01 **Establish baseline data on water quality, sedimentation loads, and erosion rates.** Headwater areas are critical for preserving the water quality in the region. Increases in sedimentation and contamination can place local residents at risk, and these data will alert scientists and decision-makers to emerging threats. 02 **Create a practical monitoring plan that measures progress towards conservation goals established in the management plan for the region.** Integral participation of local communities is critical in the design, implementation, and revision of the management plan. 03 **Document illegal incursions into the area.** Priorities include understanding the magnitude of commercial hunting and illegal logging in the area, especially along the Mazan River. 04 **Monitor populations of *Atelopus* frogs, a new species found in Alto Nanay (Fig. 7C).** Currently, Alto Nanay harbors an abundant population. However, other frogs in the genus are experiencing a severe extinction crisis, and it will be important to track the fate of the Alto Nanay population, as well as any additional populations identified in the N-M-A Headwaters.

Technical Report

OVERVIEW AND INVENTORY SITES

Authors: Corine Vriesendorp and Robert Stallard

Most—but not all—Amazonian headwaters begin high in the Andes. In the department of Loreto in northwestern Peru, a group of headwater streams originates along a small divide in the lowlands. From 270 meters above sea level springs a network of streams that flow into the Nanay, Mazán, and Arabela rivers and ultimately feed the Amazon River near Iquitos.

Although these three rivers figure among the most important waterways in the region, the headwater streams are threatened. Forestry concessions (some active, some proposed) cover the entire Mazán watershed, beginning at the mouth of the Mazán, extending to its source near the Ecuadorian border, and overlapping completely with the drainage divide where the headwater streams originate. Oil concessions now overlap the entire region.

In March of 2004, the Regional Government of Loreto (GOREL) moved to exclude 24 proposed forestry concessions from the upper reaches of the Mazán (136,058 ha; Regional Ordinance 003–2004–CR/GRL). After a series of discussions in 2005, in March of 2006 GOREL invited The Field Museum to inventory the area and provide technical support for protecting the fragile headwater ecosystems. In December 2006, based on the results from the inventory, GOREL expanded the proposed protected area beyond the excluded forestry concessions to include a greater part of the Nanay watershed. The entire area is now known as **Nanay-Mazán-Arabela (N-M-A) Headwaters** (747,855 ha, Fig. 2A).

N-M-A Headwaters is bounded loosely by the Arabela and Curaray rivers to the northeast and the Pucacuro and Tigre rivers to the southwest (Fig. 2A). A mosaic of land uses surrounds the proposed protected area. There are forestry concessions to the southeast, a proposed indigenous area (Reserva Territorial Napo-Tigre) to the northwest, and a protected area (Zona Reservada Pucacuro) to the southwest (Fig. 2A).

The banks of the Curaray are lined with villages and indigenous communities, as are the lower stretches of the Mazán, and the middle and lower stretches of the Nanay (Fig. 2A). There are also two communities along the lower Arabela River at its junction with the Curaray. Officially, no villages exist within N-M-A Headwaters.

However, in the upper reaches of the Arabela, both within N-M-A Headwaters and farther to the northwest within the proposed Reserva Territorial Napo-Tigre, there are consistent reports of indigenous people living in voluntary isolation.

During the rapid biological and social inventory of N-M-A Headwaters in August 2006, the social team surveyed communities along the Curaray and the lower reaches of the Mazán and Arabela rivers, while the biological team focused on three sites in the upper reaches of the Mazán, Nanay, and Arabela watersheds (Fig. 2A). Below we give a brief description of the sites visited by both teams.

INVENTORY SITES VISITED BY THE BIOLOGICAL TEAM

Scanning satellite images of the headwaters of the Nanay, Mazán and Arabela rivers, we chose sites that represented both headwater areas and a broad diversity of habitats. A trail-cutting team entered the field in advance of the biological team and established campsites and trails in the highest reaches of each river.

For logistical reasons, our first two inventory sites along the Mazán and Nanay rivers were established within the headwaters, but lower than originally planned because forest cover was too dense for helicopter access and water levels too low for river access. Our third site lies within the heart of the headwaters area. Here the advance team traveled by boat up the Panguana stream (Arabela headwaters) and then hiked to the headwater divide. We provide greater detail on the geology, hydrology, soils, and vegetation of each site in the technical report. Below we describe each site briefly.

Alto Mazán (15–20 August 2006; 02°35'10" S, 74°29'33" W, 120–170 m)

We established our camp on one of the few riverside terraces along the headwaters of the Mazán River. This stretch of the river is susceptible to flash flooding; our first attempts to establish camp were washed away by a 4 m rise in water levels. The Mazán has a strong current and measured 30–32 m across during our stay.

A large tributary (Quebrada Grande, ~10 m wide) joins the Mazán channel just downriver from our camp. Both the Quebrada Grande and the Mazán are turbid, entrenched waterways with active natural erosion and limited active floodplains. Inland from the river, the landscape is covered in poorly drained terraces and gently rolling, low hills (~20 m).

We did not survey much of the hill forest. The bulk of our 17.8 km of trails were concentrated in the complex of hummocky swamps, small streams, and ephemeral pools that dominates the forest along the river edge. Across the river from our campsite, we surveyed a small, blackwater oxbow lake and a *Mauritia* palm swamp.

Flooding, slumping slopes, and erosion-prone soils combine to create a landscape dominated by natural disturbance (i.e., extensive light gaps, small landslides). Soils are variable on scales of tens of meters, and contain some rounded quartz and rare rocks that likely originated in the Ecuadorian Andes. The small streams that flow between the low hills are very dilute and acid.

Despite being 180 km from Iquitos, we found ample evidence of human presence. Every day we observed one or two canoes or small boats (*peque-peques*) of hunters traveling up the Mazán. One boat descended past our camp carrying seven collared peccaries and a large game bird (Spix's Guan, known locally as *pucacunga*) to sell in Iquitos. Near our camp we observed remnants of a temporary hunting camp (1–2 years old), as well as a network of hunting trails.

Illegal logging was also evident. The advance team encountered an active logging camp 7 km upriver from our inventory site. Although the area falls within legal timber concessions, the loggers admitted not to be the concessionaires and to be extracting wood illegally.

Alto Nanay (21–24 August 2006; 02°48'23" S, 74°49'31" W, 140–210 m)

Our second camp was on a floodplain terrace overlooking the white-sand beaches of the Agua Blanca, a tributary of the Nanay River. Agua Blanca is ~18 m wide, 201 km from Iquitos, and likely not navigable year-round. As in Alto Mazán, water levels rose rapidly after daily rains, sometimes nearly 1 m in 12 hours.

On satellite images, the Nanay drainage is a different color and texture than other drainages in Loreto, reflecting a distinct underlying geology and poorer overall fertility. This was the only site we visited that had white-sand vegetation (known locally as *varillales*), a rare Amazonian habitat of extremely poor soils and a specialized flora and fauna.

We explored 25.4 km of trails on both sides of the river, traversing a large floodplain terrace with mostly brown-sand soils around our camp, an extensive clay-rich swamp next to the floodplain, as well as a complex of steep (~30°) hills that are packed close together and dominate the inland landscape. Two small patches (0.3 ha) of white-sand vegetation grow on a flatter area that abuts the steep hills. No oxbow lakes have formed in the area, but there are small pools created during flooding and rain events (known locally as *tipishcas*).

Outside of clay-rich inundated areas, brown sands and brown silty clays are the prevalent soils. Slopes and hilltops have very thick 10–20 cm root mats, are marked by a spongy forest floor, and are covered in dense leaf litter. Streams are mostly clearwaters and less dilute and turbid than in Alto Mazán. Despite the steep hills there is less physical erosion in the Nanay than in the Mazán, suggesting more resistant soils.

None of our guides from Nuevo Yarina on the Curaray River had ever visited this site. We found a small camp that appears to be 3–4 years old, and several trees (some Lauraceae, *moena*) that had been felled by chainsaw but left in the forest. About 200 m upriver from the camp, a much more valuable timber tree—a large *tornillo* (*Cedrelinga cateniformes*)—was left untouched. The intact fauna, especially the primate populations, suggests that hunting may be almost nonexistent at this site.

Panguana (26–30 August 2006; 02°08'13" S, 75°08'58" W, 160–270 m)

Our third camp was established on a hill 20 m above the floodplain of the Panguana stream, deep within the area of excluded concessions. The Panguana traces a heavily meandering path to the Arabela River, and our campsite was about midway between its source and the mouth. A ridge—a mere 270 m asl—forms the divide between the Arabela River, and on the other side, the Nanay and Mazán rivers.

We explored 18.5 km of trails, including a 12-km transect from the drainage divide to the Arabela, which descended a series of gently sloping hills and flat terraces into a large *Mauritia* palm swamp, or *aguajal*, 500 m from the river. A satellite camp was established 2.5 km from the Arabela, where the herpetological team spent a night to sample the aguajal and nearby areas.

Despite being closer to Iquitos, Peru (275 km) than Puyo, Ecuador (330 km), geologically this site is heavily influenced by the Ecuadorian Andes. The terrain is complex, with several types of 'bedrock' including hard shale that is sufficiently cracked to be eroding. Older sandy layers with embedded pebbles and cobbles cover a few areas. Some of the cobbles are so big (~1,600 cm^3) that only a large river could have deposited them. In addition, we found abundant quartz, some volcanic deposits (obsidian), fossil bivalves, and even one hard pebble that appears to be petrified wood.

The deposits underlie a landscape of gently sloping hills, terraces, and episodically inundated swampy areas. The large emergent trees growing on the hills are surprisingly mostly floodplain species. These include high densities of *Ceiba pentandra*, *Dipteryx*, *Terminalia oblonga*, and many others. The hills have a humus layer typically associated with richer soils, and may have been ideal sites for small agricultural plots more than 400 years ago. Our working hypothesis is that the floodplain trees colonized the ridges once the small settlements or subsistence plots were abandoned.

Rapid and ongoing erosion is evident nearly everywhere, from the rapidly deepening streams with steep, entrenched banks, to the extensive patches of liana tangles growing up in previously eroded areas. Streams exhibited low to intermediate conductivities overall, but spanned a broad range over small spatial scales, from low conductivities near the drainage divide (12:S cm^{-1}) to higher conductivities (80) a mere 150 m from the divide.

Our local assistants were from Buena Vista and Flor de Coco, the only communities along the Arabela River. They regularly hunt in this area, especially for white-lipped peccaries. The plentiful and diverse fauna at this site underscores the difference between subsistence hunting practiced by local communities, and the depleted mammal fauna and large-scale commercial hunting we observed in the Alto Mazán.

INVENTORY SITES VISITED BY THE SOCIAL TEAM

While the biological team was in the field, the social team surveyed 11 communities along the Mazán, Arabela, and Curaray rivers (Fig. 2A). Because of time constraints, the team did not visit communities along the Nanay River.

To the north, along the Arabela River, we worked in Buena Vista and Flor de Coco. People in these two communities belong to the Arabela indigenous group, and operate independently of existing indigenous federations. To the northeast, along the Curaray River, we visited five communities. Four are communities of Quichua people that form part of the FECONAMNCUA (Federación de Communidades Nativas de Medio Napo, Curaray y Arabela) indigenous federation, and one, Santa Clotilde, the district capital of the Napo region, is a *mestizo* community. The Quichua native communities are Bolívar, Shapajal, Soledad, and San Rafael. To the southeast, along the Mazán River, we visited three mestizo communities, Libertad, Puerto Alegre and Santa Cruz, and the district capital, Mazán.

In addition to the community surveys, the social team also carried out semi-structured interviews with government authorities, including mayors and INRENA officials, as well as civil organizations, including church groups active in environmental issues, youth groups, and environmental organizations.

We discuss these communities, as well as the others in the region that we did not visit, in more detail in "Human Communities: Social Assets and Resource Use." For summary information on communities in the vicinity of Nanay-Mazán-Arabela Headwaters, please see Appendices 8 and 9.

GEOLOGY, HYDROLOGY, AND SOILS

Author/Participant: Robert F. Stallard

Conservation targets: Complex geology and associated (poor-to-rich) soils developed within the only large headwater region north of the Amazon and outside of the Andes; soils and some of the bedrock that are easily eroded; a combination of soils and elevations over 200 m that resemble Andean foothills, but are isolated from the Andes by distance and intervening valleys

INTRODUCTION

There are no published studies of the geology or the soils of Nanay-Mazán-Arabela (N-M-A) Headwaters and surrounding areas. A broader look at the region's geology and landscape is given in Appendix 1. We encounter virtually the same geologic/geomorphic units in the N-M-A region as are found in the well-studied region around Iquitos and Nauta. From old to young (see Appendix 1), these are:

- The Pevas Formation, with blue, often fossil-rich sediments, rolling hills, intermediate soils, and higher-conductivity waters
- Unit B, with yellow-brown sediments, some gravel, rolling hills, intermediate soils, and low-conductivity waters
- Unit C, with yellow-brown sediments, abundance of gravel, steep hills, poor soils, and low-conductivity clear and acid black waters
- Quartz-sand unit, with sands, flat-topped, very poor soils, and acid black waters
- Terraces, with flat surfaces, some with flood-plain features, not presently flooded, swamps, many water types
- Floodplain, with flat surfaces, currently flooded, floodplain features, swamps, and many water types

Central to the geologic history represented by these six units is a huge sediment-accumulation surface that formed during the uplift of the Eastern Cordillera of the Andes (Fig. 2B). The Pevas Formation was deposited before this time, while Unit B, Unit C, and the sands that became the white-sand units were deposited during this time. Following this uplift much of the region was eroded and filled to form a flat planation surface (a land surface in which the hills have been eroded down and the valleys filled up to create a plain)(Coltorti and Ollier 2000). Some of the white sands probably formed on this surface. The more recent, ongoing uplift of the Andes tilted this surface to the east, and rivers have eroded much of it. The terraces and floodplains postdate this tilting.

Erosion of the old surface left isolated hills whose summits align with the old surface. These summits can potentially isolate plant and animal populations, and where they are flat, which is rarer still, they provide the setting for the white-sand soils and the associated organisms (islands within islands). The highest hilltops in the inventory of N-M-A Headwaters (at the Alto Mazán and Panguana sites) appear to align with this surface as do the white-sand areas (known locally as *varillales*) along the lower Nanay River and white-sands near the Gálvez-Blanco Divide in eastern Loreto (Stallard 2005a, b). Because the present study is closer to the Andes, the hill summits are taller and create environmental conditions not found at the more distant hilltops at the lower Nanay or the Gálvez-Blanco Divide near the Brazilian border.

METHODS

The various geologic/geomorphic units can be differentiated, and their nutrient quality assessed, using a range of characteristics, including topographic form, soil texture and color, water conductivity, color, pH, and geology.

Soils, topography, and disturbance

Along selected trails at each camp, I assessed soil color visually, with Munsell soil color charts (Munsell Color Company 1954), and soil texture by touch (see Appendix 1B, Vriesendorp et al. 2005). Because the soil was generally covered by leaf litter and often a root mat, I used a small soil auger to retrieve samples. I also noted activities of bioturbating organisms (such as cicadas, earth worms, leaf-cutting ants, and mammals), frequency of treefalls involving roots, presence of rapid-erosion indicators (head cuts, bank failures, landslides), the importance of overland-flow indicators (rills, vegetation wrapped around stems indicating surface flow), evidence for flooding (sediment deposited on fallen tree trunks, extensive gley soils), absence or degree of development of root mat, and indicators of poor to very poor soils.

In addition to looking at soils, I also made an attempt to qualitatively describe hill slopes and large-scale disturbances. For hill slopes, this included (1) an estimate of topographic relief, (2) spacing of hills, (3) flatness of summits, (4) presence of terraces, and (5) evidence of bedrock control. The major types of natural disturbance expected for western lowland Amazonia are extensive blowdowns (Etter and Botero 1990; Duivenvoorden 1996; Foster and Terborgh 1998), small landslides (Etter and Botero 1990; Duivenvoorden 1996), channel migrations by alluvial rivers (Kalliola and Puhakka 1993), and rapid tectonic uplift or subsidence that changes hydrology (Dumont 1993).

Rivers and streams

I assessed all bodies of water along the trail systems visually and via measurements of acidity and conductivity. Visual characterization of streams included (1) water type (white, clear, black), (2) approximate width, (3) approximate flow volume, (4) channel type (straight, meandering, swamp, braided), (5) height of banks, (6) evidence for overbank flow, (7) presence of terraces, and (8) evidence of bedrock control of the channel morphology. Low conductivities (<10 :S cm^{-1}) indicate very dilute waters and low nutrient status. Acid waters (pH <5) are also very dilute and lacking in nutrients, but have higher conductivities from the organic acids in the water. For waters with a pH >5 in the western Amazon Basin, higher conductivities (>30 :S cm^{-1}) often indicate the presence of unstable minerals, such as calcite ($CaCO_3$), aragonite ($CaCO_3$), and pyrite (FeS_2). In the general region around N-M-A Headwaters, these minerals are abundant in some layers of the Pevas Formation.

To measure pH, I used an ISFET-ORION Model 610 Portable System with a solid-state Orion pHuture pH/Temperature Systems electrode. For conductivity, I used an Amber Science Model 2052 digital conductivity meter with a platinum conductivity dip cell. The use of pH and conductivity to classify surface waters in a systematic way is uncommon, in part because conductivity is an aggregate measurement of a wide variety of dissolved ions. However, graphs of pH vs. conductivity (see Winkler, 1980) are a useful way to classify water samples taken across a region into associations that provide insights about surface geology (Stallard and Edmond 1983, 1987; Stallard 1985, 1988, 2005a, b; Stallard et al. 1990).

RESULTS

Site descriptions

I present the results of this study in the order sites were visited.

Alto Mazán

This site is located in a region of low rolling hills on the right bank of the Mazán River across the river from a small blackwater oxbow lake (*cocha*). The gentle rolling hills are generally low, less than 30 m, with flat swampy areas in-between. Because streams that flow through some of the flat areas are entrenched, they are best described as low terraces. Root mats were common, but not thick, an indicator of poor to intermediate soils. The substrate appeared to be mostly yellow to brown mudstones, sandy mudstones, and sands. A few gravel-rich layers contributed pebbles (mostly quartz, minor rock fragments) to the streams. In the lower slope of one hill and in a stream bed, I found layers of blue clay overlain by a dark, sandy, blue clay with fossil leaf fragments, followed by a sand and gravel layer. Both of these sites had soil slumps. This may be a prograding coastal sequence of the type described for the uppermost Pevas Formation by Vonhof et al. (2003).

The two main rivers at the site, the Mazán River and the Quebrada Grande, are entrenched in their channels and have very small floodplains, evidenced by small blackwater lakes nearby. The former floodplain forms a swampy terrace along both rivers where the camp was built. I found no evidence that this terrace now floods. Both rivers are quite turbid, indicating considerable physical erosion, and both rivers had bank failures visible from the trails. Smaller streams became turbid after rains indicating active erosion of uplands. The streams also had conductivities near 8 :S cm^{-1}. I did not see many head cuts, the upstream end of an entrenched channel on a stream where actively cutting new banks. Streams entrench when there is a relative drop in the elevation of the channel into which they feed, either because the land has risen or the river downstream has dropped. In the case of the Mazán River, the Napo River controls base level. In turn, the Mazán River controls the level for its tributaries. The smaller streams near the camp were not as turbid as the Mazán River or the Quebrada Grande. Combined with the development of incipient floodplain on these larger rivers, this may indicate that the main cycle of entrenchment, while still active, has now passed well upstream of the study site.

