Nature and ecology of Río Abiseo National Park

Kenneth R. Young / Blanca León

The biological wealth of Peru is linked to the presence of the Andean mountain range and its dual effect as both a barrier and biological corridor. The evolution of the Andes within the territory now occupied by Peru has bequeathed the nation's physical geography countless gradients in the form of fertile slopes and arid valleys, across an altitudinal range extending from sea level to more than 6000 meters. Through an understanding of the geography of Peru's territory, we gain greater insight into its biological richness.

Set into the eastern slopes of the Andes, Río Abiseo National Park (PNRA) lies between the Marañón and Huallaga river valleys, where the landscape is defined by its rugged nature. It is in this context that the PNRA boasts the environmental gradients that make possible the presence of a mosaic of vegetation, ranging from alpine grasslands to montane and pre-montane forests, and the dense tree cover typical of cloud forest habitat. The establishment of the PNRA in 1983 marked the culmination of efforts to combine conservation of the biota and the moist montane forests of northern Peru with protection of the legacy left to the nation by those human groups who once occupied this region. The PNRA now forms part of a national system of protected natural areas that conserves Peru's rich biological diversity.

Our aim is to present what is known about the habitats, biological diversity, and the ecology of the PNRA, through information based upon studies of the flora that defines the character of the park's landscapes, and which provides the setting for the presence of other aspects of the area's biological diversity.

We believe that the PNRA constitutes an enormous natural laboratory, a place that offers perfect conditions for the long term study of local geography, landscapes, biota, ecology and cultural heritage, the results of which have the potential to contribute to the conservation of these forests of the Andes, as well as to a greater understanding of the links between human activity and the biophysical environment.

Extreme topography

The history of the Peruvian Andes is complex. The age of the metasedimentary rock at the center of Peru's eastern Andes is estimated to be between 285 and 340 million years (Mišković *et al.* 2009), while the orogeny itself is associated with the subduction of tectonic plates dating back to the Mesozoic (Haeberlin *et al.* 2004, Faccenna *et al.* 2017). The area occupied by the PNRA incorporates part of the Pataz batholith and the Marañón complex, which constitute zones of interest in our understanding of the chronology of Andean orogeny (Chew *et al.* 2016).

The formation of the eastern Andes mountains in the area occupied by the PNRA has resulted in a topography that extends from 350 meters to almost 4350 meters above sea level. The hills across different sections of the western part of the PNRA possess rugged slopes, without ice cover. The valleys are the result of the action of rivers and water erosion, where the weakening of slopes has been followed by rock falls and landslides. For their part, the highest peaks exhibit the results of direct glacial influence, dating from colder periods in the Earth's history.

The three main river basins of the PNRA are the Montecristo, Tumac and Abiseo, which contain a complex continuous system of broad valleys formed in the past by glaciation, as well as steeper and narrower valleys, ending in the valley of the Huallaga River. This hydrological connectivity is the foundation for the life cycles contained within the park, linking the upper zones, where tributaries of the Huallaga River rise, with the rest of the watershed. Fish and aquatic invertebrates form part of the food cycle of the area's bodies of water, with their distribution determined by water temperature, quantities of dissolved oxygen, and flow rate (for example, certain species have adapted to withstand the force of fast flowing water).

When a drop of water falls from the sky, it will eventually form part of a lake or river, or be absorbed into the soil, becoming in this way part of the water and nutrient cycle of the local ecosystem. Plants within the PNRA depend upon this moisture, the dampness of the soil, and in many cases upon the additional water provided by mists. The soils of the forest are not fertile, and therefore the plants that live there have adapted to grow with few nutrients and in acidic conditions, employing mycorrhizas and other physiological adaptations.

Epiphytic plants thrive on humidity and their physiology serves, as we will see later, as an indicator of local variations across ecosystems. The torrential rains that fall from September to April flood rivers, and the shaping of the landscape over centuries is achieved by the action of rivers and other geomorphological factors that shift sediments and alter topography.

The present-day landscape of the PNRA above 3500 meters is dominated by broad valleys once covered by glaciers. The U-shaped form of these valleys, the presence of moraines, and steep slopes, reflect the impact of glacial masses upon the geomorphology of the zone. The most recent period during which ice sheets achieved their maximum extension is known as the Last Glacial Maximum, or LGM. Simulations of the Last Glacial Maximum in the Andes indicate that the maximum extension of this event occurred across different periods, between 34,000 and 21,000 years ago (Smith *et al*. 2005).