The combination of gentle hills underlain by yellow to brown sediments, poor to intermediate soils, and turbid low-conductivity streams, all indicate that Unit B dominates the landscape (Appendix 1). The outcrops of the Pevas Formation are low in the landscape, and these seem to be layers that lack the unstable minerals that would raise the conductivity of stream water. This is a landscape composed of easily eroded substrates, and erosion, reflected in the turbidity of the rivers, is quite active. Loss of forest cover and the destruction of the root mat, by deforestation or agriculture, would greatly increase erosion on this landscape.

Alto Nanay

This site is located in a region of steep hills on the left bank of the Agua Blanca, a principal tributary to the Nanay River. The substrate is a mix of compacted yellow-brown mudstones, sandstones, and minor conglomerates. These hills are typically high, 30 to 50 m, with steep slopes, deep valleys (some of which have swampy, U-shaped bottoms). The hills with narrow tops tended to have soils of yellow-brown clays and thin root mats, while hills with broader, flatter tops have yellow-brown, sandy clay soils and thick root mats, sometimes 10–20 cm. Root mats were common, and often thick, an indicator of poor to very poor soils. They were thinnest on the clay soils, and thickest on the hummocky areas.

The hill nearest the camp on the opposite side of the river had two extensive flatter upland areas at different elevations. These flat areas had well developed white quartz sand soils and distinctive white-sand vegetation (*varillal*). The white quartz sand areas were partially bordered by areas of thick (20–40 cm or more) hummocky root mat over yellow-brown, sandy clay soils. The main rivers appeared to be slightly entrenched, and the camp was built on a young, low terrace into which the tributaries were also entrenched. Beyond this terrace, there was a step up to a higher terrace with a hematite-cemented sandstone and conglomerate. This harder rock appears to control the base level of streams upslope rather than the level of the Agua Blanca. I visited another large tributary 3.5 km directly west of camp, and its bank, lower terrace, cemented ledge, and upper terrace were arrayed in the same ways as the Agua Blanca.

The two main rivers at this site, the Agua Blanca and the large tributary, are somewhat entrenched but both are forming floodplains as evidenced by numerous small *cochas* (oxbow lakes). None of the rivers at the site are turbid, even after major rains. There were no active head cuts, and the one small landslide that I found was years old and covered with medium-sized trees. Banks fail on both tributaries, and both had extensive treefalls into the channel. The banks appear to be sand, however, and failure would contribute more to bed load than to suspended load or turbidity. Physical erosion appears to be minor. Most of the streams also had conductivities between 4–6 :S cm^{-1}, while blackwater streams associated with swampy areas on the terraces had conductivity of about 12 :S cm^{-1}, because of their acidity. These conductivity values indicate very low dissolved solids and rather poor soils. I did not find any streams draining the white quartz sands. Stream beds were mostly sand, with some gravel (quartz and rock fragments) at lower elevations and some clay bottoms at the highest. I was on the trail during a huge storm, and the root mat absorbed most of the water. There was no overland flow, and streams rose slowly.

The combination of high, steep hills underlain by yellow to brown sediments, poor to very poor soils, and clear low-conductivity streams, all indicate that Unit C dominates this landscape (Appendix 1). The cemented sandstone and conglomerate may be the basal conglomerate for this unit. The presence of white quartz sand on flatter upland areas at different elevations is consistent with their active formation on this landscape, as was seen more dramatically during the Matsés inventory for the site on the Gálvez-Blanco Divide (see Itia Tëbu site, Stallard 2005a, b). Although both physical and chemical erosion rates are quite low, slopes are steep and loss of forest cover and root mat would likely promote both gullying and landslides, thereby dramatically increasing physical erosion.

Panguana

The Panguana is a small tributary of the Arabela River. Trails created a complete transect from its divide with the Tigre river drainage all the way to the Arabela River. The divide is a narrow ridge of steep hills that are clearly visible on radar topographic imagery (Fig. 2A). The highest summits appear to be aligned with the old Pliocene alluvial plain described earlier. Elsewhere in the catchment, the hills are lower rolling hills, generally less than 30 m, steeper and more developed than those at Alto Mazán but considerable less steep and high, except at the divide, than those of Alto Nanay. Closer to the Arabela River, the hills became lower and more gentle, finally giving way to a low flat terrace with a large *Mauritia* palm swamp (known as an *aguajal*). Often areas between hills were flat and swampy. Terraces were numerous and at a full range of elevations; even the highest ridge had three terrace levels. Most streams were entrenched and head cuts were numerous, with several per kilometer along all trails. The only obvious active floodplain was on the Arabela.

Away from the divide, I found the rocks of the Pevas Formation in all the large- and medium-sized rivers. These include numerous outcrops and boulders of mudstone, some which contained abundant mollusk fossils. Larger pieces of mudstone formed part of the river gravel and finer pieces formed part of the sand. All of the rivers that had headwaters near the divide had large quantities of gravel and cobbles of chert (hard, durable, microcrystalline quartz typically formed in sedimentary settings with the help of groundwater), rock fragments, and quartz, the suite of rock types that characterize the basal conglomerate of Unit C. In addition to these rock types, I found one rounded piece of obsidian, a volcanic glass that could only come from the Andean volcanoes. Smaller streams that had headwaters away from the divide often did not have hard-rock pebbles, and a few lacked mudstone pebbles, especially at higher elevations in the lower hills.

The channel in the lower middle Panguana, about one third of the way between the Arabela and the divide, had banks and bed of a harder mudstone. It is likely that the erosion of this mudstone controls the base level for the region upstream. The mudstone is quite fractured and would not sustain a major hillslope, but the blocks are too large to be moved by the flow of the Panguana, which instead must cut through them. Root mats were absent except in two areas, one in the higher elevations near the divide and the other on the lowest terrace. Where present, they were not thick, indicating that these are areas of poorer soil.

There is a wide range of water types at this site, reflecting the varied geology and soils. Rivers showed a range of turbidity. Clear waters included water draining swamps and streams that were not entrenched. Streams with beds of quartz sand and hard gravel without abundant mudstone pieces had slight turbidity. Larger streams with abundant mudstone pieces in the sand and gravel also had turbid waters, more so after rains. Small streams that were turbid after rain became clear two or three days later.

Conductivity also showed a large range of variation. Streams close to one another had similar values, perhaps indicating the effect of shared substrate and soils. I found the lowest conductivities, 10–13 :S cm^{-1}, in swamp waters that were somewhat acid, black waters, presumably rain-fed and in streams close to the divide. I found conductivity values from 50–80 :S cm^{-1} in streams close to the divide, but farther away from the divide, and in lower hills, than the low-conductivity streams. The trail system crossed into the Tigre River basin sufficiently far to show this pattern on both sides of the divide. Most of the remaining streams in the upper half of the Panguana catchment had conductivities in the range of 20–50 :S cm^{-1}. Higher conductivities indicate the presence of reactive minerals in the Pevas sediments in this part of the Panguana catchment. Most of the streams in the lower half of the Panguana catchment had conductivities in the range of 13–20 :S cm^{-1}, which appears to be associated with the hard mudstone, just described. This mudstone must lack abundant reactive minerals. The Arabela River had a conductivity of about 15 :S cm^{-1}, indicating that the reactive minerals seen in the upper Panguana catchment are not abundant in most of the Arabela Basin.

The generation of so many head cuts could be a significant factor for forest disturbance in the Panguana catchment. The entrenchment associated with head cut development often proceeds in pulses. The head cut typically erodes until it is stopped by a particularly large tree root. The head cut does not proceed until the root dies or is undermined. The head cut then advances rapidly, often toppling the tree that blocked its growth, as well as any trees that it undermines until it is again blocked.

The varied landforms, stream chemistry, and soil quality indicate that most of the sedimentary units found in the Iquitos area are present in the Panguana catchment and adjacent Arabela River. The widespread presence of exposed Pevas Formation and Pevas mudstone pieces in most rivers indicates that the Pevas Formation is the primary substrate at lower elevations. Unit B may be present in hilltops, but all streams had higher conductivities than at Alto Mazán. Thus Unit B may be thinner or absent. The steep slopes, root mat, and the low conductivity waters near the divide argue for this to be Unit C. The hard-rock clasts (any single, physically transported grain of rock, no matter the size, within a sedimentary rock) were both larger (the largest found was rounded, 20 x 10 x 8 cm) and more abundant than at Alto Nanay. This would be consistent with being closer to the Andean source, but it may also reflect larger paleo-channels in this region. Terraces were numerous in the Panguana catchment, on the other side of the divide in the Tigre catchment, and as a big terrace along the Arabela. The lower Panguana also had a large terrace that could be either attributed to the Panguana or the Arabela. Finally, the Arabela has an active floodplain with numerous meanders.

This is a landscape that appears to be eroding rapidly and would be subject to considerable erosion if forests were cleared. There is no root mat to block initial effects of deforestation, even if done in a selective manner, and erosion should be immediate and dramatic. Entrenchment would accelerate as trees with roots that block head cuts are removed, and the fairly impermeable soils would be subject to intense overland flow, and rill formation.

DISCUSSION

The geology of N-M-A Headwaters shows that the geologic units of the Iquitos region extend towards the Andes. The biggest change is that the fine gravels near Iquitos become coarse gravels and cobbles. We observed white sand formation in Alto Nanay. From the Matsés inventory (Vriensendorp et al. 2006), we see this same suite of geologic units continuing as far as the Blanco and Yaquerana rivers in eastern Loreto.

All these landscapes are fragile and subject to accelerated erosion. The Pevas Formation and Unit B would experience an acceleration of erosion processes, while Unit C settings would likely have landslides, which are rare at present (I saw only one), drastically increasing erosion rates compared to the low rates at present. Quartz sand soils are especially vulnerable, sand is easily eroded, and once the hydrologic barriers break that promote white-sand formation and sustain white-sand communities, they will disappear.

PARTICIPATORY RESEARCH

Stream-water chemistry, geologic observation, landform description, soil characterization, and simple water-quality measurements are adequate to map this landscape using the characteristics in Appendix 1. With the purchase of soil-color charts and an inexpensive coring tool, soils and underlying material exposed in stream channels can be easily mapped in a way that is sufficient to characterize much of this landscape. The mapping would involve extracting a soil plug and recording (1) location, (2) presence and thickness of root mat, (3) color and texture of core top, (4) color and texture of texture of core bottom, (5) steam type, (6) channel shape, (7) hill form, and (8) description of bank and bed material [Pevas/ not Pevas, pebbles/no pebbles]. The only instrumentation required is a GPS for measuring location in regions without suitable maps and suitable pH and conductivity meters (which are costly to purchase and maintain) for characterizing stream water.

In this general region, the landscape between the Arabela and the Cururay has taller hills that appear to have flat tops. In terms of priorities, to the south of the Panguana, and to the west of the Nanay, within the Tigre Basin, is a sloping flat region that looks quite interesting.

FLORA AND VEGETATION

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Conservation targets: Small populations of valuable timber species (e.g., *Cedrela fissilis* and *C. odorata*, Meliaceae; *Cedrelinga cateniformis*, Fabaceae s.l.) logged at unsustainable levels elsewhere in Amazonia; large populations of timber species of lesser value (*Virola* spp., Myristicaceae; various species of Lecythidaceae, Lauraceae, and Fabaceae s.l.; *Calophyllum brasiliense*, Clusiaceae; *Simarouba amara*, Simaroubaceae) that are increasingly exploited for timber as higher value timber species become extinct; a mosaic of poor, intermediate, and rich soils that span a nearly complete gradient of soil fertilities and that represent habitats not protected within national (SINANPE) or regional protected areas; the westernmost extent of the poor-soil Central Amazonian flora; 5–10 species potentially new to science

INTRODUCTION

Nanay-Mazán-Arabela (N-M-A) Headwaters lie within an area in Ecuador and Peru that contains the most diverse plant communities in the world (ter Steege et al. 2006). Prior to our inventory, botanists had not visited the area. Three areas with relatively well-known floras—Yasuní National Park in northeastern Ecuador (Valencia et al. 2004), the biological reserves near Iquitos in northern Peru (Vásquez-Martínez 1997), and Manu National Park in southeastern Peru (Foster 1990; Gentry and Terborgh 1990)—provide the best points of reference for understanding the flora and vegetation of N-M-A Headwaters.

METHODS

During a rapid inventory the botanical team characterizes the diversity of vegetation types in an area, covering as much ground as possible. We focus on the most common and dominant elements of the flora, while keeping an eye out for rare or new species. Our catalogue of the plant diversity in the area reflects collections of plant species in fruit or flower, sterile collections of interesting or unknown species, and unvouchered observations of well-known, widespread species and genera in Amazonia.

We made several quantitative measures of plant diversity including six transects of understory trees (1–10 cm DBH): three in Alto Mazán, two in Alto Nanay, one in Panguana. In a patch of white-sand at Alto Nanay, we measured all stems (>5 cm DBH) in a 0.1 ha plot. In a variety of habitats at each site, N. Dávila recorded the richness of 100 of the largest trees (individuals >40 cm DBH), using a combination of binoculars, bark characteristics, and fallen leaves to identify individuals to species.

In the field, R. Foster took ~900 photographs of plants. These photographs are being organized into a preliminary photographic guide to the plants of the region, and will be freely available at *http://fm2.fieldmuseum.org/plantguides/.*

Plant specimens from the inventory are housed in the Herbario Amazonense (AMAZ) of the Universidad Nacional de la Amazonía Peruana in Iquitos, Peru. Duplicate specimens have been sent to the Museo de Historia Natural (USM) in Lima, Peru, and triplicates to The Field Museum (F) in Chicago, USA.

FLORISTIC RICHNESS AND COMPOSITION

During our 16 days in the field, we distinguished ~1,100 plant species. We recorded ~500 unvouchered common species and collected ~600 specimens (Appendix 2). We estimate a regional flora of 3,000–3,500 species. Other rapid inventories in lowland Amazonia have recorded 1,000–1,500 species in similar time frames using similar methods (along the Yavarí River, Pitman et al. 2003; along the Apayacu, Ampiyacu, and Yaguas rivers, Vriesendorp et al. 2004; between the Yaquerana and Blanco rivers in the Matsés region, Fine et al. 2006; in the Zona Reservada Sierra del Divisor, Vriesendorp et al. 2006). We did not sample several major habitat types within N-M-A Headwaters, including the large *Mauritia* palm swamps (*aguajales*) along the major rivers (Mazán, Curaray, Arabela), the hills inland from the Mazán River, or the high terraces and low hills dominated by *Tachigali* (Fabaceae s.l.) trees, easily visible from the air because of a recent reproductive event.

Across our inventory sites the majority of soils had intermediate to poor fertilities, although some richer clays are distributed patchily across the landscape. Because soil fertility was heterogenous across the area, different families were most diverse at a single site, e.g., Chrysobalanaceae at Alto Mazán, Vochysiaceae and Melastomataceae at Alto Nanay, and Meliaceae, Burseraceae, Euphorbiaceae, Piperaceae, and Pteridophyta at Panguana. A few families were diverse at all three sites, including Annonaceae, Lauraceae, Menispermaceae, Myristicaceae, Fabaceae s.l., and Sapotaceae. Palm diversity at all three sites ranged from average at Alto Mazán (22 spp.) and Alto Nanay (25) to low at Panguana (18).

At the generic level, richness of *Matisia*, *Eschweilera*, *Rudgea*, *Psychotria*, *Tachigali*, and *Machaerium* was high at all three sites. Certain genera were especially rich at one site, e.g., *Guatteria* in Alto Mazán, *Micropholis* in Alto Nanay and *Ficus, Paullinia* and *Inga* in Panguana. Species of *Parkia, Brownea, Gloeospermum*, and *Dilkea* were surprisingly abundant at all three sites, although not particularly species rich.

VEGETATION TYPES AND HABITAT DIVERSITY

We surveyed three sites, each in a separate watershed and each with a different underlying geology. Across these sites, roughly from east to west, we observed several strong gradients. Humidity, epiphyte diversity, and overall plant diversity increased from Alto Mazán to Alto Nanay to Panguana. Similarly the *supay chacras*, or "devil's gardens," increased in size and diversity across sites. Supay chacras are open areas dominated by plants with ant mutualisms, almost always including *Duroia hirsuta* (Rubiaceae) and *Cordia nodosa* (Boraginaceae).

High levels of natural disturbance characterize all sites, although the causes may vary among sites.

Several regional floras appear to intersect within N-M-A Headwaters, including the diverse flora growing on intermediate to poor soils in Yasuní, Ecuador; the low diversity flora from the poor soils of reserves near Iquitos, Peru; and the intermediate diversity flora that grows on rich floodplain soils in Manu, Peru. For each site, we describe the unique combinations of these floras and the gross habitat types we visited, highlighting site-to-site variation wherever possible.

Alto Mazán

Our trails were concentrated in areas near the river, where we sampled the forest of the floodplain, both annually flooded and rarely flooded forest on low terraces, including patches of high, closed-canopy forest. In addition, we surveyed one of the low hills that dominate areas away from the river, a blackwater lake, and a small *Mauritia* palm swamp. Soils were mainly sandy loams and clays in the inundated areas, with sandier soils on the terraces, and clay on the hill. High levels of natural disturbance mark the landscape, including small landslides on the hills and streambanks, open swamps with tree dieback, and frequent treefalls, creating highly irregular canopy cover. Emergent trees measured 35–45 m. Plant communities were a mix of rich- and poor-soil specialists, including species well known from Yasuní, Ecuador to the west, and from brown-sand areas around Iquitos to the east. Except for Annonaceae, very few species were flowering or fruiting.

Several typical floodplain species were present, e.g., *Manilkara inundata* (Sapotaceae), *Calophyllum brasiliense* (Clusiaceae), *Pachira* sp. (Bombacaceae), *Mabea* spp. (Euphorbiaceae), *Acacia* sp. (Fabaceae s.l.), while some of the more characteristic floodplain species such as *Ceiba pentandra*, *C. samauma*, and *Ficus insipida* were missing. Mixed in with these species was a flora more typical of poorer soils, including *Eschweilera* spp. (Lecythidaceae), *Licania* spp. (Chrysobalanaceae), and *Micrandra spruceana* (Euphorbiaceae). This mix of species reflects small-scale differences in soil fertility. Both inundated areas—floodplain and swamp—had hummocky terrain, where a few meters might separate *Miconia tomentosa* (Melastomataceae) growing on a raised area of sandier soil from *Mauritia flexuosa* (Arecaceae) growing in water-logged clay soils.

In all habitats except the swamps and frequently flooded forest, much of the understory was dominated by *Lepidocaryum tenue*, an understory palm known locally as *irapay*. These large patches of clonal palms (*irapayales*) depress local diversity, and tend to be concentrated on lower hill slopes or well-drained (often sandy) areas. Another almost ubiquitous species was the small filmy-fern, *Trichomanes hostmannianum*.

As a quick measure of understory diversity (outside of the irapayales), we established three transects of 100 individuals (1–10 cm DBH): one on a low terrace with low irapay densities, one on a high terrace, and one in a seasonally inundated area along the Mazán River. Richness in these transects was moderately high, with 68, 77, and 63 species respectively.