The effect of glaciation also influenced the form of the surfaces and substrate of the upper valleys. A series of moraines are found occupying positions generally at right angles to the meeting points of valleys with lakes and glacial cirques. Today, the landscape of the park's western area is blessed with several lakes that are relics of the glacial period. The influence of the historic movement of glaciers in the upper reaches of the PNRA can also be seen in the gigantic rocks found scattered across grasslands and slopes. One of these forms the roof of the Manachaqui Cave, a site containing evidence of human settlement dating back some nine thousand years (Church, 1996).

Broadly speaking, the influence of glaciers is only apparent at altitudes in excess of 3200 meters, below which the valleys narrow into a V-shaped form. Slopes are composed of steep gradients, and in most of the valleys evidence of landslides is conspicuous. The existence of montane forest on these types of slopes leads to physical instability in the substrate, visible in the form of mudslides that tear away part of the vegetation, and in ravines that become flooded during the rainy season. On intermediate slopes, forest tree cover grows taller, with canopies forming some 25 meters above the ground, and emergent trees soaring to heights of up to 35 meters. The banks of rivers are covered in low growth forest, composed of trees measuring between 5 and 10 meters in height; this forest is similar in height to that found on steeper slopes, in rugged areas with gradients in excess of 40°.

The biodiversity of Peru is the product of a complex and dynamic history (Young, 2009). For many groups of organisms, the connective processes of the highlands and their formation explain their diversification and evolutionary characteristics. A recent study of butterflies from the colorful *Morpho* genus (Nattier *et al*., 2017), in Peru's eastern Andes, demonstrated the way in which massive geological and climatic events in the past can help us to date speciation processes. Regardless of the ability to move possessed by different species, topography appears to act as an insuperable barrier, as do climatic variations over time. The PNRA offers countless possibilities for such study.

Environmental gradients

The area occupied by the PNRA incorporates three large ecological zones (Young & León, 1988): the tropical alpine, montane forest, and pre-montane forest zones. In their turn, these contain a variety of habitats and plant communities. The local climate has not been studied in detail, but by extrapolating data gathered for the eastern slopes of the Andes as a whole, we can state that at altitudes between 1500 and 2500 meters the temperatures range from 17 to 25 °C, while between 2500 and 3500 meters the temperatures are lower, ranging from 8 to 17 °C. Above 3500 meters, temperatures can drop to freezing at certain times of the year, with occasional snowfall.

The territory of the park is dominated by highlands, with grasslands accounting for 22% and montane forest above 1500 meters for around 53%. Variations in the geography of the park mean that each ecological zone is characterized by specific flora, with the forested areas constituting those with the greatest wealth of plant life, although the alpine zone dominated by high grasslands also boasts considerable diversity in comparison with other similar areas (Young, 2010). In the valley floors, high altitude wetlands are dominated by a diverse community of Cyperaceae and other marsh grasses, associated with poorly drained locations.

The pre-montane forest contains some species with ranges that extend as far as higher altitudes, as well as elements of the flora associated with lowland forest, and which extend down as far as that habitat. Other species are adapted specifically to this zone, and are therefore considered characteristic of the moist pre-montane forest of the PNRA. In this area, there are major populations of Amazonian species which constitute a source of genetic material.

The montane forest is characterized by different plant types associated with the degree of humidity, ranging from moist forest to rainforest. The wettest places are enveloped in persistent mists, and are composed of cloud forest. In the case of certain species of fauna, such as the yellow-tailed woolly monkey (*Lagothrix flavicauda*), montane forests are their exclusive habitat, which is why this primate is seen as these forests' emblematic species. In this type of forest, it is also common to find evidence of the spectacled bear (*Tremarctos ornatus*), the range of which appears to extend as far as the upper reaches of the park.

In the western area of the PNRA, there exist several types of environmental variation, one of which is edaphological. For example, differences in degrees of drainage are readily apparent across the landscape above 3000 meters. In areas with limited drainage, mostly situated on valley floors, biological communities occur as a matrix of grasslands, where species of the Cyperaceae family dominate. These grasslands are home to particular fauna, such as wild guinea pigs, mice and amphibians. Zones with good drainage tend to be occupied by forests and interesting areas of transitional scrubland between the grasslands and forest.