On the low terrace, the most common species were a *Dilkea* (Passifloraceae) and two species of *Iryanthera* (Myristicaceae), and the most common families were Lauraceae (7 species), Fabaceae s.l. (6), Burseraceae (5), and Euphorbiaceae (5). We found the highest diversity on the high terrace with 77 species. This transect was dominated by *Rinorea lindeniana* (Violaceae), *Brownea grandiceps* (Fabaceae s.l.), and *Senefeldera inclinata* (Euphorbiaceae), and the richest families were Annonaceae (10 species), Fabaceae s.l. (8), and Euphorbiaceae (6). In the inundated transect the common species were *Rinorea lindeniana,* the *Iryanthera* and *Dilkea* from the first transect, and a *Matisia* sp. (Bombacaceae). Here the dominant families were Fabaceae s.l. (9), Annonaceae (6), Myristicaceae (5), and Lecythidaceae (5). Within the three transects (300 individuals) we found a total of 177 species in 36 families, with only 10% of the species shared among transects.

In addition, we surveyed the tree composition in a 100-stem transect (individuals >40 cm DBH) and registered 70 species. The most common trees included three Fabaceae s.l.—a *Tachigali* sp. whose leaves have a golden underside, *Parkia multijuga*, and a *Dipteryx* sp.—as well as one Lecythidaceae, *Eschweilera* sp.

Alto Nanay

This site most closely resembles areas near Iquitos, though with much higher hills, and likely represents the westernmost extent of the poor-soil Central Amazonian flora. Species overlap exists with Yasuní, although Yasuní has no white-sand flora and may receive more rainfall than any of our inventory sites within the N-M-A Headwaters. Very few species were flowering and fruiting, similar to Alto Mazán.

In Alto Nanay we sampled a sandy floodplain, a large swamp, steep hills that are closely packed together, and a couple of patches of pure white-quartz sand near the base of the hills. This site, too, is marked by disturbance, but treefalls occur mainly in valleys created by the steep hills where the terrain is unstable. Tree canopies were lower overall compared to the other two sites, measuring 25–35 m, with an occasional emergent of 45 m.

Hilltop floras varied from moderately diverse tall forest to shorter low-diversity assemblages with thin stems. Although the low-diversity communities appeared structurally similar to the white-sand vegetation known locally as *varillales*, most high hilltops were underlain by clays and brown (not white) sands, and white-sand specialist plants were not present. Several hilltops were covered in stems of *Marmaroxylon basijugum* (Fabaceae s.l.) draped in a thin-stemmed *Chusquea* bamboo. In Yasuní this *Marmaroxylon* is also most abundant on hilltops, but within a much more diverse plant community. Many other hilltops, on clay, had a distinct understory of the long-leaved stemless palm, *Attalea insignis*.

Surveys of 100 canopy trees registered 74 species, a moderately rich overstory community compared to other Amazonian sites. The most important plant families were Fabaceae s.l., Chrysobalanaceae, Sapotaceae, and Vochysiaceae, and the most common species were *Tachigali* spp., *Parkia* spp., *Hymenaea* spp. (Fabaceae s.l.); *Licania* sp. (Chrysobalanaceae), *Micropholis* spp. and *Pouteria* spp. (Sapotaceae), as well as a remarkably abundant group of Vochysiaceae: *Erisma* spp., *Qualea paraensis*, *Q. trichanthera*, and *Vochysia* sp. The largest trees we observed were *Goupia glabra* (Celastraceae), *Parkia multijuga* (Fabaceae s.l.), *Anaueria brasiliensis* (Lauraceae), *Huberodendron swietenioides* (Bombacaceae), and *Cariniana decandra* (Lecythidaceae). We did not observe a true floodplain flora, instead the riverside was dominated by species common in open areas, e.g., *Acacia* sp., *Cecropia* sp. (Cecropiaceae), and *Cespedezia spathulata* (Ochnaceae).

Our trails crossed two small areas (0.5 ha) of white-sand vegetation growing on flat areas near the base of the steep hills. These patches were too small to distinguish on the satellite image, however, we imagine that similar habitats are distributed patchily within the upper Nanay drainage. In a 0.1 ha sample of white-sand vegetation, we recorded 113 individuals (DBH >5 cm), representing 66 species within 22 families. We did not register some of the common white-sand specialists typical of areas near Iquitos, such as *Pachira brevipes* (Bombacaceae), *Dicymbe amazonica* (Fabaceae s.l.), *Caraipa* spp. (Clusiaceae), or species that we registered commonly in the vast white-sand areas near the Blanco river (Fine et al. 2006) such as *Platycarpum orinocensis* (Rubiaceae) or *Mauritia carana* (Arecaceae). The most common plant was *Macrolobium microcalyx* (Fabaceae s.l.), a species that dominated the sandstone hilltops in the Ojo de Contaya and Divisor sites during the Sierra del Divisor inventory in southeastern Loreto (Vriesendorp et al. 2006). Other common species in these varillales included the white-sand specialists *Emmotum floribundum* (Icacinaceae), *Macoubea guianensis* (Apocynaceae), *Ladenbergia* sp., *Remijia* sp., and *Pagamea* spp. (Rubiaceae), *Salpinga* sp. (Melastomataceae), *Trichomanes crispum* (Pteridophyta), *Odontonema* sp. (Apocynaceae), and *Ocotea aciphylla* (Lauraceae).

We again evaluated understory diversity, in two transects each with 100 individuals (1–10 cm DBH). One transect was situated along a low terrace adjacent to the Nanay River; this area may inundate periodically. We found 76 species within 34 families, dominated by Sapotaceae (8), Chrysobalanaceae (6), Myristicaceae (6), and Melastomataceae (6). Common species were either poor-soil species, e.g., *Iryanthera* cf. *elliptica, Marmaroxylum basijugum,* or disturbance-loving species, e.g., *Miconia* sp. (Melastomataceae). In our second transect, in tall forest on a flat-topped hill, we registered the highest transect diversity of the inventory, 83 species within 30 families. The more common species were *Eschweilera* sp., *Memora cladotricha* (Bisnoniaceae), and a different *Miconia* sp., with dominant families Annonaceae (8 species), Sapotaceae (8), and Lauraceae (7). Within the two transects (200 individuals) we found 141 species and 41 families.

The palm *Oenocarpus batahua* (known locally as *hunguraui*) was abundant in the low terraces at the Alto Nanay. In a 1-ha transect (1,000 m x 10 m), we counted 85 individuals over 3 m tall.

Panguana

Forests in Panguana include many species representative of better-known Amazonian floras (e.g., Manu and Yasuní) that grow on intermediate to rich soils. Compared to Alto Mazán and Alto Nanay, clay soils predominate here, soils are more heterogeneous overall, and the flora is extremely diverse. Habitats range from steep ridges that form the drainage divide, high round-topped hills, flat-topped terraces, a large *aguajal*, extensive and frequently inundated bottomlands by the Panguana stream and its tributaries, and disturbed areas between hills, covered in extensive liana tangles. Many more species were fruiting or flowering in Panguana compared to the other inventory sites, especially large-fruited species important for mammal and large bird populations.

Our most remarkable observation at this site was a floodplain flora—giant *Ficus insipida* and *Poulsenia armata* (Moraceae), *Terminalia oblonga* (Combretaceae), *Ceiba pentandra* and *C. samauma* (Bombacaceae, Fig. 5E), *Couroupita guianensis* (Lecythydaceae), *Sterculia apetala* (Sterculiaceae), *Parkia nitida* and *Dipteryx sp.*(Fabiaceae s.l.)—growing on the tops of the hills! These species need open areas, free of root competition, with plentiful light to regenerate, suggesting the hilltops were cleared in the last 400–500 years. Given the rich soils and humus layer, our working hypothesis is that the hilltops probably supported small-scale agricultural plots prior to the arrival of the Spanish, similar to other non-swampy areas with fertile soils in the Amazon (Mann 2005), and these giant trees are the remnants of first-generation tree colonization of abandoned fields.

Canopy tree composition was markedly different at this site compared to Alto Mazán and Alto Nanay, and canopies were higher on average (40–50 m). We registered 76 species in 100 individuals, with genera and species typical of richer soils, including *Inga* spp., (Fabaceae s.l.); *Brosimum* spp., *Pseudolmedia* spp., *Batocarpus amazonicus* (Moraceae); and *Guarea* spp. (Meliaceae). The abundant open areas were often colonized by *Cecropia sciadophylla* and *Pourouma* spp. (Cecropiaceae), and *Huertea glandulosa* (Staphyleaceae). Typically, in later secondary forests we observed *Coccoloba* spp. (Polygonaceae), *Inga* spp., *Tachigali* sp., *Sapium marmieri* (Euphorbiacae), *Ficus* spp., and *Brosimum* spp. For emergent trees, *Parkia multijuga*, *P. nitida*, and *Dialium guianense* (Fabaceae s.l.) were among the most common species.

We surveyed one understory transect of 100 individuals on the high hills and terraces at this site, where the overstory was dominated by floodplain species. We registered 81 species within 26 families, the more common species were a *Brownea* sp. (Fabaceae s.l., an understory tree with beautiful red flowers), and 2 spp. of Lauraceae. The dominant families were Fabaceae s.l. (8), Rubiaceae (8), Annonaceae (5), and Moraceae (5).

EXTREME PATCHINESS

At all three sites we observed patchiness (local homogeneity) of two different kinds: common species that almost always are clumped wherever they occur in Amazonia, and species rare elsewhere that were unexpectedly common in this region. Species that commonly form patches include *Lepidocaryum tenue*, *Rinorea lindeniana*, *R. viridifolia*, and several species of Rubiaceae (*Rudgea, Coussarea*); these species were locally abundant at one or more of our sites. Rare species included *Ampelozizyphus amazonicus* (Rhamnaceae) and *Anisophyllea guianensis* (Anisophyllaceae), both locally extremely abundant in Alto Nanay, sometimes covering entire hillsides. In Panguana, an area 20 x 20 m was covered almost entirely in *Rinorea guianensis* (Violaceae), a rare subcanopy tree.

NEW SPECIES, RARITIES, AND RANGE EXTENSIONS

Neotropical plant distributions remain poorly understood. Because of the proximity of N-M-A Headwaters to Ecuador (and because the area had never been previously visited by botanists), several of our collections are new records for Peru. These include *Touroulia amazonica* (Quiinaceae, Fig. 5I), a tree with distinctive lobed leaves known from Brazil, and an unnamed *Quararibea* with bullate, chartaceous leaves known from only a couple of individuals in Yasuní (Valencia et al. 2004). Perhaps our most remarkable record is an unusual herb with deeply lobed leaves from Panguana, *Tacca parkeri* (Fig. 5F), in the Taccaceae, a new family for Peru. We suspect that, as specialists examine fertile collections from the inventory, new records for Peru will continue to accumulate.

Some records have already been confirmed as new species. These include a *Calyptranthes* (Myrtaceae, Fig. 5C) with winged stems and tiny flower buds (B. Holst and L. Kawasaki, pers. com.), as well as an *Anomospermum* (Menispermaceae, Fig. 5B) with pendant yellow fruits (R. Gentry-Ortiz, pers. com.). Both of these new species were growing in the understory at Panguana.

Several other species are notable records. In Panguana we collected *Ruellia chartacea* (Acanthaceae, Fig. 5H), known from the Andean foothills in Ecuador, Colombia, and Peru. It is only rarely collected this far out into the upper Amazon basin.

In Alto Nanay we found abundant populations of *Wettinia drudeii* (Arecaceae, Fig. 5G), a poorly known palm restricted to northern Peru, eastern Ecuador, and southern Colombia. Vegetatively, this species closely resembles *Iriartella stenocarpa*, a better-known poor-soil specialist, and botanists may be overlooking *W. drudei* in poor soil sites.

In Alto Nanay we found a canopy tree, *Tachigali* sp., with brilliant leaves, many leaflets, and no domatia. The taxonomy of this genus remains unresolved, but we have never seen this species before and it may be new to science. Another canopy tree, a *Dipteryx* sp. (Fabaceae s.l.), had miniature leaves compared to the species we know from other sites, and does not resemble any of the *Dipteryx* reported from the Reserva Ducke in Brazil (Ribeiro et al. 1999).

We found fallen flowers and leaves of two *Dimorphandra* species (Fabaceae s.l.), a canopy tree. Four species are known from Peru, but virtually never collected, so our collections represent a significant increase in collections for Peruvian herbaria.

In Alto Mazán we found populations of an understory plant with sterile characters (leaves, stipules) that suggest *Naucleopsis ulei* (Moraceae). However, individuals were flowering and fruiting at 2-m heights, rather than the 10 m heights typical of *N. ulei* and with much smaller flowers and fruits. Our record represents *Naucleopsis humilis*, a species we were not familiar with until this inventory, and one that is likely often overlooked.

We found a terrestrial bromeliad, *Pitcairnia* (Fig. 5D), with a large spicate inflorescence and yellow flowers at Panguana. We suspect this species may be new, and found only a single population. Also at Panguana, we found *Ficus acreana*, a new record for Peru, previously known only from Brazil and Ecuador. We registered the same *Ficus* in Sierra del Divisor along the Brazilian border (Vriesendorp et al. 2006), suggesting that the species may be more broadly distributed in Loreto.

OPPORTUNITIES, THREATS, AND RECOMMENDATIONS

For plant communities in N-M-A Headwaters, timber concessions and related deforestation currently pose the greatest threat. The most valuable timber species—*Cedrela fissilis*, *Cedrela odorata*, *Cedrelinga cateniformis*—occur at extremely low densities. We did not observe any mahogany, *Swietenia macrophylla* (Meliaceae) during the inventory, and given the absence of a pronounced dry season, we suspect that this species does not occur here.

However, less valuable timber species (e.g., *Eschweilera* spp., *Virola* spp., various species of Lauraceae and Fabaceae s.l., *Simarouba amara*, Simaroubaceae; *Minquartia guianensis*, Olacaceae; *Calophyllum brasiliensis*, Clusiaceae) make up much of the forest in this region. If these species became an important part of the timber market and large-scale areas were cleared, the impact would be devastating. Vegetation plays a critical role in securing the loose soils that dominate this area, and clearcutting would promote increased erosion and heavy sedimentation.

We recommend immediate protection of the N-M-A Headwaters, and urge that other headwater areas in Loreto that overlap with forestry concessions (e.g., the Orosa and Maniti rivers in the Yavarí watershed) be formally protected.

FISHES

Authors/Participants: Philip W. Willink and Max H. Hidalgo

Conservation Targets: Communities of species adapted to the headwaters, sensitive to the effects of deforestation, and probably endemic to the region (*Creagrutus, Pseudocetopsorhamdia, Characidium, Hemibrycon, Bujurquina*); species probably new to science (*Pseudocetopsorhamdia, Cetopsorhamdia, Bujurquina*); species of high value in the ornamental fish trade (*Monocirrhus, Nannostomus, Hemigrammus, Hyphessobrycon, Otocinclus, Apistogramma, Crenicara*)

INTRODUCTION

Nanay-Mazán-Arabela Headwaters are unique among Peruvian headwaters with a drainage divide below 300 m. They are located north of the Marañón-Amazonas, close to the border with Ecuador, and separated from the Andes by more than 300 km. These headwaters in the lowland forest are divided amongst the tributaries of the Napo, Tigre, and Amazonas rivers. There are well-known studies of fishes in nearby basins, such as the Pucacuro (Sánchez 2001), Corrientes (UNAP 1997), and Pastaza (Willink et al. 2005). However, no ichthyologists previously had visited the N-M-A Headwaters region. The principal objectives of the present study are to inventory the fishes that inhabit this region and determine the conservation status of its fish communities.

METHODS

Fieldwork

During 13 days of fieldwork, we sampled aquatic habitats in three sites. We collected fishes during the day with assistance from a local guide. We hiked to all sites, with the exception of two in Alto Mazán where we paddled a kayak to sample a short distance along the Mazán River and to sample a blackwater lagoon in front of the base camp. We evaluated 20 sampling stations during the entire inventory, with six or seven stations per site. The geographic coordinates of each sampling point and basic characteristics of the aquatic environment are summarized in Appendix 3.

Of the 20 sampling points, 14 were lotic habitats (e.g., rivers and streams), and 6 were lentic habitats, including a blackwater lagoon, a *Mauritia* palm swamp known as an *aguajal* (in Alto Mazán), and four temporary small ponds and stream backwaters with still waters (Alto Mazán and Alto Nanay). In Panguana all sampled habitats were lotic. The streams and small ponds varied in water type (black, clear, and white), while the principal rivers (e.g., the Mazán) were white water.

Collection and identification

We collected fishes using four different types of fishing gear: three nets between 3 and 10 m in length, 1.5 to 2 m in height, and with a mesh size of 3 to 5 mm, and a castnet. We conducted numerous hauls with the nets along the shore and throws with the castnet, covering a sampling area of ~11,000 m^2 (Appendix 3). Additionally, the local guides in each camp used fishing lines and hooks to capture some species.

Fishes were immediately placed into 10% formalin for 24 hours, then preserved in 70% alcohol. We identified specimens each day in camp. Collections were deposited in the Museo de Historia Natural in Lima, and in The Field Museum of Natural History in Chicago, USA. Some of the identifications in the field were not to the level of species, and instead were categorized as "morphospecies" (e.g., *Hemigrammus* sp. 1). These species need a more detailed examination in the laboratory. This same methodology has been applied in other rapid inventories, e.g., Yavarí (Ortega et al. 2003a) and Ampiyacu (Hidalgo y Olivera 2004).

RICHNESS AND COMPOSITION

In 13 days we recorded (collections and observations) 4,897 individuals corresponding to 154 species, 86 genera, 30 families, and nine orders (Appendix 3). We consider this high diversity for a headwater region. The order Characiformes (fishes with scales but without spines in the fins) harbored the most species (92) and represented 60% of our records. The Siluriformes (catfishes) represented 23% of the diversity (36 species), Perciformes (fishes with spines in the fins) 8% (13 species), and Gymnotiformes (electric fishes) 3% (5 species). Beloniformes (needlefishes), Cyprinodontiformes (annual fishes), Myliobatiformes (stingrays), Batrachoidiformes (toadfishes), and Clupeiformes (herrings and anchovies) were 1% each (1 or 2 species).

At the family level, Characidae (tetras, piranhas, and others) was the best represented, with 41% (63 species). This pattern also predominates in other areas of Amazonian Loreto (Ampiyacu, Yavarí, Matsés, and Pastaza). Among the genera with the most frequently observed species in N-M-A Headwaters, we found *Moenkhausia* (11 species), *Hemigrammus* (10), *Hyphessobrycon* (6), *Creagrutus* (5), *Astyanax* (3), and *Jupiaba* (3). Together, these accounted for 60% of the species of Characidae.

Another family, Loricariidae (armored catfishes), represented 10% (15 species). Within Loricariidae, the genus *Hypostomus* had the greatest number of species (4). Cichlidae (cichlids) was moderately represented with 8% (12 species). Crenuchidae, with 6% (9 species), was best represented by the genus *Characidium*, with 4 species.

The majority of species (approximately 70%) were of small adult body size (no more than 15 cm in length) and principally within Characidae and Loricariidae. These species are adapted to the small headwater tributaries of terra-firma forests. In some cases, these species are unique to the region (*Astyanacinus, Astyanax, Creagrutus, Hemibrycon*, and *Characidium*). A few species were medium to large in body size. No migratory catfishes (such as *doncella*, *tigre zúngaro*, and *dorado*) were recorded during the rapid biological inventory. However, these species, in addition to other important species for local peoples (e.g., fishes with scales and other catfishes), are present in the Curaray and Arabela rivers, based on information compiled during the rapid social inventory (Appendix 3).

DIVERSITY WITHIN THE SITES

Based on fish richness in the biological inventory (154 species in 20 sampling stations), we estimate that 240 species are present in the entire N-M-A Headwaters (using EstimateS, Colwell 2005). The richness is notable because the area represents a relatively small region that harbors the headwaters of three distinct watersheds (Nanay, Mazán, Arabela) and we sampled the region rapidly. The surface area (approximately 136,000 ha) is only 6.7% that of Pacaya-Samiria, yet it contains a similar number of species (J. Albert, pers. comm.). The diversity represents 28% of the Peruvian continental ichthyofauna recognized to date (Ortega and Vari 1986; Chang and Ortega 1995).

Alto Mazán

This site was the most diverse of the inventory. We recorded 92 species (60% of the inventory total) corresponding to 62 genera, 26 families, and eight orders. Most of the diversity was within Characiformes with 62% (57 species), followed by Siluriformes with 20% (18 species), Perciformes with 9% (8 species), and Gymnotiformes with 5% (5 species). The other four orders were represented by 1 species each (Appendix 3B).

For Alto Mazán, the most diverse family was Characidae with 42% (39 species), followed by Loricariidae with 10% (9 species), and Cichlidae and Crenuchidae with 8% (7 species) each. Among the Characidae, small species of the genera *Moenkhausia, Hemigrammus*, and *Hyphessobrycon* were the most common in the majority of sampled habitats.

The Alto Mazán fish community is composed of species typical of the Amazonian lowlands, and had higher diversity than the two other inventory sites, Alto Nanay and Panguana. The diversity difference reflects the greater numbers of habitat types, water volume, and water types in Alto Mazán (Appendix 3). Thirty-nine species were collected only at this site. For example, *Anchoviella* and *Thalassophryne* were only encountered in the white waters of the Mazán River, while *Boulengerella* was found only in the blackwater lagoon. These habitats were not found at the other two sites. Other species, like *Myleus* and the majority of *Hemigrammus*, *Hyphessobrycon*, and *Moenkhausia,* are representative of Amazonian lowland fauna.

We did not record large catfishes (e.g., *Pseudoplatystoma* spp. and *Zungaro*) or large, scaled fishes (e.g., *Prochilodus, Brycon, Mylossoma, Plagioscion*, and *Cichla*). These species could be in Alto Mazán, and have been observed in nearby basins like Pucacuro (Sánchez 2001) and others with similar characteristics (e.g., Ampiyacu River, Hidalgo and Olivera 2004).

Alto Nanay

This site was second in diversity in the inventory. We recorded 78 species (51% of the inventory total) corresponding to 54 genera, 19 families, and 6 orders. Most of the diversity was in Characiformes with 64% (50 species), followed by Siluriformes with 21% (16 species), and Perciformes with 10% (8 species). Combined, the other three orders accounted for 5% (4 species).

Similar to Alto Mazán, Characidae had the highest number of species with 41% (32 species). The Alto Nanay fish community was dominated by small, characid species of the genera *Moenkhausia*, *Hemigrammus*, and *Hyphessobrycon* that lived in the large tributary of the Nanay River (the Agua Blanca), and the smaller streams within the forest. The clear to slightly turbid waters of all the habitats favor species with showy colors, some of which were unique to this site, such as *Nannostomus mortenthaleri* (Fig. 6B), *Hyphessobrycon loretoensis*, and *Crenicara punctulatum*. These ornamental fishes are prized in the pet trade.

Moenkhausia cf. *cotinho* and *Knodus* sp. were the most abundant species. They were frequently encountered in the streams of Alto Nanay and constituted almost 50% of fish abundance. For this site, 30 species were unique to the entire inventory. These included *Cetopsorhamdia* sp. (Fig. 6C), *Myoglanis koepckei* (Fig. 6F), *Leporinus* sp. A, *Curimatella* sp., *Creagrutus* cf. *pila*, and *Corydoras* cf. *sychri*. Agua Blanca was the most important habitat because it was the largest waterway and harbored 47% of the Alto Nanay diversity (37 species).

At this site, we observed few species typically found in the turbid water habitats of the Amazonian lowlands, such as those we saw in Alto Mazán. However, we began recording some species, e.g., *Jupiaba* and various heptapterid catfishes, that prefer swift flowing habitats with clear and black water.

Panguana

This site represented the lowest diversity in the inventory. We recorded 57 species (36% of the inventory) corresponding to 45 genera, 17 families, and seven orders. Characiformes was the most diverse order with 63% (35 species), followed by Siluriformes with 21% (12 species), and Perciformes with 5% (3 species). The other four orders accounted for the remaining 11% (with either 1 or 2 species per order). The family Characidae had the highest number of species (28) representing 49% of total richness. Loricariidae was in second place with 14% (8 species).

We encountered the lowest diversity at this site in comparison to Alto Mazán and Alto Nanay because the variety and size of aquatic habitats, and quantity of water were smaller. This site is closest to the headwater origins and drainage divides. Our sampling sites were small streams within the forest, with moderately swift currents, stream bottoms variably composed of sand, mud, and gravel, and with moderate to shallow depths. These characteristics resemble those of “rapids” in Andean foothill streams.

The fish community of Panguana was dominated by small characids (*Knodus*, *Moenkhausia*, and *Astyanax*), but we also observed armored catfishes of the genus *Ancistrus* and the cichlid *Bujurquina* sp. 2 (Fig. 6D) in all of the sampled streams. The most common species in Panguana was *Knodus* sp. (41% of the abundance). The species within this genus are all small (<7 cm as adults) and in Peru are most abundant in watersheds close to the Andes e.g., Megantoni (Hidalgo and Quispe 2005), Bajo Urubamba (Ortega et al. 2001), Pachitea (Ortega et al. 2003b), and other mountainous areas like Sierra del Divisor (Hidalgo and Pezzi da Silva 2006).

In Panguana, 27 species were unique to the entire inventory, e.g., *Astyanax* spp., *Creagrutus* sp. 3, *Creagrutus* sp. 4, *Hemibrycon* spp., and *Astyanacinus multidens*. These are species usually encountered in the Andean foothills similar to *Knodus*. Together with these species we observed groups from the Amazonian lowlands, like stingrays (*Potamotrygon*, Fig. 6H), catfishes (*Pimelodus ornatus*), piranhas and relatives (*Serrasalmus* spp. and *Myleus*), and large characids (*Leporinus*). These species are present far into the headwaters, reaching small streams with bottoms of gravel and leaves, less than 3 m in width, and less than 30 cm in depth. The relative abundance of such a variety of these lowland species could reflect great fish abundance in the Arabela River and its lagoons.

COMPARISON AMONG SITES

The diversity of fishes and biomass decreased from Alto Mazán to Panguana in relation to the decrease in habitat diversity and quantity of water (size of the watershed). Similar patterns occur in other areas of Loreto. Examples include systems with streams draining terra firme forests and medium-sized rivers, like the Ampiyacu (Hidalgo and Olivera 2004), as well as those flowing from the Andes to Amazonian lowlands, as observed in Manu (Ortega 1996) and Megantoni (Hidalgo and Quispe 2005).

The similarity in species composition among the three sites was low, with only 14 species in common (*Apistogramma* sp. 1, *Characidium* cf. *zebra*, *Charax* sp., *Chrysobrycon* sp., *Farlowella* sp., *Hoplias malabaricus*, *Knodus* sp., *Limatulichthys griseus, Moenkhausia comma, M. dichroura, M. oligolepis, Phenacogaster* sp., *Potamorrhaphis eigenmanni*, and *Tyttocharax* sp.). This represents less than 10% of the species total for the inventory. The fact that these taxa are shared among the three sites indicates that there are local species widely distributed throughout the Tigre-Napo region (with the exception of *Apistogramma* sp. 1, which may be unique to the N-M-A Headwaters).

Of these species, *Hoplias malabaricus*, *Knodus* sp., *Limatulichthys griseus, Moenkhausia comma, M. dichroura, M. oligolepis, Phenacogaster* sp., *Potamorrhaphis eigenmanni*, and *Tyttocharax* sp. are widely distributed throughout Peru, but their abundances vary with habitat. For example, *Hoplias malabaricus* is a generalist predator that is not very abundant in large rivers, but is frequently encountered in lagoons or small ponds with mud or leaf bottoms, where it waits for possible prey. *H. malabaricus* is very resistant to significant changes in the physiochemical properties of water. On the other hand, the tiny *Tyttocharax* (which is one of the smallest vertebrates in the Neotropics) inhabits only clear or blackwater streams of high water quality.

The percentage of species unique to each site was high, ranging from 38% for Alto Nanay to 42% for Alto Mazán and 48% for Panguana. This indicates broad variation in fish species composition within a relatively small study area at relatively low elevation (less than 270 m asl). Especially notable is that each inventory site appears to house different fish communities that may be unique to each basin's headwaters.

This has been observed in other regions of Andean headwaters, including Megantoni (Hidalgo and Quispe 2005) and recently in the Sierra del Divisor (Hidalgo and Pezzi da Silva 2006). This is consistent with the hypothesis that headwater regions are isolating mechanisms (Vari 1998, Vari and Harold 1998).

NEW SPECIES, RARE SPECIES, AND/OR RANGE EXTENSIONS

We estimate that 12 species are new records for Peru or new to science (Appendix 3). Among the potentially new species are two small heptapterid catfishes found in streams with sand bottoms in Alto Nanay (*Cetopsorhamdia*, Fig. 6C) and in the riffles of the streams in Panguana (*Pseudocetopsorhamdia*, Fig. 6A). *Bujurquina* sp. 2 (Fig. 6D) from Panguana may also be a new species.

In the Mazán River, we encountered *Thalassophryne amazonica* (Fig. 6E), a species that is not very common in

Amazonia. The family is principally marine. This species is poorly represented in scientific collections. It has spines in the dorsal region that are connected to venom glands that can cause intense pain. We recorded a heptapterid catfish, *Myoglanis koepckei* (Fig. 6F), described originally from the lower part of the Nanay (Chang 1999). It was initially known from the three type specimens. Eight examples were collected in the Matsés inventory (Hidalgo and Velásquez 2006). We collected it in the headwaters of the Nanay, which is now the northernmost record for the distribution of this species.

DISCUSSION

The diversity of fishes in N-M-A Headwaters is very high (154 species) considering that the aquatic habitats present are medium-sized to small, and that large lakes and extensive flooded zones are absent. These headwaters are not as rich in species as some lower elevation areas of the Peruvian Amazon (Pastaza, 277 species, Willink et al. 2005; Yavarí, 240 species, Ortega et al. 2003a; Ampiyacu, 207 species, Hidalgo y Olivera 2004). However, on a global scale, the area harbors substantial significant species richness. An inventory of the Pucacuro River watershed, which borders N-M-A Headwaters, reported 148 species (Sánchez 2001), mainly species widely distributed throughout Loreto. In contrast, the species that live in the headwater streams of Panguana and Alto Nanay are different.

In the Cordillera Azul, Cordillera del Cóndor, Cordillera de Vilcabamba, Megantoni, and the Alto Madre de Dios, the elevational gradients are much more pronounced, which causes rivers and streams to cover greater distances. This creates significant differences in the physiochemical properties of the water between high and low elevations, principally in regard to the temperature of the water, quantity of nutrients, and amount of dissolved oxygen. In N-M-A Headwaters region, these characteristics do not vary as markedly as in the Andes. The water quality measures fall within what is expected for lowland forests, yet the differences seem to be large enough to influence the habitat preferences of some species.

The fish fauna includes genera usually found in the Andean foothills mixed with forms from the Amazonian lowlands, in an area that is isolated from the Andes. We encountered a mixture of common species with wide distributions and general habitat preferences (*Hoplias* and various species of *Moenkhausia,* among others), lowland species that seem to have dispersed into these headwaters (*Potamotrygon, Hemigrammus*, and *Hyphessobrycon*), and species usually abundant in the Andean foothills up to 1,000 m elevation (some species of *Creagrutus, Hemibrycon, Knodus*, and large species of *Astyanax* and *Characidium*).

These headwaters are unique in Peru because the majority of other headwaters begin along the slopes of the Andes, as is the case with the rivers to the west and southwest of the Marañón-Amazonas. To the north of this area, all the largest rivers (e.g., Putumayo, Napo, Tigre, Pastaza) originate in the Ecuadorian Andes.

THREATS

Deforestation of riparian areas and upland primary forest increases erosion and leads to subsequent sedimentation of aquatic habitats, especially in the terra firme forests of the headwaters. Sedimentation produces changes in microhabitats for species living along stream or river bottoms (benthic species), such as *Characidium, Melanocharacidium, Potamotrygon*, and various small catfishes.

Similarly, increases in sedimentation affects aquatic insect larvae (benthic macroinvertebrates), which were relatively abundant in the streams of the three sites, especially in Panguana (e.g., Plecoptera, Ephemeroptera, Trichoptera, and Megaloptera). These macroinvertebrates serve as food for fishes. Their presence and abundance indicates high water quality, which is why they are used to monitor environmental impacts in aquatic habitats.

Another related effect of deforestation is reduction of allochthonous material provided by the surrounding vegetation (leaves, sticks, terrestrial insects falling into the water). This material is critical for many fishes, as it is as source of food, refuge, and nesting sites.

In combination, these effects would produce local changes in community structure by changing food web structure, diversity and fish biomass. On a larger scale, fewer nutrients would travel downstream via rivers into the floodplain, thereby also affecting those ecosystems and decreasing their productivity.

Other threats to the fish community are large-scale extractive activities, such as overfishing (e.g., using poison or dynamite to harvest fishes). These activities are not selective and have a tremendous impact on the fishes at the population level (at least locally) by producing mass mortality and creating near-impossible odds for population recovery. For humans who inhabit the impacted area, there are fewer fishes available for consumption. Additionally, fishing with large boats with refrigeration capabilities increases the pressure on resources in the medium- to long-term by reducing populations to sizes below the minimum-size permitted by Peruvian law for commercial species.

Petroleum exploitation represents another threat to the fish communities because of the high contamination risk for aquatic habitats. Oil exploration and extraction generates petroleum, derivatives, and drilling liquids with a high content of heavy metals that contaminate nearby waters. These substances can overwhelm rivers and streams, generating strong impacts both in the short-term (death) and long-term (bioaccumulation, biomagnification).

OPPORTUNITIES

N-M-A Headwaters represents a great opportunity to conserve an area with high fish diversity. This region is interesting for scientific study as well as an important management priority for the local human communities.

Probably a few species of large catfishes, such as *Pseudoplatystoma* (doncellas and tigre zúngaros) inhabit Alto Mazán. Other genera, like *Brachyplatystoma* (dorados, saltones, and a few others), do not reach these areas, but they are present in the Arabela and Curaray (Appendix 3). The entire drainage needs to be protected to conserve large migratory catfishes. However, from an environmental perspective, the health and protection of the headwaters is beneficial to the entire area downstream.

Headwaters with drainage divides within lowland Amazon likely create isolated habitat "islands" for fish species, especially those that appear to be endemic to the region. This creates an excellent opportunity for biogeographic and evolutionary studies.

RECOMMENDATIONS

- Prohibit commercial fishing.
- Enforce prohibited fishing methods (e.g., poisons, dynamite) and minimum catch sizes.
- Investigate other important habitats for fishes, such as the Arabela River and associated lakes. They likely harbor important species for consumption, such as migratory catfishes.
- Continue inventories beyond N-M-A Headwaters, focusing on other headwater streams within the same watershed to determine whether species are restricted to particular headwaters or watersheds, and verify if N-M-A Headwaters represent a biographic island or an extension of the Ecuadorian Andes (Fig. 2B).
- Design and implement a monitoring and inventory plan for large catfishes, paying particular attention to determining whether these species spawn in the headwaters.
- Monitor fish abundances and fisheries in N-M-A Headwater region.

AMPHIBIANS AND REPTILES

Authors/Participants: Alessandro Catenazzi and Martín Bustamante

Conservation targets: An abundant population of *Atelopus* sp. (Fig. 7C), a new species within a genus considered threatened with extinction throughout its geographic range; amphibians and reptiles whose reproduction and life histories depend on streams; two species that are new to science: *Atelopus* sp. (Fig. 7C) and *Eleutherodactylus* sp. (Fig. 7A); species with commercial value, such as turtles (*Geochelone denticulata*) and caimans (*Caiman crocodilus*), especially in riparian forests and oxbow lakes at the Arabela and upper Mazán rivers

INTRODUCTION

Northern Loreto is poorly known from a herpetological point view, with the exception of Duellman and Mendelson's report (1995) on the headwaters of Tigre and Corrientes rivers (~120 km southwest of Nanay-Mazán-Arabela Headwaters) and an amphibian and reptile inventory in the Pucacuro watershed (Rivera et al. 2001). Other herpetological surveys in Loreto focus on the herpetofauna around Iquitos (Dixon and Soini 1986; Rodríguez and Duellman 1994) and the Reserva Nacional Allpahuayo-Mishana. In addition, herpetologists have conducted rapid inventories in Loreto, including the Matsés region (Gordo et al. 2006), the Yavarí River (Rodríguez and Knell 2003), Sierra del Divisor (Barbosa and Rivera 2006) and the Ampiyacu, Apayacu, Yaguas, and Medio Putumayo rivers (Rodríguez and Knell 2004). All studies in the region report very high richness of amphibians and reptiles.

Our inventory of Nanay-Mazán-Arabela (N-M-A) Headwaters was a great opportunity to explore herpetological communities in streams and forests in a drainage divide of the upper Amazonian basin. The area represents the only place west of Iquitos where Amazon headwaters originate within Peru and not in Ecuador. Despite their singularity, these habitats have not been well studied and are not represented in protected areas in Loreto.

METHODS

We worked from 15 to 30 August 2006 on the upper reaches of the Mazán River, Nanay River, and Panguana stream (a tributary of the Arabela River). We searched for amphibians and reptiles opportunistically by walking trails, surveying water bodies (oxbow lakes, streams, etc.), and by sifting through the leaf litter in potentially good sites for herpetofauna (areas with abundant leaf litter, bases of tree buttresses, dead logs, palm leaves). Our search effort was 187 person-hours, with 72, 51 and 64 person-hours in the Alto Mazán, Alto Nanay and Panguana sites, respectively. We surveyed six days in Alto Mazán, four days in Alto Nanay, and five days in Panguana.

We identified each captured or observed species, and recorded abundance. We identified several frog species by their call and included observations by other researchers and members of the logistics team. We photographed at least one individual for most of the species observed during the inventory.

For species with uncertain identifications, potentially new species or new records, and for species that are poorly represented in natural history collections, we made a reference collection (87 specimens: 76 amphibians and 11 reptiles). These specimens were deposited in the Museo de Historia Natural de la Universidad Nacional Mayor de San Marcos (Lima) and the Museo de Zoología de la Pontificia Universidad Católica del Ecuador (Quito).

RICHNESS AND COMPOSITION

We found 54 amphibian species and 39 reptile species, with amphibian species representing 2 orders, 8 families and 21 genera, and reptiles representing 3 orders, 14 families and 32 genera. The most diverse families were Hylidae, Brachycephalidae and Leptodactylidae for amphibians, and Gymnophtalmidae, Colubridae and Polychrotidae among reptiles.

The species richness recorded during the inventory (54 amphibians, 39 reptiles) represents ~50% of the amphibian diversity and ~40% of the reptile diversity we estimate occurs in the entire N-M-A Headwater region. Our estimates are based on previous studies in other Amazonian localities (Duellman and Mendelson 1995; Rivera et al. 2001). We recorded 93 species in just 15 fieldwork days, which indicates the N-M-A region harbors extraordinary herpetological diversity. This is not surprising because amphibian and reptile communities in Loreto and the Ecuadorian Amazon are considered the most diverse in the world.

Headwater areas lack large water bodies, and water sources are distributed more irregularly than in floodplain forests. The most common amphibians were species that live in leaf litter and do not depend on large aquatic habitats for their reproduction, such as the toad *Rhinella* [*Bufo*] "margaritifer," and the frogs *Allobates* [*Colostethus*] *trilineatus* and *Eleutherodactylus* *ockendeni*. Another interesting leaf litter frog is *Syncope tridactyla* (Fig. 7G); this frog was previously known from only one specimen collected at the type locality (Duellman and Mendelson 1995). Most of the tree frogs (Hylidae) we found during the inventory were riparian species or species that breed in oxbow lakes and streams, such as *Hypsiboas boans*, *H. lanciformis,* and *H. geographicus*.

Reptiles are not limited by aquatic habitat availability for reproduction. Nevertheless, common species in this group, such as *Kentropix pelviceps*, *Gonatodes humeralis* and *Anolis fuscoauratus* among lizards and *Imantodes cenchoa*, *Xenoxybelis argenteus* and *Leptodeira annulata* among snakes, were also associated with leaf litter and understory vegetation. We found some snake species with aquatic affinities in the *Mauritia* swamps, such as the coral snake *Micrurus lemniscatus* and the frog-egg eater *Drepanoides anomalus*.

The pattern of lizard richness roughly seems to follow a productivity gradient across our inventory sites. We found eight lizard species in the white and brown sand (nutrient-poor) forests in Alto Nanay, and up to 16 species in a forest growing on nutrient-rich clay soil forests in Panguana. We observed ~5 times as many individual lizards in Panguana as in Alto Nanay.

We found several rare frog species that are characteristic of small streams (Fig. 3B). Several individuals (calling males, egg clutches) of the rare *Cochranella midas* were found, as well as an abundant population of *Atelopus* sp. (Fig. 7C), a species within the most threatened frog genus in the Neotropics.

DIVERSITY AT THE SITES

Alto Mazán

We recorded 25 amphibian and 21 reptile species. Three amphibian and one reptile species were recorded only at this site in the inventory. The most common species were *Rhinella* [*Bufo*] "margaritifer," *Allobates* [*Colostethus*] *trilineatus* and *Hypsiboas geographicus* among amphibians, and *Gonatodes humeralis*, *Kentropyx pelviceps* and *Anolis fuscoauratus* among reptiles. Similar to other groups (plants and mammals), the number of species per sampling effort was low at this site, possibly due to the low diversity of sampled habitats. We did not survey the hills about 300–500 m from the river, which could hold different amphibian and reptile species. The habitats we sampled were close to the river and lacked hills. In these habitats, a great part of the diversity was composed by species associated with aquatic habitats, such as oxbow lakes, *Mauritia* swamps, marshes and temporary ponds. We found considerable snake diversity in the *Mauritia* swamps. At the oxbow lake near the camp, we observed several treefrogs (Hylidae) and individuals of *Caiman crocodilus*.

Alto Nanay

This was the site with the smallest sampling effort and the lowest number of species. We found 40 species, with 27 amphibians and 13 reptiles. Ten amphibian and four reptile species were found exclusively at this locality. The most common amphibians were *Rhinella* [*Bufo*] "margaritifer," *Allobates* [*Colostethus*] *trilineatus* and *Eleutherodactylus peruvianus*, whereas the most common reptiles were *Imantodes cenchoa*, *Xenoxybelis argenteus,* and *Potamites* [*Neusticurus*] *ecpleopus*.

One of the highlights of this locality was an abundant population of *Atelopus* sp. (Fig. 7C). This new species of harlequin frog has survived the severe extinction process affecting the genus throughout the Neotropics (La Marca et al. 2005). *Cochranella midas*, another representative of a frog family (Centrolenidae) that is threatened by declines in other Neotropical sites, was abundant in Alto Nanay. We recorded intense reproductive activity of *C. midas* along two streams.

Panguana

At Panguana we recorded the highest diversity of amphibians (31 species) and reptiles (26 species). Fifteen amphibian and 11 reptile species occurred exclusively at this locality. The most common amphibian species were *Eleutherodactylus ockendeni*, *Allobates* [*Colostethus*] *trilineatus,* and *Rhinella* [*Bufo*] "margaritifer." *Kentropyx pelviceps*, *Imantodes cenchoa,* and *Anolis trachyderma* were the most common reptiles.

Panguana is dominated by hills (up to 270 m) and forms part of a complex topography that extends from the base of the Andes in Ecuador to northern

Loreto. We expected to find similar species richness and composition in Panguana, Alto Mazán, and Alto Nanay. We think that the greater number of species in Panguana compared to Alto Mazán and Alto Nanay may reflect greater forest productivity and more complex relief in Panguana. These conditions favor frog species that do not depend on water bodies for reproduction, e.g., *Eleutherodactylus* spp. In contrast, frogs that require large water bodies, e.g., species in the Hylidae and Leptodactylidae, should be more common in Alto Mazán and Alto Nanay.

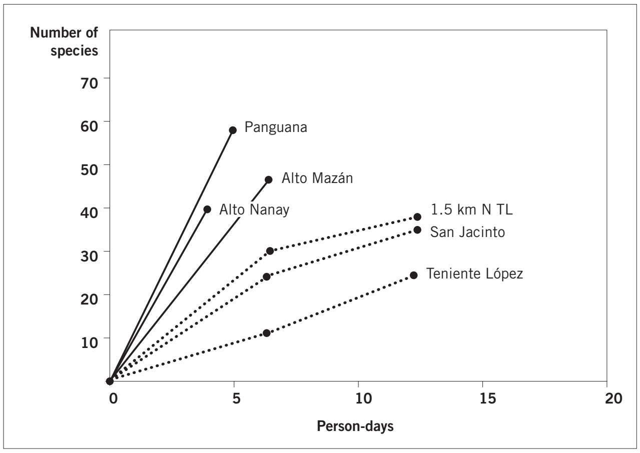

Fig. 11. Species accumulation curves for amphibians and reptiles during the first 12 person-days in three sites of the Tigre and Corrientes basins (1.5 km north of Teniente López, San Jacinto, Teniente López: Duellman and Mendelson 1995) and 4–6 person-days in our sites in N-M-A Headwaters (Panguana, Alto Nanay, Alto Mazán).

COMPARISON WITH THE HERPETOFAUNA OF NEARBY SITES

Duellman and Mendelson (1995) documented the herpetofauna of the Tigre and Corrientes watersheds, 120 km southwest of N-M-A Headwaters. The Tigre and Corrientes basins have topographical characteristics similar to those we encountered in this inventory. Duellman and Mendelson found 68 amphibian and 46 reptile species, with a sampling effort of 66 person-days, between January and April 1993. One difference is that in addition to transect surveys, they also sampled herp species by using pitfall traps. Our sampling effort was smaller (30 person-days) but our cumulative numbers of species by sampling effort were greater than theirs (Fig. 11). In both studies, the most abundant species were those that live in the leaf-litter. In addition, both our study and theirs estimate that the recorded diversity corresponds to approximately half the number of species we expect to find in N-M-A Headquarters.

Rivera et al. (2001) intensively sampled amphibians and reptiles at several sites along the Pucacuro River, which is the closest river drainage west of the Mazán and Nanay drainages. They found 84 amphibian and 64 reptile species. The well-known herpetofauna of the forests along the lower Nanay river, in the Allpahuayo-Mishana National Reserve, includes 83 species of amphibians and 120 species of reptiles (Álvarez et al. 2001). These two studies underscore the impressive herpetological diversity of the region.

NEW AND RARE SPECIES, RANGE EXTENSIONS

A species of frog, *Cochranella midas*, is a new record for Loreto. This glass frog was abundant along small streams of the Alto Nanay. A *Cochranella* frog, possibly belonging to the same species, has also been reported from Allpahuayo-Mishana and Pucacuro.

In Panguana we found an individual of *Syncope tridactyla* (Fig. 7G), a species previously known only from its type locality, San Jacinto in the Corrientes watershed. This species was described by Duellman and Mendelson (1995).

We found five toadlets of a new species of *Atelopus* (Fig. 7C) during an hour of intensive searching along 20 m of a stream in Alto Nanay. This species has been previously reported from Lorocachi, in the Ecuadorian province of Pastaza, near the border with Peru, but its taxonomic status has not been resolved (Coloma 1997). There also is a photographic record from the Apayacu river, southeast of N-M-A Headwaters (Bartlett and Bartlett 2003).

Several *Eleutherodactylus* species remain unidentified, but at least one species is new to science, clearly distinguishable from other species in the genus by its distinctive blue coloration in the groin and hidden parts of arms and legs (Fig. 7A).

In addition to these new records, we found species whose southernmost distribution limit is now N-M-A Headwaters, such as *Hypsiboas nympha* (third published report for Amazonian Peru), *Osteocephalus cabrerai* (second published report for Amazonian Peru), and *Osteocephalus* cf. *fuscifacies* (described and known from Ecuador, first report for Peru).

THREATS, OPPORTUNITIES, AND RECOMMENDATIONS

Commercial logging and related activities represent the main threat to the herpetofauna. These activities include logging, construction of trails, use of tractors and heavy machinery, transportation through rivers and large streams, and hunting. Habitat destruction and fragmentation by selective logging and deforestation are a threat to the many rare species associated with primary forests, and can create conditions where these rare species are replaced by widespread, opportunistic species. Tractors and heavy machines change drainage patterns and represent a major threat to species that breed in small streams and ponds. Stream- and pond-breeding species are an important component of the herpetofauna of N-M-A Headwaters. Transportation along rivers can be a source of disturbance for large reptiles and for those species that are vulnerable to hunting (caimans and turtles). Habitats along headwater streams are extremely sensitive to changes by deforestation or contamination.

Oil exploration and extraction activities are a potential threat. Some negative consequences of these activities are habitat changes associated with road and oil pipe construction, and contamination from industrial by-products and oil spills. The headwaters of the Tigre and Corrientes rivers, which have an orography and herpetofaunas similar to those of the Mazán headwaters, are already negatively impacted by oil spills and water pollution with the by-products of oil extraction.

N-M-A Headwaters represent a unique opportunity to protect amphibian and reptile communities that are among the richest on the planet, and that are under-represented in other protected areas. Several amphibian species reach their southern limit of geographic distribution within N-M-A Headwaters, and do not occur in other areas of Loreto. These species are found in the Ecuadorian Amazon in areas of complex orography. Effective protection of N-M-A Headwaters will conserve abundant, intact populations of herpetofauna restricted to hill forests.

Many species in headwater habitats are especially vulnerable because they have low population density or peculiar life histories. For species with low population density, such as large reptiles, commercial hunting and overexploitation should be forbidden. Headwater populations could serve as refuge, from which large reptiles could recolonize areas that have been over-exploited. The harlequin frog *Atelopus* sp. (Fig. 7C) is a highly vulnerable species deserving immediate conservation and research efforts. We need to extend our knowledge of the biology and distribution of this species, and to develop monitoring programs for its populations.

Our main recommendation is to exclude forestry and oil concessions from N-M-A Headwaters. Extractive activities will cause substantial diversity loss among amphibian and reptile species. We recommend incorporating the greatest number and diversity of aquatic habitats within N-M-A Headwaters, especially oxbow lakes and old river and stream meanders, because including these habitats will dramatically increase the number of protected species of amphibians and reptiles. To ensure the population viability of large reptiles, we recommend increasing the connectivity among habitats and ecosystems. In this vein, we recommend establishing biological corridors between nearby areas in Loreto and Ecuador, such as Güeppi and Yasuní.

BIRDS

Participants/Authors: Douglas F. Stotz and Juan Díaz Alván

Conservation targets: A dozen bird species restricted to white-sand forests, rare habitats within Peru and Amazonia; diverse avifauna of terra firme forests; game birds, e.g., Salvin's Curassow (*Crax salvini*) under considerable hunting pressure in other parts of their range, especially in Loreto; isolated populations of foothill species

INTRODUCTION

Loreto is an extraordinarily diverse area for many organisms, including birds. However, much of northwestern Loreto remains poorly known, as most avian surveys have concentrated on areas close to the Amazon River. We surveyed a previously unknown area in northwestern Loreto between the Curaray and Tigre Rivers, in Nanay-Mazán-Arabela (N-M-A) Headwaters (Fig. 2A). Several areas provide important points of reference for our inventory. In 1993, Álvarez (unpub.) surveyed the birds of the Tigre River, the major drainage south of the area we surveyed. In 1925, the Ollalas made important collections near the mouth of the Curaray River, ~140 km southeast of our first inventory site. However, some of the Ollalas records should be treated with caution as there are questions about the reliability of the locality data (T. Schulenberg pers. comm.).

Perhaps the most relevant site for comparison is the well-studied Allpahuayo-Mishana National Reserve near Iquitos on the lower Nanay River (IIAP 2000, Álvarez 2002). Allpahuayo-Mishana supports extensive areas of white-sand soils and a well-documented poor-soil specialist avifauna. Recent rapid inventories in the Ampiyacu, Apayacu, Yaguas, and Medio Putumayo (AAYMP) drainages (Stotz and Pequeño 2004) and the proposed Reserva Comunal Matsés (Stotz and Pequeño 2006) also provide relevant points of comparison. The AAYMP is a relatively rich soil area north of the Amazon and east of the Napo River, while the proposed Reserva Comunal Matsés is south of the Amazon with a broad range of soil fertilities, including white sands.

METHODS

Our protocol consisted of walking trails, looking and listening for birds. We (Stotz and Díaz) conducted our surveys separately to increase the independent-observer effort. Typically, we departed camp before first light, remaining in the field until mid-afternoon, returning to camp for a 1–2 hour break, and going back to the field until sunset. We tried to cover all habitats within an area, although total distance walked at each camp varied with trail length, habitat, and density of birds. Each observer typically covered 5–10 km per day.

Both observers carried a tape recorder and microphone to document species and to confirm identification using playback. We kept daily records of species abundances, and compiled these records during a round-table meeting each evening. Observations by other members of the inventory team, especially D. Moskovits, supplemented our records.

We spent four full days at Alto Mazán and Panguana, and Díaz spent an extra day at Alto Mazán. At Alto Nanay, we spent only three full days in the field. Stotz and Díaz spent ~88 hours observing birds at Alto Mazán, ~67 hours at Alto Nanay, and ~ 83 hours at Panguana.

In Appendix 5, we estimate relative abundances using our daily records of birds. Because our visits to each of these sites were short, our estimates are necessarily crude, and may not reflect bird abundance or presence during other seasons. For the three inventory sites, we used four abundance classes. *Common* indicates birds observed daily in substantial numbers (averaging ten or more birds); *fairly common* indicates that a species was seen daily, but represented by fewer than ten individuals per day. *Uncommon* birds were encountered more than two times during the inventory, but not seen daily, and *rare* birds were observed only once or twice as single individuals or pairs.

RESULTS

We recorded 372 species of birds during the rapid inventory of N-M-A Headwaters of northwestern Loreto. Broadly speaking, this is a typical number of species for rapid inventories of this duration and number of sites in western Amazonia. The forest birds that occur in N-M-A Headwaters represent a rich assemblage, enhanced by the variety of soils and forest types found in the region. However, because of the absence of large, slow-moving rivers and substantial oxbows lakes in the survey area, a number of species associated with extensive successional vegetation, beaches, and/or river islands are likely rare or absent. We estimate that the total avifauna is 480 to 500 species.

Avifaunas at surveyed sites

Bird species richness varied dramatically across sites, roughly correlated with variation in soil richness. We recorded 297 species at Panguana, the site with the richest soils, 271 species at Alto Mazán, with intermediate soil richness, and 221 species at Alto Nanay, the area with the poorest soils.

Alto Nanay

Poor soils dominate Alto Nanay, and consequently bird richness and abundance were low, although not as low as at the white-sand site (Itia Tëbu) surveyed during the Matsés inventory (Stotz and Pequeño 2006). Bird richness and abundance were highest close to the river and declined into the hills away from the river. Away from the river, bird species associated with poor-soils, especially white sands, were much more diverse and abundant.

A well-defined set of species specializes on forests on white sand and other extremely poor soils in the Iquitos area (Álvarez and Whitney 2003), including at least four recently described species restricted to these forests in northeastern Peru. Of the 19 species listed by Álvarez and Whitney (2003) as associated with white-sand and other extremely poor soils in northeastern Peru north of the Amazon, we registered 11 at Alto Nanay. These include three of the four newly described species—Ancient Antwren (*Herpsilochmus gentryi*, Fig. 8A), Allpahuayo Antbird (*Percnostola arenarum*, Fig. 8G), and Mishana Tyrannulet (*Zimmerius villarejoi*, Fig. 8C)—and five species only recently recorded for the first time in Peru: Brown-banded Puffbird (*Notharcus ordii*, Fig. 8B), Zimmer's Tody-Tyrant (*Hemitriccus minimus*), Helmeted Pygmy-Tyrant (*Lophotriccus galeatus*), Saffron-crowned Tyrant-Manakin (*Neopelma chrysocephalum*), and Pompadour Cotinga (*Xipholena punicea*, Fig. 8F). We discuss these poor-soil specialists, important bird conservation targets for this area in more detail below.

Although bird abundance at Alto Nanay was generally low in the forest compared to the other two sites, the abundance and diversity of army-ant-following birds was higher here. In addition to good numbers of the regular ant-followers, other antbird species that are typically irregular at ant swarms, like Rufous-capped Antthrush (*Formicarius colma*), Mouse-colored Antshrike (*Thamnophilus murinus*), Black-faced Antbird (*Myrmoborus myotherinus*), and Spot-backed Antbird (*Hylophylax naevius*), occurred regularly at the ant swarms at this site.

Alto Mazán

The Alto Mazán site had a moderately rich avifauna, with the greatest diversity of frugivorous species in the inventory. However, the abundance of birds in the forest here was slightly below average for an Amazonian site. Although the soils were not notably poor, we observed a few species associated with poor soils, *Herpsilochmus gentryi* (Fig. 8A), White-ringed Flycatcher (*Conopias parva*), and Orange-crowned Manakin (*Heterocercus aurantiivertex*, Fig. 8D). All were less abundant than at Alto Nanay. The first two species occurred in small numbers in fairly open forest with an understory dominated by *Lepidocaryum tenue* palms (known locally as *irapay*) on the moderate-sized hills well away from the river. We saw the *Heterocercus* once in a small *Mauritia* palm swamp (*aguajal*).

Despite evidence of hunting in the area, game birds were generally common and diverse, with four species of Cracidae and seven species of Tinamidae. This suggests that hunting in the region may focus mostly on mammals.

Notable records from this site included one sighting of the patchily distributed and always rare Zigzag Heron, *Zebrilus undulatus*, near the small oxbow lake. Slaty-backed Forest-Falcon, *Micrastur mirandollei*, typically quite rare and outnumbered by other forest-falcons, was fairly common at this site, with multiple birds heard daily. The only other forest-falcon we recorded here was a single record of Collared Forest-Falcon, *Micrastur torquatus*.

Panguana

Panguana was easily the most diverse site. Both species richness and abundance of birds was greater here than at the other two sites. Game birds were common. Most notable was the abundance of Salvin's Currasow, *Crax salvini*, the largest game bird in the region and usually quite scarce and skittish. Here pairs were relatively tame and seen daily, and a pair with young was observed on one occasion.

Two elements of the avifauna were found only at Panguana and not elsewhere on this survey: One, a set of species associated with tangly, riverine forest and two, a set of birds that are mostly associated with the Andean foothills, but which occur locally in northern Amazonia. Many of the riverine species are widespread and common, but a handful of species constituted significant records. These included a couple of relatively minor range extensions. Plain Softtail, *Thripophaga fusciceps*, is patchily distributed in Amazonia, with the only previous records north of the Amazon and west of Brazil being a handful of records from eastern Ecuador (Ridgely and Greenfield 2001). Long-tailed Tyrant, *Colonia colonus*, is typically found in the lowlands at the base of the Andes in northwestern Amazonia; our records at Panguana extend the range eastward about 200 km.

Andean foothill species found at Panguana included five species: Sapphire Quail-Dove (*Geotrygon sapphirina*), Black-throated Brilliant (*Heliodoxa schreibersii*), White-shouldered Antshrike (*Thamnophilus aethiops*), Scaled Antpitta (*Grallaria guatemalensis*), and Black-and-white Tody-Flycatcher (*Poecilotriccus capitalis*). All of these species are primarily foothill species, but their distributions extend out into the northwestern Amazonian lowlands. *Grallaria guatemalensis* was known previously in the Peruvian lowlands only from records along the Tigre River (Álvarez, unpubl.), although it is widespread in the eastern lowlands of Ecuador. *Geotrygon sapphirina* is widespread in eastern Ecuador, but not previously known from the lowlands of Peru north of the Amazon.

DISCUSSION

Birds of poor-soil forests (*varillal*)

Between 1997 and 2005, ornithologists (especially J. Álvarez and his colleagues) discovered four species new to science and several other species that were new from Peru in surveys of white sand areas near Iquitos (Álvarez and Whitney 2001, 2003; Isler et al., 2002a; Isler et al., 2002b; Whitney and Álvarez 1998, 2005). Although found on white-sand soils, these species do range more extensively through Amazonia, especially northeastern Amazonia.

Of the nineteen species of birds (Álvarez and Whitney 2003) associated with poor soils, especially white sands, we found eleven. These include three of the four newly described species (*Herpsilochmus gentryi*, *Percnostola arenarum*, and *Zimmerius villarejoi*), five species recently added to the known Peruvian avifauna (*Notharcus ordii, Hemitriccus minimus*, *Lophotriccus galeatus*, *Neopelma chrysocephalum*, and *Xipholena punicea*), and three white-sand species that have been long known from Peru but only recently associated with poor soils, Rufous Potoo (*Nyctibius bracteatus*), Zimmer's Antbird (*Myrmeciza castanea*), and *Conopias parva*. We recorded an additional two species associated with poor soils but not mentioned by Álvarez and Whitney (2003): Fuscous Flycatcher (*Cnemotriccus fuscatus duidae*) and *Heterocercus aurantiivertex* (Fig. 8D).

Eight poor-soil species known from northwestern Loreto (Álvarez and Whitney) were not recorded on this inventory. These are Gray-legged Tinamou (*Crypturellus duidae*), Barred Tinamou (*Crypturellus casiquiare*), White-winged Potoo (*Nyctibius leucopterus*), Band-tailed Nighthawk (*Nyctiprogne leucopyga*), Cherrie's Antwren (*Myrmotherula cherriei*), Cinnamon-crested Spadebill (*Platyrinchus saturatus*), Cinnamon Tyrant (*Neopipo cinnamomea*), and Iquitos Gnatcatcher (*Polioptila clementsi*). All are known from the lower Nanay or Tigre rivers. All of these unrecorded species except the *Polioptila* range east locally in poor-soil areas at least as far as southern Venezuela.

Álvarez (2002) grouped the birds associated with white-sand forests at Allpahauyo-Mishana on their degree of specialization on these forests, ranging from facultative (more common in white-sand habitats than other habitats) to obligate (always in white-sand habitats). The poor-soil species at Alto Nanay run the gamut of specialization with 6 of the 8 obligate, 6 of the 8 near-obligate, and 6 of the 10 facultative species present. Given the broad representation of white-sand birds, it seems likely that all of the white-sand species of northwestern Loreto would be found on the upper Nanay with additional surveys, except perhaps the extremely rare and restricted *Polioptila clementsi.*

Polioptila clementsi is known only from a small population. It is very patchily distributed at Allpahuayo-Mishana (Whitney and Álvarez 2005), and is absent from much habitat that appears to be appropriate. With only a single known population and a total population estimate of fewer than 100 individuals, it is considered Critically Endangered (BirdLife International 2000). It co-occurs with several of the species we recorded, so it is possible that it occurs in other poor-soil habitats of northern Loreto. Survey of appropriate habitat for this species is a high priority. Although none of the other white-sand specialists are considered endangered, *Percnostola arenarum* (Fig. 8G) and *Zimmerius villarejoi* (Fig. 8C) are treated as Vulnerable (BirdLife International 2006a, 2006b), and *Herpsilochmus gentryi* (Fig. 8A) as Near-Threatened (BirdLife International 2000).

The four newly described species, plus *Myrmeciza castanea* (Fig. 8E) and *Heterocercus aurantiivertex* (Fig. 8D), are restricted to northwestern Amazonia in Peru and/or Ecuador. *Percnostola arenarum* was previously known only from Allpahuayo-Mishana and its immediate vicinity, and recent records from the lower Morona River. *Zimmerius villarejoi* was previously known from Allpahuayo-Mishana and near Tarapoto in San Martín. The other species restricted to northwestern Amazonia are known to extend into Ecuador. The other species of poor-soil birds we observed extend east into at least central Amazonia, although *Neopelma chrysocephalum* and *Xipholena punicea* (Fig. 8F) previously had been recorded in Peru only from Allpahuayo-Mishana.

Comparison among sites

The three sites shared 151 species. At Panguana, the most diverse site, we found 51 species not recorded at the other two sites. In Alto Mazán we found 33 unique species, while the least diverse site, Alto Nanay still had 23 species recorded only there. The unique species at Panguana included 21 species found in dense, tangly forest along the Panguana stream, a habitat not encountered at the other sites, and 5 species associated with foothills in much of their range (discussed above). Ten of the unique species at Alto Nanay were found primarily on the hills with poor-soils and relatively open canopy forests away from the river, a habitat absent at Panguana and much more poorly developed at Alto Mazán. Seven of the remaining species only found at Alto Nanay were rare species from along the river edge. At Alto Mazán, the unique species (21) were mainly at the river edge or using the river itself.

Low diversity at Alto Nanay was reflected in many different groups but the most notable group was the frugivores, especially parrots (7 species compared to 13 and 14 at Alto Mazán and Panguana respectively), tinamous (only 3 species at Alto Nanay), and Icteridae (a single sighting of Yellow-rumped Cacique, *Cacicus cela* was the only record of this family). The absence of *Mauritia* palm swamps near Alto Nanay may play a role in the scarcity of frugivores, especially among the larger parrots. Only one *Ara* macaw (Scarlet Macaw, *Ara macao*) was present at Alto Nanay, compared to four species at the other two sites. Hummingbirds were also less abundant and diverse at Alto Nanay, with only 7 species recorded (compared to 8 at Alto Mazán and 12 at Panguana), and only one species, Fork-tailed Woodnymph (*Thalurania furcata*), seen more than once or twice.

In contrast, ant-following birds were best represented at Alto Nanay, with observers encountering multiple swarms each day. At Alto Mazán, only one ant swarm with birds at it was seen, while Panguana had intermediate numbers of these birds. All three camps had good numbers of mixed species flocks in the understory. We generally found species typical of canopy flocks in association with the understory flocks. Flock size and abundance was highest at Panguana, and lower, but about equal in average size and abundance, at the other two sites. This mirrored the overall abundance of birds among the sites. Birds were notably more abundant at Panguana than the other two sites. Alto Mazán and Alto Nanay showed similar patterns of abundance for understory insectivores, but as noted above, Alto Nanay had fewer large frugivores and hummingbirds.

At all three sites we recorded the newly described Brown-backed Antwren, *Myrmotherula fjeldsaai*. This species has a range restricted to eastern Ecuador (south of the Napo River) and Loreto between the upper Tigre and the mouth of the Curaray River. Contrary to our expectations we found this species co-existing with Stipple-throated Antwren, *Myrmotherula haematonota*, which replaces it to the south and east. At each site, *M. haematonota* outnumbered *M. fjeldsaai*. However, neither species was particularly common at any of the inventory sites. Typically, in the Amazonian lowlands, a species of checker-throated *Myrmotherula* is present in most or all of the understory mixed-species flocks in the forest. Oddly, at Alto Mazán and Alto Nanay most flocks lacked a checker-throated *Myrmotherula*, while at Panguana, the most common checker-throated species was Rufous-tailed Antwren, *Myrmotherula erythrura*, which is slightly larger and forages somewhat higher. We found it in most flocks.

Comparison with other rapid inventories in Loreto and other areas in Loreto

Overall, the number of species of birds encountered here was very similar to the number of other rapid inventories of similar duration in Loreto. We found 372 species, compared to 362 on the Ampiyacu, and to 376 at the three main inventory sites at Matsés. Brief surveys along the Blanco and Gálvez rivers at Matsés contributed an additional 40 species. Similarly Stotz found 43 species not recorded during this survey in a day observing birds at the Army post at the mouth of the Curaray River. However, this army post is 140 km from the area we surveyed and the habitats at Curaray (extensive second growth, large, slow-moving river with extensive beaches, and cochas) are either quite rare or absent from the surveyed region. At Matsés, the sites surveyed casually are within or immediately adjacent to the area being considered for protection.

Differences among sites were somewhat smaller at Ampiyacu than those shown among sites on this survey or on the Matsés inventory. There appeared to be less diversity in soil types at Ampiyacu. At both Matsés and on this survey, one site had notably poor-soils. At the white-sand site on the Matsés inventory, Itia Tëbu, we found only 187 species compared to 221 at Alto Nanay. Itia Tëbu lacked the characteristic white-sand specialists of the Iquitos region. Only the relatively widespread *Hemitriccus minimus* and *Cnemotriccus fuscatus duidae,* and the somewhat less habitat-restricted *Conopias parva* were found there. This constrasts with Alto Nanay, which has at least thirteen species of poor-soil specialists. At Itia Tëbu, the unique elements in the *varillal* (stunted forest on white sand) consisted of widespread Amazonian species associated with low stature open forests of a number of types. These included White-chinned Sapphire *(Hylocharis cyanea*), Blackish Nightjar (*Caprimulgus nigrescens*), and White-lined Tanager *(Tachyphonus rufus*). None of these species were found at Alto Nanay.

The Reserva Nacional Allpahuayo-Mishana is the heart of the poor-soil specialist avifauna in Peru. There are approximately 475 species of birds known from the area (IIAP 2000). The higher richness than that we found is in part a reflection of better and more varied aquatic habitats, and in part much greater fieldwork than the few days we spent during this inventory. Most of the poor-soil species are more abundant at Allpahuayo-Mishana than we found them at Alto Nanay. Most are also fairly strongly restricted to varillal, a much more stunted forest than any of the habitats were encountered. Besides the classic white-sand birds, Allpahuayo-Mishana also has two of the open habitat species, *Caprimulgus nigrescens* and *Hylocharis cyanea*, which we found at Itia Tëbu, on the Matsés inventory, but not on this inventory. A third species, the poorly-known White-bellied Dacnis (*Dacnis albiventris*) which was recorded on the Matsés inventory on poor soils, but not in *varillal,* is also known from Allpahuayo-Mishana. Despite Allpahuayo-Mishana being such a center of diversity for white-sand birds, two of the white-sand bird species known from northwestern Loreto, *Myrmotherula cherriei* and *Lophotriccus galeatu,* are not known from there. We found *L. galeatus* at Alto Nanay, but *Myrmotherula cherriei* remains known in Peru only from the Tigre River (Álvarez and Whitney 2003).

RECOMMENDATIONS

Protection and management

The avifauna in the headwaters region is almost purely a forest avifauna, so maintaining an extensive forest cover in the region is the most critical action that can be taken to protect the birds of the region. Most crucial are the forests that cover the steep hills away from the river. These forests are on poor soils and are not very tall. These sites are not really appropriate either for agricultural development or logging. They are also home to the specialized set of "poor-soil" birds that include most of the restricted-range and newly described birds.

The commercial hunting that is currently occurring in the region does not focus on birds, however some of the larger species (currasows, guans, and perhaps the largest tinamous) might become more of a target as populations of mammals decline with uncontrolled hunting. Given the poor soils in much of the surveyed region, it seems doubtful that commercial hunting could be sustained, even under regulation. We strongly urge controlling hunting, except for subsistence hunting by residents of the villages on these rivers. Without such controls, we expect that large birds and mammals will disappear. The possibility exists that exploitation of parrot populations could develop in the region unless controls are put into place. Once again, populations of the large species (macaws, *Amazon* parrots) seem insufficient to be exploited commercially, so any such exploitation should be strictly controlled.

Since access to the area is via rivers, communities on rivers have a huge role to play in protecting the area and monitoring people entering the region. By working with the communities, it should be possible to reduce uncontrolled exploitation of the resources in the headwaters, including game birds and parrots.

Inventories and Monitoring

The poor soil areas north of the Amazon in Loreto need further inventory for birds. It appears that the Nanay drainage may be the most important for the specialists, but some of the species (e.g., *Herpsilochmus gentryi* and *Myrmeciza castanea*) have wider ranges. Most important would be to survey for the Iquitos Gnatcatcher (*Polioptila clementsi*), known only from a population of well under 100 individuals at Allpahuayo-Mishana. Additionally, there are white sand species known from elsewhere in northern Peru, like White-masked Antbird (*Pithys castanea*), Black Manakin (*Xenopipo atronitens*), and Red-shouldered Tanager (*Tachyphonus phoenicius*) that have not been found in northern Loreto.

MAMMALS

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Conservation targets: Abundant, intact populations of mammals in the Arabela headwaters, threatened elsewhere in Amazonia; substantial populations of equatorial saki monkey (*Pithecia aequatorialis*), a range-restricted primate occurring in Peru only on the left bank of the Marañón River between the Napo and Tigre rivers; the giant armadillo (*Priodontes maximus*), listed as Vulnerable (IUCN) and Threatened (CITES); primates that are important seed dispersers but threatened by commercial hunting, especially the white-bellied spider monkey (*Ateles belzebuth*), listed as Vulnerable (IUCN), the common woolly monkey (*Lagothrix poeppigii*), listed as Near Threatened (IUCN), and the red howler monkey (*Alouatta seniculus*); top predators e.g., jaguar (*Panthera onca*) and puma (*Puma concolor*) that are important in regulating prey populations; the Brazilian tapir (*Tapirus terrestris*), an important dispersal agent, especially of large seeds, listed as Vulnerable (CITES, IUCN); three bat species (*Artibeus obscurus, Vampyriscus bidens*, and *Diphylla ecaudata*) considered Lower Risk/Near Threatened (IUCN)

INTRODUCTION

The Peruvian Amazon is a global center of mammal diversity. Information exists about the mammal communities of the entire region (Pacheco 2002, Voss and Emmons 1996); however information about local mammal communities and distributions remains limited, especially in northern Peru (Emmons 1997). A few areas have been studied intensively, e.g., the Napo watershed and the Pacaya Samiria National Reserve (Aquino and Encarnación 1994; Aquino et al. 2001; Heymann et al. 2002), but mammal communities for many important areas, including Nanay-Mazán-Arabela (N-M-A) Headwaters, remain unknown.

In this chapter, we present the results of a mammal survey in N-M-A Headwaters, an area between the

Curaray and Pucacuro rivers near the border with Ecuador (Fig. 2A). We compare species richness and abundance of mammals among three sites, highlight important observations, identify target species for conservation, and provide recommendations for their conservation.

METHODS

From August 15 to 30, 2006, we conducted mammal surveys at three localities: Alto Mazán, Alto Nanay, and Panguana. We used observations and signs to evaluate the community of medium and large mammals, and used mist nets to census bats. We did not evaluate the community of small non-volant mammals because of time constraints.

At each site, we walked along trails at a rate of 0.5–1 km/hr for a period of 5 to 7 hours starting at 7 a.m. and again at 7 p.m. For each species, we recorded (1) date and time, (2) location (trail name/number and distance), (3) species name, and (4) number of individuals. We also recorded secondary signs (e.g., tracks, feces, wallows, burrows, or food remains) that indicate mammal presence (Wilson et al. 1996). To match a sign with a species, we used a combination of field guides (Aquino and Encarnación 1994; Emmons 1997), our personal experience, and local knowledge. In addition, we incorporated mammal sightings by other members of the inventory team and local assistants. Using the plates in a field guide (Emmons 1997), we interviewed local people about the presence of large and medium mammal species in the area.

We captured bats using 6 m mist nets, deploying 18–20 nets along trails, natural gaps, and in the gaps formed when clearing the small helipads. We opened the nets for ~6 hours beginning at sunset, between 5:45 and 6:00 p.m., when bats start foraging. We identified and released each bat.

RESULTS AND DISCUSSION

We expected to find a rich mammal community in the N-M-A Headwaters. Using published distributions maps of Neotropical mammals (Aquino and Encarnación 1994; Emmons 1997; Rylands 2002), we estimate 59 species of large and medium size mammals occur in the entire N-M-A Headwaters. During two weeks, we covered 230 km (80 km at Alto Mazán, 70 km at Alto Nanay, and 80 km at Panguana) and registered 35 (ca. 60 %) of the expected species (Appendix 6). We registered 12 (80%) of 15 primate species expected in the area, 4 (80%) of 5 ungulates, and 7 (50%) of 14 carnivores.

Typically, bat species richness is high in Neotropical rainforests, and this area is no exception. In N-M-A Headwaters, we expect ~65 species (Hice et al. 2004; Ascorra et al. 1993). With a sampling effort of 554 open-net-hours (194, 180, and 180 open-net-hours at Alto Mazán, Alto Nanay, and Panguana respectively), we captured 20 bat species during seven nights (Appendix 7), which represents 31% of the expected species, and includes 10 frugivores, 3 nectivores, 5 insectivores, 1 hematophage, and 1 omnivore.

Below we give a brief overview of each site, followed by comparison among our inventory sites and comparisons with several other mammal inventories in Loreto.

Alto Mazán

During six days, we registered 26 species of medium and large mammals in Alto Mazán. Commercial hunting was evident in the area, and mammals, especially monkeys, seemed afraid of humans. Despite hunting impacts on the mammal fauna, we did observe ten primate species, including the range-restricted *Pithecia aequatorialis*, and registered signs of large ungulate species, such as Brazilian tapir (*Tapirus terrestris*), collared peccary (*Pecari tajacu*), the white-lipped peccary (*Tayassu pecari*), and the red brocket deer (*Mazama americana*), which are sensitive to hunting.

Although richness of primates and ungulates was high, the abundance of some species was low. For instance, species sensitive to hunting or other anthropogenic activities, e.g., *Alouatta seniculus* and *Lagothrix poeppigii*, were less abundant here than in other sites in Amazonia with low or nonexistent hunting pressure, including our other inventory sites, Alto Nanay and Panguana. Almost all of our ungulate records come from tracks, and these tracks suggest densities are also low.

At this site, we observed what appear to be two species of saki monkeys, *Pithecia aequatorialis* and *Pithecia monachus*. We observed the two species foraging independently as well as in the same troop. However, after returning from the field, we realized that the taxonomy of *Pithecia* remains muddled, especially the degree of color and pattern variation within species, and the level of sexual dimorphism. We cannot be sure whether *P. aequatorialis* and *P. monachus* are two valid species and maintain their differences in sympatry, or whether they represent color morphs of the same species (see Notable Records, below; Fig. 9C).

In Alto Mazán some habitats provide key resources for mammals, especially *Mauritia* swamps (locally called *aguajales*). We recorded nine species of monkeys, and observed tracks of four ungulate species (Brazilian tapir, deer, collared peccaries, and white-lipped peccaries) in this habitat.

With a capture effort of 194 open net-hours, we identified seven species of bats: four frugivores and three insectivores. Species richness and abundance was lower than expected, most likely a combination of the low availability of fruit in the area and late afternoons rains that continued into dusk, the time of greatest bat activity.

Alto Nanay

In four days, we found 17 species of medium and large mammals in Alto Nanay, including 8 species of primates and 4 species of ungulates. Species richness was the lowest at this site, and lower than expected given that hunting appears almost nonexistent in this area. However, the low richness likely reflects the poor soils, low productivity, and scarce fruit resources at this site, rather than any human impacts.

Again we observed two species that appear to be *Pithecia aequatorialis* and *Pithecia monachus*. We recorded them foraging independently, but also observed mixed groups as in Alto Mazán.

We made two diurnal observations of *Tapirus terrestris*, the largest terrestrial mammal in the Amazon and a species that is vulnerable to hunting.

With a total capture effort of 180 open-net-hours, we captured 10 individuals belonging to seven bat species. We made one particularly intriguing bat observation. At a site dominated by *Lepidocaryum tenue* palms (known locally as *irapay*), we captured four individuals of *Phyllostomus elongatus*, an omnivore. In addition to the captures, we encountered several large holes in the nets presumably made by this species or *Phyllostomus hastatus,* another omnivore. No bats were captured eating the fruits of irapay, however, the sheer abundance of these bat species in an area so dominated by these clonal palms suggests that these bats may be feeding on irapay fruits. Notably, in areas without irapay we did not capture any *Phyllostomus hastatus* or *P. elongatus*. We recommend further studies—additional surveys as well as diet studies—to determine whether bats are dispersal agents for this palm.

Panguana

This was our most diverse site. In five days, we found 31 species of medium and large mammals, including 11 primates, 4 ungulates, and 7 carnivores. People from the communities Flor de Coco and Buena Vista situated along the Curaray River (15–20 km from Panguana) practice subsistence hunting in this area. Current hunting levels are small-scale, and the mammal community appears robust.

Among the highlights were abundant populations of species sensitive to large-scale hunting, including *Alouatta seniculus, Ateles belzebuth, Lagothrix poeppigii, Tayassu pecari,* and *Pecari tajacu*, as well as records of two top predators, *Panthera onca* and *Puma concolor.* During our diurnal censuses, we found fresh tracks of both cats along the trails. We suspect that these two large cats also occur in the other two sites, but that the clay soils in Panguana allowed us to better observe tracks than the sandier soils in Alto Mazán and Alto Nanay. In addition, prey species (e.g., *Tayassu pecari*) were more abundant in Panguana.

Some habitats present in Panguana are very important for mammals. In a single day, we observed 4–5 groups of primates in the ridge forest. In this habitat, we registered plant species with abundant fruits (e.g., *Ficus, Marcgravia,* and *Astrocaryum*) and large groups of monkeys feeding on them. In addition, three large herds of *Tayassu pecari* (~150) and a large troop of *Ateles* *belzebuth* (~20) were recorded in the *Mauritia* palm swamp near the Arabela River.

Similar to Alto Mazán and Alto Nanay, we observed groups of what appeared to be *Pithecia aequatorialis* and *P. monachus* separately as well as together.

With a total capture effort of 180 open-net-hours, similar to Alto Mazán and Alto Nanay, we identified 13 species of bats, including 7 frugivores, 3 insectivores, 1 omnivore, 1 nectivore, and 1 hematophage. The high number of frugivorous species captured at this site almost certainly reflects the fruiting species of *Ficus* and *Piper* in the area. Our most surprising capture was *Diphylla ecaudata* (Fig. 9B), a hematophagous species that feeds on birds and is rarely encountered in bat surveys. Our capture represents one of the few records for Loreto (Field Museum 2006; Solari pers. comm.; Velazco pers. comm.).

Comparison among inventory sites

The majority of species was shared among sites, but there were marked differences in abundances and richness of mammals. Given distribution maps, we were expecting the same species of large and medium mammals at the three sites. However, observed richness varied from 17 species (Alto Nanay), to 29 (Alto Mazán), to 31 (Panguana). All species registered in Alto Nanay were also found at the other two sites, and 25 species were shared between Alto Mazán and Panguana.

Differences in observed species richness and abundance among sites almost certainly reflect a combination of environmental and anthropogenic factors. We found evidence of hunting at all three sites, but with markedly different intensities. At Alto Mazán, commercial hunting was evident. Both the advance team and the inventory team observed hunting parties as they traveled upriver in boats (*peque-peques*) and canoes. One canoe returned downriver with seven dead white-lipped peccaries and one Spix's guan (*Penelope jacquacu*). Interviews with our local assistants confirmed that hunting in the area is for commercial and not subsistence purposes. Middlemen (known as *habilitadores*) provide boats, canoes, gasoline, guns, bullets, and food to local residents, who hunt for large amounts of bushmeat (500 kg). The demand for bushmeat in Iquitos is high, and wild game is openly available in restaurants and markets. Illegal logging also was observed in Alto Mazán, and this likely increases the hunting pressure on mammal populations in the area. Typically loggers hunt for subsistence in the forest, however because of their extended stays in the forest, their meat demands can have a strongly negative effect on local mammal populations.

In contrast, mammal populations at Alto Nanay appeared to be almost entirely free of hunting. This may be because the area is perhaps the most difficult to access, with only seasonal boat traffic during high water levels. Moreover, we registered low species richness and low species abundance of mammals at this site, making the site less favorable for hunters.

Local people from the communities of Flor de Coco and Buena Vista hunt in Panguana. They practice small-scale hunting, and are conscious of the negative effects of large-scale commercial hunting. At Panguana, the presence of large groups of woolly monkeys, howler monkeys, and spider monkeys; large herds of white-lipped peccaries; and numerous tracks of collared peccaries, deer, jaguar, puma, and tapir suggest that currently small-scale hunting is compatible with maintaining a healthy mammal community.

Notable records

We made several notable observations during our inventory of N-M-A Headwaters. On four occasions, individuals of *Pithecia* (Fig. 9C), with physical characteristics resembling *P. aequatorilis* and *P. monachus*, were observed together in the same group. We (authors and D. Moskovits) made these observations at all the three inventory sites. However, our observations are complicated by conflicting descriptions of the taxonomy of these species (Hershkovitz 1987; Aquino and Encarnación 1994; Emmons 1997; Heymann pers. comm.; Voss pers. comm.). We cannot be sure whether we observed two species, or different color morphs of a single species. We strongly recommend a taxonomic revision of the genus based on the collection of new specimens, an analysis of molecular data, and an exhaustive revision of existing museum specimens.

Panguana was the only place where we observed *Ateles belzebuth*. Given the sensitivity of this species to hunting pressure (Aquino pers. comm.), its absence from Alto Mazán may reflect impacts of large-scale commercial hunting, and from Alto Nanay may reflect the low fruit availabilities during our inventory. However, we cannot be certain that *Ateles* is truly absent from either of these sites, as this species may migrate locally, and could occur at either Alto Mazán or Alto Nanay during other parts of the year.

Surprisingly, we did not find the red howler monkey, *Alouatta seniculus*, at Alto Nanay, despite an otherwise intact mammal fauna and almost no evidence of hunting. This is a widespread species, and we suspect that it may be responding to the low fruit availabilities in Alto Nanay.

Another notable record was the gray river dophin, *Sotalia fluviatilis*, at Alto Mazán in a small (30–35 m wide, ~4 m deep) tributary of the Mazán River. We suspect that the low water levels in Alto Nanay and Panguana restrict dolphins from these areas, but that these aquatic mammals likely occur along the Arabela River.

Our most interesting bat record was the capture of *Diphylla ecaudata*, a widely distributed but rarely captured hematophagous species. This is one of the few records for the species in Loreto. They live in mature forests and are specialized to feed on birds. It was captured in the gap used as the heliport in Panguana.

Conservation targets

Thirty-two species of large and medium mammals in N-M-A Headwaters are conservation targets internationally (CITES 2006 and IUCN 2006) and nationally (INRENA 2004). All of these species are listed in Appendices 6 and 7. Several species threatened elsewhere, e.g., *Alouatta seniculus, Ateles belzebuth, Lagothrix poeppigii, Pithecia aequatorialis,* and *Tapirus terrestris*, are abundant in Panguana, suggesting this area could act as a refuge for depleted mammal populations in other parts of Loreto.

Comparison to other sites in northern Loreto

Our closest point of comparison is the Zona Reservada Pucacuro directly southwest of Nanay-Mazán-Arabela Headwaters. During a mammal inventory in the Pucacuro watershed, Soini et al. (2001) registered 48 species of medium and large mammals. In surveys of Pucacuro, researchers evaluated 35 localities, and 800 km, compared to our study of three localities and 230 km. Despite substantial differences in sampling intensity, we found 73% of the species recorded in Pucacuro. Twelve species of primates were found at both sites, with 11 of these species shared between the inventories. *Pithecia monachus* was recorded only in N-M-A Headwaters, and *Callimico goeldii* was found only in Pucacuro. We recommend additional surveys in N-M-A Headwaters, particularly of areas with slender vegetation e.g., white-sand forests or riverine habitats, where *C. goeldii* may occur. Typically this species occurs at low densities and can be difficult to detect in short time periods. Bat richness in N-M-A Headwaters was greater than in Pucacuro, though both areas should be inventoried more completely. Twenty bat species were captured in N-M-A Headwaters compared to 11 species found in Pucacuro.

A mammal inventory in the Nanay Basin (Soini 2000) registered 38 species of medium and large mammals in 53.7 km and four sampling sites. Here eleven primates were found, including *Callicebus torquatus*, a species we did not record in N-M-A Headwaters. This species may be strongly associated with white-sand forests known as *varillales* (Aquino pers. comm.), and we surveyed only two small patches of varillales in Alto Nanay. If larger patches of varillal occur in N-M-A Headwaters, *C. torquatus* may occur in the area. *Ateles belzebuth* was not registered in the Nanay Basin, and may reflect local extinction of this species by large-scale hunting.

During the rapid inventory in Ampiyacu (Montenegro and Escobedo 2004), an area north of the Peruvian Amazon near the Colombian border, 39 species of medium and large mammals were recorded. Again, the most remarkable differences between Ampiyacu and N-M-A Headwaters are the presence of *Callicebus torquatus* and the absence of *Ateles belzebuth* in Ampiyacu. Montenegro and Escobedo (2004) attributed the absence of *Ateles* to intensive hunting pressure. A similar richness of bats was recorded in Ampiyacu, with 21 species compared to the 20 species we captured in N-M-A Headwaters, despite the Ampiyacu survey covering 19 days rather than the 16 days we sampled. In terms of bat composition, as in Ampiyacu, 85% of captured bats in N-M-A Headwaters belonged to the family Phyllostomidae. However, only eight species were shared between sites. This difference may be simply due to limited sampling effort.

CONCLUSIONS

N-M-A Headwaters support a rich and abundant mammal community; in two weeks we recorded 35 species of large and medium mammals and 20 species of bats. Many of these species play an important role in the forest, and include seed dispersers (tapirs, spider monkeys, howler monkeys, woolly monkeys, and frugivorous bats), pollinators (nectarivorous bats), and top predators (jaguars and pumas). Conserving the mammal community is important for preserving ecosystem function as well as species threatened or locally extinct in other parts of the Amazon Basin.

THREATS AND RECOMMENDATIONS

Threats

Large-scale hunting is an overwhelming threat, especially for highly prized and vulnerable species. The impact on species populations is dramatic and often irreversible. For instance, some populations of white-bellied spider monkeys and white-lipped peccaries have been locally exterminated in the Amazon (Peres 1996; Soini et al. 2001; Naughton-Treves et al. 2003; Montenegro and Escobedo 2004). Habitat destruction is also a potential threat. Anthropogenic activities, such as timber extraction, gold mining, agriculture, cattle ranching, can eliminate habitat critical for mammal populations, and these impacts can cascade down to other trophic levels.

Recommendations

We recommend the immediate protection of N-M-A Headwaters because this area is rich in mammals and provides a refuge for species hunted to local extinction elsewhere. For this protected area to succeed, local people should be directly involved in the protection and management of the area. To this end, we recommend a broadly participatory process to determine zoning and sustainable use of the area's resources, as well as establishing a local system to monitor threats and mammal populations, especially game species.

HUMAN COMMUNITIES: SOCIAL ASSETS AND RESOURCE USE

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INTRODUCTION

Nanay-Mazán-Arabela (N-M-A) Headwaters represents several watersheds, including the Arabela, Curaray, Mazán, and Nanay rivers. Between 16 and 28 August 2006, the social inventory team visited six sites along two of the rivers closest to N-M-A Headwaters: the native communities of Flor de Coco and Buena Vista on the Arabela River, and the villages of Puerto Alegre, Libertad, Santa Cruz, and Mazán (the district capital) on the Mazán River. Although the communities on the Curaray River are less closely linked to the resources of N-M-A Headwaters, the Curaray represents an important access route to the area. The five sites we visited along this river included the native communities of Bolívar, Shapajal, Soledad, and San Rafael; and Santa Clotilde (the Napo district capital). We were unable to visit the communities of the Nanay River due to logistical and time limitations.

The 11 communities and villages we visited share characteristics that are common to Amazonia. Settlements tend to be small, with an average population of 185 inhabitants (Appendix 8). The villages along the Arabela and Curaray are intercultural, with native Arabela and Quichua ethnic groups as well as migrants from other parts of Peru and Ecuador. Another common denominator of these communities is their settlement pattern. In both the Arabela and the Curaray, historically, indigenous groups settled areas closest to the headwaters, then moved downriver over the past several decades, in part reflecting changes in their relationship with commercial markets (Lou 2003). The settlement pattern along the Mazán River was different because of a Reserved Zone, a protected area for water and fish resources, established by a resolution from the Ministry of Agriculture in 1965. When the protected area was created, traditional inhabitants (indigenous people and *ribereños*) along the Mazán River were forced to emigrate to other locations, and the area remained largely unpopulated for about 20 years until groups began to settle there again, starting in 1985.

Settlement patterns are strongly linked to boom-and-bust extraction periods that historically occurred in and around the city of Iquitos. During the boom cycles of heavy extractive activities (e.g., rubber, gold, wild animal skins), people from other areas came to the region and settled along the banks of large rivers, precipitating indigenous groups to flee from their ancestral lands. Some indigenous groups contacted by evangelical missionaries eventually resettled areas and obtained titles to their lands under Law #22175. Other indigenous groups fled from immigrants and missionaries and sought refuge in the most remote areas of the forest. In Peru these indigenous groups are known as "people living in voluntary isolation."

Despite these great waves of extraction and migration, the majority of communities along these three river basins have maintained a subsistence-oriented lifestyle, complemented by small-scale commercial activities to meet basic needs. The most recent wave of extraction has been characterized by an enormous increase in logging, oil exploration, commercial fishing, and gold mining. These extractive activities are accelerating at an unsustainable pace, and expanding towards areas where a subsistence-oriented lifestyle has historically predominated. Large-scale commercial extraction increasingly pressures local people in the region to exploit their natural resources in an unsustainable manner by accelerating their integration into the market economy.

METHODS

The social science team organized informational workshops about the rapid inventory for the communities, worked with community members to sketch resource use maps, participated in daily activities, and conducted interviews to gather data on demography, social assets, and the economic impact of commercial extraction activities. We also conducted interviews in Iquitos (28–30 August) with staff of governmental and non-governmental institutions to compile demographic data, documents, and previous studies.

We designed the workshops as a means to exchange information with local residents. In them, we explained the motivation, methods and expected outcomes for the rapid inventory. We asked the residents to tell us about their perspectives on the challenges they face, the state of their environment, and their quality of life. We were able to get a sense of the daily life and social assets of local populations through our visits to family horticultural plots, our participation in communal work activities and celebrations, our shared meals with families, and the systematic interviews with community leaders, authorities or other key actors. We also engaged workshop participants in participatory map-making of community natural resource use. The maps helped us understand the extent of the territory they used for hunting, fishing, horticulture, and other subsistence activities.

We conducted more intensive work in five sites: the native community of Buena Vista (Arabela River), the native communities of Bolívar and San Rafael (Curaray River), and the Napo and Mazán District Capitals (Santa Clotilde and Mazán, respectively). We selected these communities based on their population size and relative importance to N-M-A Headwaters.

Less intensive work was conducted in the native community of Flor de Coco (Arabela river), the native communities of Shapajal and Soledad (Curaray river), and in the villages of Puerto Alegre, Libertad and Santa Cruz (Mazán river), where we held informative workshops and collected data on resource use.

All of the communities were exceptionally friendly and very interested in the rapid inventory. The families who provided lodging and meals were generous hosts, and everyone enthusiastically shared their experiences and perspectives with us.

DEMOGRAPHY AND INFRASTRUCTURE

The majority of people living along the Arabela and Curaray rivers belong to the Arabela and Quichua ethnic groups. Along the Curaray River, there are nine communities, with a population of 1,171 people (Appendix 8). On the Arabela River, there are only two communities, Buena Vista (officially recognized by the Ministry of Agriculture) and Flor de Coco. The combined population of these two communities is 357, according to the November 2005 municipal census. Also, there are reports of indigenous groups in isolation (known as the "*Pananujuri*") on the upper Arabela River and other nearby rivers near the Ecuadorian border (see Brief Overview of Indigenous Settlement Patterns, below).

All of the communities on the Arabela and Curaray rivers have primary schools, and in 2004, Buena Vista established a bilingual (Arabela-Spanish) secondary school. There are also health services in the majority of communities along these two rivers, delivered either through community health clinics, small dispensaries, or vaccination campaigns. In San Rafael and Buena Vista, the health clinics also have laboratories and technicians supported by the Santa Clotilde Vicariate and both communities have public telephones and short wave radios that are in operation during set schedules.

Currently mainly *ribereño* and *mestizo* groups inhabit the Mazán River basin, there are 10 communities with ~950 people (Appendix 8). All ten communities have primary schools, and Libertad has a health center. There is no radio or telephone communication in the Mazán communities.

In some of the communities in the three watersheds, there are battery-powered or solar-powered electric generators. The hospitals in both district capitals receive patients from their entire respective regions. Both district capitals, Santa Clotilde and Mazán, have electricity for five hours every night and have potable water.

BRIEF OVERVIEW OF INDIGENOUS SETTLEMENT PATTERNS

The indigenous groups that today are referred to as Arabela can be described in two categories: (1) those that were evangelized and eventually obtained land tenure, and (2) those that remain isolated deep in the forest. Both groups belong to the Záparo ethno-linguistic family, which spans the Ecuador-Peru frontier region, and historically called themselves Tapueyocuaca or Puyano until they were given the name Arabela by Spanish colonizers (For information on Arabela and Záporo communities, see: Fabre 2006, Gordon 2006, Granja 1942, O'Leary 1963, Perú Ecológico 2005, Rich 1999, Simson 1878, and Steward 1948). The group that was eventually evangelized settled first on the Arabela River in 1945. They came under the control of a rubber baron and worked for him for many years. When they emerged from this bondage, they became associated with missionaries from the Summer Institute of Linguistics, which produced the most detailed study of their language and bilingual educational materials (Rich 2000). Between 1945 and 1980, this sedentary group of Arabela began to lose elements of their traditional dress, crafts, and other aspects of cultural identity. In 1980, they obtained title for the "native community of Buena Vista" near the Arabela river headwaters, but subsequently moved downriver for more direct access to commercial market activities (Lou 2003). Today, members of the communities on the Arabela River refer to themselves as Arabela.

Since they moved to their present location, the rate of interethnic marriage has increased among the Arabela in the communities of Flor de Coco and Buena Vista. Community members are considered Arabela if either mother or father belong to this ethnic group. With this criterion, 76% and 50%, respectively, of Buena Vista and Flor de Coco community members are considered Arabela. There are also members of the Arabela ethnic group downriver in the community of Shapajal (which is also linked to Buena Vista via a trail).

Since settling on the Arabela River, these communities (Buena Vista and Flor de Coco) have maintained sporadic ties to bands from the same ethnolinguistic family that today remain in isolation, and which they refer to as Pananjuri (possibly the same as the Tagaeri or the Feromenami) as well as the Huaorani. There are several reports that cite evidence of the current presence of these groups in the headwaters of the Curaray, Tigre and

Arabela rivers as well as other streams in the frontier region (Defensoría del Pueblo 2001; Lou 2003; Repsol Exploración Peru 2005; Lucas date unknown).

Further downriver, populations along the Curaray are recognized as native communities belonging to the Quichua ethnic group. They are likely to belong to the large Quichua populations that live along the Napo River in Ecuador and Peru (Whitten 1978). According to oral histories taken from elder residents, the Curaray communities started as settlements around the 1930s (before this, there were probably dispersed family settlements along the river) when a German settlement was founded at Santa Clotilde. Also during this time, the Curaray Military Base was established where the Curaray River meets the Napo River. Between 1940 and 1950, this Military Base was considerably larger than it is presently, had a working school, and housed military families who bought meat, fish and other products from the nearby communities. The majority of these communities obtained native community titles in the 1990s (except Shapajal, which has completed the land titling process and is awaiting final approval). There are strong ties between the Curaray communities and Santa Clotilde through the Vicariate schools (all of the communities have children studying and living in Santa Clotilde), and through kin relations.

SOCIAL AND CULTURAL ASSETS

The assets we identified in the communities include social and cultural characteristics as well as resource-use practices that are compatible with Amazonian environments. Although there are similar assets found in all three watersheds, we first describe those of the native communities along the Arabela and Curaray rivers before turning to the assets found in the settlements along the Mazán River.

Social and cultural characteristics

Communities on the Arabela and Curaray rivers

These communities continue to maintain certain patterns of social organization common among Amazonian indigenous societies that contribute to the maintenance of a distinct cultural identity. These patterns constitute the fundamental aspects of their social structure and orient members toward a more communal and egalitarian lifestyle, as opposed to one that is more stratified or individualistic.

In all of the communities visited, an important part of community life is based on communal work, the *minga*. In Buena Vista and Flor de Coco, we observed various mingas, including one to construct thatched roofs, one by the high school students to tend to their own school garden (*huerta escolar*), and one for a family to clear their field, or *chacra*. This pattern of working in mingas effectively reduces the need to pay for hired help and foments general economic equality among community members. Indeed, communities are only slightly socially stratified.

We also observed the importance of reciprocity in community life, marked by the frequent sharing of resources within the community. A good example of this occurred in San Rafael, where we observed how meat was distributed after community members successfully hunted 10 white-lipped peccaries. Although some community members did sell some of the meat either to neighbors or local merchants, many shared most of their meat with members of their extended family. We observed another example in Buena Vista, when a group of women who went together to a chacra, the small horticultural plots where families grow staple crops. In this case, the women who accompanied the owner of the field helped themselves to manioc that they harvested while working. This sharing of resources is commonly extended throughout a community. For example, communities that had an electric generator or solar panels frequently had communal televisions and during the evenings, community members came together in their meeting hall or school to watch television or movies. In none of the communities visited (except district capitals) did we observe the use of an electric generator or television by an individual family. This type of sharing not only foments a sense of community, but also helps maintain a relatively low level of resource consumption compared to what would be needed if each family had to meet their family's consumption needs individually.

Another social pattern that exists in these communities is an explicit sense of social cohesion, fomented by kinship ties within and between communities, active leadership, and the delivery of health services and commercial activity. The population of Buena Vista highlights the importance of intra-community kinship ties, as the ~278 people who live there belong to one of only five extended families. In San Rafael, roughly 163 community members make up six extended families. These intracommunity kinship ties ensure social cohesion that in turn facilitates community organization. The intercommunity kinship ties, such as the case of Arabela who live in Shapajal, facilitate relations and communications between populations. We also observed active leadership in many communities, including regularly scheduled meetings and participatory decision-making processes. Buena Vista and San Rafael also had a loudspeaker system used daily to communicate news, announcements, and call community members to meetings.

Intercommunity communication and coordination is also facilitated by the delivery of health services and by the presence of local merchants. In the Santa Clotilde district, there is a contract signed between the Vicariate and the public health-care system. The hospital of the Vicariate is the base for training local health-care technicians. It also provides lab equipment and medical supplies to local community health-care centers along the Curaray, Arabela and Napo rivers. The health-care centers in San Rafael and Buena Vista were well supplied with medicine and run by technicians trained in Santa Clotilde. The hospital staff members from Santa Clotilde make frequent visits to vaccinate and educate community members on prevention of contagious diseases. These visits facilitate the flow of information between communities as all the communities know the hospital staff and local health care providers very well. For these reasons, the health-care system can be considered a double asset, acting as a vector for establishing links between communities and at the same time, providing important health services. Local merchants from Iquitos and Mazán also are vectors for communications flow, as they carry news and messages from village to village during their trading trips.

Gender equity is another characteristic of the communities visited. A large proportion of women commonly attend community meetings, and many also hold positions of leadership and authority. We observed a willingness to share daily tasks between men and women, where men care for children and women work in the fields. This pattern of work organization reflects a lower level of gender stratification in the region than perhaps is the case in the society at large.

The revitalization of native languages is an important asset we found in some of the Arabela and Curaray communities. In Buena Vista, for example, the primary school launched a bilingual education program two years ago to revitalize the Arabela language. The school is equipped with bilingual teaching materials produced by the Summer Institute of Linguistics (a U.S.-based missionary organization with a long-established presence in South America and dedicated to documenting and preserving indigenous languages and creating Christian texts in those languages). Of the 11 total teachers, 9 are bilingual in Arabela and Spanish, and 2 of those also speak Quichua. We observed a general interest of youth in learning the Arabela language (See also Viatori 2005).

Another asset that we observed in the region is the coordination between the communities situated along the Curaray river and the Federation of Native Communities of the Middle Napo (Federación de Comunidades Nativas del Medio Napo, Curaray y Arabela, FECONAMNCUA), which in turn belongs to the Organización Regional AIDESEP Iquitos (ORAI), the regional representative branch of the Asociación Indígena para el Desarrollo de la Selva Peruana (AIDESEP), the national organization that represents the majority of indigenous communities in Peru. This coordination has permitted local communities to obtain land titles for their communal territories and submit requests for expansion of these territories. To date, however, none of these expansion requests have been granted by the Ministry of Agriculture's Special Program for Land Titling and Tenure (PETT).

Mazán watershed

The settlements along the Mazán river share some of the same social assets found along the Curaray and Arabela rivers, including communal work patterns, local economies based on reciprocity, active leadership, and gender equity. The cultural exchanges between indigenous and mestizo communities have contributed to rural cultural and social processes that sustain a subsistence-based economy and regulate links between community members and natural resources. In the past, when boom markets have fallen, rural populations have distanced themselves from commercial markets, migrating to more remote areas with more fertile and "pristine" forests necessary for meeting their subsistence needs with minimal dependence on commercial markets.

In addition to the existence of these subsistence-based patterns, there is a history of organizations that were created to act in favor of economic rights at the district level. These actions started in the Mazán region around 1985, when community members who had recently repopulated the Mazán River felt that they were harshly treated by the administrating agencies of the Reserved Zone. One of the first results of these organizations was the establishment of protection activities that were carried out at community level in coordination with the Fisheries Division (Dirección de Pesquería.) Since then, community members concerned with maintaining their close links with natural resources have continued to organize at the grassroots level with the support of the San José de Amazonas Parish in the Mazán District.

The most recent actions taken by these local communities have sprouted from local concerns regarding forest resources. In 2002, the forests along the Mazán were categorized as permanent production forests (*bosques de producción permanente),* meaning that they would be given as concessions for timber extraction. This categorization was perceived by local community members to be a threat to their access to their natural resources, and local communities came together in 2003 to form two new organizations: the Asociación Distrital de Pequeños y Medianos Productores y Extractores Forestales del Mazán (ADIPEMPEFORMA), and the Comité Multisectorial. These two organizations have since fought against the establishment of timber concessions on lands considered to be part of their communities and for a system of community-based management of the natural resources.

Resource use

In this section, we discuss patterns of resource use from the Arabela, Curaray, and Mazán watersheds. Local practices compatible with conservation continue to exist but have decreased with the appearance of commercial markets in the region. As is the case with most indigenous and mestizo communities in the Amazon, the subsistence economy predominates in this region. This indicates that local populations still have sufficient forest resources with which to meet their basic necessities (although in Mazán, people now have to travel much farther than they did a few years ago in order to find animals—as far as 5–6 days upriver by canoe, when less than five years ago they needed only travel one day by canoe).

The subsistence economy is based on the use of natural resources for family consumption and the small-scale commercialization of fish, meat, and agricultural products in local markets. In order to meet their subsistence needs, families along these three watersheds cultivate primarily manioc and plantain, corn, *pijuayo* (fruit of the *Bactris gasipaes* palm), and other fruits that may vary from community to community. Their fields have an average size of about 0.5–1 ha and each family may have two to five fields in various phases of fallow (*purma)*. The fields are semi-diversified, where one product predominates (generally manioc), but is associated with other plants such as pineapple, pijuayo, papaya, plantains, or fruit trees. This type of horticulture does not cause large-scale deforestation, provides families with the basis for the daily diet, and is supplemented by hunting and fishing.

Interethnic marriages have facilitated the diversification of crop varieties. Families maintain relations with relatives in other watersheds (such as the Napo), who provide different varieties of seeds and seedlings when they visit each other. In Buena Vista and Bolívar, we observed seven or eight varieties of manioc and in Bolívar, one family also had *mandi* (a type of root tuber, *Colocasia esculenta*), that they had brought back from a family visit.

The forest provides local populations with basic materials for house construction and artifacts needed in their daily life (canoes, hammocks, utensils, tools, etc.) Water quality is also critical for local subsistence economies. This resource base, necessary for a good quality of life, is complemented with some additional products (machetes, salt, sugar, kerosene, cartridges, clothes, school materials) and consumer products (batteries, radios, toys) that are purchased.

In the Curaray and Arabela, local communities are linked with the market through visits from two or three Iquitos- and Mazán-based merchants who come by boat to buy or exchange dried fish, forest meat, manioc flour, and small amounts of products harvested from their fields. This type of commerce functions as a barter economy where rifle cartridges, or salt used to dry fish, is provided by the merchant to a community member, who in turn provides the merchant with game meat or dried fish and buys certain basic necessities with the remaining credit. It is difficult to quantify the scale of the exchange of fish or meat given the informality of these exchanges, the changing needs of the families, and the variations of products provided by the forest during different times of the year. The merchants visit communities roughly every 6 to 7 weeks, but not all families barter every time.

In the Mazán watershed, the local economy is slightly different, given the proximity of these communities to large urban centers of Iquitos and the Mazán district capital. These communities sell their products directly in Mazán or Iquitos at higher prices, but at the same time have to invest in the cost of transportation and of living in the city. Another difference between the Mazán communities and those of the Arabela and Curaray is that the forests along the Mazán River are more degraded. This region has been more affected by previous waves of extraction, by the pressure on the resources posed by the city of Iquitos, and by the forestry concessions. As they continue to seek ways to stabilize the commercial extraction of the forest resources in the region to more sustainable scales, these communities continue to live subsistence lifestyles to the extent that they are able. As phrased by the health care provider in Libertad, "Nobody is dying of hunger here, we have enough."

Another natural resource use asset that we observed along the three watersheds is the transmission of knowledge related to the use of medicinal plants. In the community of Santa Cruz on the Mazán River, we observed a shaman using medicinal plants to conduct a ceremony to cure an infant. In San Rafael on the Curaray River, two elderly brothers were known in the community as being shamans, and shared with us preparations of plants that they use to cure different illnesses. Many of these plants are commonly known in the Amazon basin for their healing properties, such as *sangre de grado, uña de gato, ojé,* and *sacha curarina*. Today, there is a growing market in Iquitos for these herbal remedies and urban residents are familiar with the curative properties attributed to certain plant extracts. Certain native beliefs regarding links between spirituality and plants, animals, or places continue to exist. For example, some of the elders in Buena Vista indicated that the *colpas*, or salt licks, are sacred and that each one has its caretaker, from whom permission must be granted, in order to hunt (Rogalski 2005). This knowledge and set of beliefs contribute to local regulation of resource use.

Finally and most importantly, a valuable asset in all three watersheds is the local action taken to protect areas from illegal overharvesting of natural resources. In Buena Vista and Flor de Coco, for example, community members have decided in the last year to control access to the Arabela River. Anyone that passes these last two communities must request permission and explain their motives. In this way, community members are effectively stopping the fishing vessels and illegal loggers from entering the headwaters. In Shapajal, on the Curaray River, community members have placed signs at the points of entry to their oxbow lakes, warning commercial fishermen not to enter. In other communities, such as Soledad and San Rafael, local community members have reported illegal loggers to the authorities (such as the Commander of the Curaray Military Base downriver or the INRENA offices in Santa Clotilde and Mazán).

All of the communities that we visited along the Arabela and Curaray rivers have requested an expansion to their territories with the hopes of controlling access to and sustainably managing the natural resources on which they depend for their subsistence needs. In Santa Clotilde, a multi-stakeholder committee has formed to unite forces to control commercial extractive activities. The fathers at the vicariate have publicly reported the inhumane working conditions at the timber camps, as evidenced by the countless patients with no access to health-care insurance that they have received at their hospital who have suffered injuries, including children.

On the Mazán River, eight communities are requesting local forest lots known as "*bosques locales,*" two with the support of INRENA (Puerto Alegre and Corazón de Jesús), and six with support from the Municipal Government (14 de Julio, Santa Cruz, Primero de Julio, Libertad, San José, and Vista Buena). During our visit, community members that are involved in these requests stated their reasons: "We want to implement protection activities, manage forest and water resources, and re-define the alternatives for local community members who extract timber at a very small-scale so that it's permitted by the law."

All of these actions indicate the willingness on the part of the majority of the local community members to seek new alternatives for better management of the resources that still exist in this region close to N-M-A Headwaters.

THREATS

During the rapid inventory, local community members repeatedly expressed the concern that their subsistence resource base is being threatened primarily by large-scale fishing activity in their oxbow lakes. The large fishing vessels equipped with refrigeration systems, commonly referred to as *congeladoras,* harvest massive quantities of fishes with large nets, poisons, and explosives along the rivers as well as the oxbow lakes within community boundaries. Local people perceive that they cannot compete with these large-scale extractors, and that an important source of their subsistence base is rapidly declining. In addition to concerns about overfishing, local communities have also expressed concern about a marked increase in the extraction of wood, which not only causes a decrease in timber resources, but also in non-timber forest products and faunal populations. Although some community members periodically become involved in these activities along the Arabela and Curaray watershed, the majority does not and is often unaware of deals made by others. On the Mazán River, there are more local people who have become involved in the timber extraction, which implies the imminent threat of consequences to their well-being.

During our visits, possible threats posed by the presence of oil-extraction activities of REPSOL, a Spanish-Argentine petrol company seemed to be of lesser concern to the local communities. REPSOL has negotiated potential benefits with several communities, but practical information about the extraction process, community rights, case studies of previous efforts, and other important and relevant facts had not been provided by REPSOL. Community members, therefore, had insufficient context in order to negotiate on sound footing with REPSOL.

Finally, some communities mentioned the extraction of gold as being a threat to their subsistence base. According to many community members, these extractive activities have recently increased—particularly along the Curaray and Napo river headwaters—but also on the Mazán River headwaters.

The combined effect of these threats not only places at risk the forest resources, but also the quality of life of local populations, and simultaneously decreases ecosystem services that are delivered to larger cities, such as Iquitos.

RECOMMENDATIONS

In addition to the general recommendations, the social science team has more specific recommendations oriented toward supporting plans to prioritize the well-being of local communities and their natural resources.

First, we recommend that the requests for territorial expansion of the native communities along the Curaray and Arabela rivers be approved. These requests are in different phases of evaluation, but due to lack of resources in the communities and/or in ORAI/AIDESEP, they have not yet been approved. The expansion of these territories will support community-based initiatives to protect forest resources and for this reason require continued evaluation. We also recommend that these expansions be accompanied by technical support to develop management plans and zoning of the titled lands.

Second, we recommend that the proposal submitted by ORAI/AIDESEP for the creation of the Napo-Tigre Territorial Reserve (Reserva Territorial Napo-Tigre) carefully is considered. This proposal is aimed at ensuring territorial rights to the Pananujuri, or Tagaeri, an indigenous group that remains in voluntary isolation. The area of this proposed reserve overlaps with the area that has been ceded to the petrol company REPSOL-YPF for exploration and exploitation of oil. The presence of REPSOL could pose an imminent threat to the indigenous group if they were to come into contact, mainly due to the spread of diseases and/or the possibility of conflicts. In spite of these potentially harmful consequences of the unresolved overlap, REPSOL has already initiated activities in the area.

Third, we recommend that the multi-stakeholder committee of Mazán and ADIPEMPEFORMA be strengthened so that they may continue to consolidate their natural resource management plans and local micro-enterprises with the vision of incorporating community-based management of natural resources in this watershed. The Institute for Research in the Peruvian Amazon (Instituto de Investigaciones de la Amazonía Peruana, IIAP) has developed some proposals that could form the basis for this type of management.

Finally, we recommend that the new regional conservation project of Loreto (PROCREL) becomes involved in these three watersheds, seeking new ways to increase local participation and leadership in protected areas. The communities, their organizations, and the district institutions have many capacities and assets with which to implement effective management.