In terms of landscape, the presence of an altitudinal range is also associated with changes in precipitation, humidity and temperature. These environmental differences make possible the presence of diverse types of habitat, in terms of both the soil substrate and areas of exposed rock, as well as the presence of other types of substrate such as the surfaces of branches and tree trunks within the forest. In the PNRA, epiphytic plants constitute important elements of the park's diversity, and in areas with high concentrations of cloud cover and humidity these species include bryophytes, ferns, orchids, bromeliads and fungi, while in less humid areas lichens tend to dominate. Altitudinal range also enables mobile species, such as large birds, to access a number of ecological niches. Some species change location during the year, as they follow the availability of seasonal fruits.

Across the altitudinal range we observe different types of ecosystem. Lines of contact between two ecosystems or types of vegetation are known as ecotones. The upper limit of the forest forms an ecotone subject to modification in terms of structure and composition by the effects of climate change, or by alterations resulting from anthropic processes. Another important ecotone is the limit of constant mists. These mists produce the cloud forest found at between 2700 and 3200 meters above sea level, depending on exposure to Amazonian winds.

Altitude and flora

"*Descending along those tributaries of the Huallaga we found between 3700 and 3600 meters the first hills of the high forest. They appeared as patches alternating with grassland. Between 3400 and 3300 meters the grassland disappears and one enters the forest.*" Weberbauer (1945: 532).

The historic description left to us by the botanist Augusto Weberbauer (1920, 1945; see León, 2002) was confirmed by the work of Young (1990, 1991 a, 1993 a, b, c), who conducted a study of three types of areas containing woody species. His data indicates that their altitude and the distance from forest edges constitute environmental gradients essential for understanding differences in the structure and composition of the forests within the park above 3200 meters. The influence of altitude was noted not only in the changes in arboreal species present, but also in terms of their regeneration. Also, areas of forest less than 40 meters from the forest edge were denser and more stunted than areas deeper within the forest, with the presence of woody species that require high levels of light. We can suppose that many species of animals are also adapted to live in these border areas, as well as deeper in the forest.

The type of vegetation most associated with the eastern slopes of the Andes is that of forests, and therefore it might be assumed that arboreal species are the most dominant group in terms of species richness; however, it is herbaceous plants which actually constitute the most dominant group in terms of the variety of their forms and the wealth of their components. This pattern expressed in the dominance of herbaceous plants is also found in other habitats across the slopes of the Andes, such as rocky areas, grasslands, wetlands, and open undisturbed zones.

The PNRA is one of the few protected natural areas of Peru for which a detailed list of flora has been compiled (Young & León, 1990; León *et al*., 2010). The plant collections compiled are kept in the herbariums of three major national institutions: The Natural History Museum (MHN) of San Marcos National University; the Herbarium of the National University of Trujillo (HUT); and the Herbarium of La Molina National Agrarian Museum (MOL). These collections have served as reference points for several studies, and will continue to do so in the future.

The flora of the entire area of the PNRA is believed to be composed of some 4000 vascular plants, representing approximately 16% of Peru's flora (Brako & Zarucchi, 1993; Ulloa *et al*., 2004; León *et al*., 2010). This flora reflects the species richness of the Amazonian slopes in the north of the country, and forms an essential part of the complex biogeography of both the northern part (the Chachapoyas region) of the eastern Andes, and that of Huancabamba-Marañón. In addition, studies have confirmed the presence of a rich variety of non-flowering plants, most notably pteridophytes, lichens, mosses and algae.

In-depth studies of the biodiversity of the PNRA have been conducted principally in the moist grassland and montane forest zones. Plots established in the southern part of the PNRA for the monitoring of climate change, situated above 4000 meters, indicate the presence of 50 to 60 species, comparable to the results for areas of Ecuador located at similar altitudes (Sklenář & Jørgensen, 1999). This flora is composed predominantly of herbaceous perennials and non-woody plants, dominated by grasses and graminoids (Poaceae and Cyperaceae). In forested Andean zones, calculations indicate the presence of between 10 and 60 tree species, including understory woody species. The presence of bamboos (*Chusquea* spp.) is conspicuous, with their populations forming large groups and often dominating montane forests, particularly at forest edges or in clearings (Young, 1991a). The richness of other groups of plants is remarkable; for example, more than 200 species of ferns have been recorded (Young & León, 1991), and of these a dozen are arborescent ferns, some of which grow up to 12 meters in height. These arborescent ferns form relatively dense populations in the understory, where their long leaves recall those of palm trees. In the montane forest, exposed sites are dominated by palms from the genera *Ceroxylon* and *Prestoea*.

In the upper reaches of the PNRA, five families of vascular plants account for 28% of the total species richness: Asteraceae, Poaceae, Dryopteridaceae, Polypodiaceae and Orchidaceae. Across the altitudinal range, and in each of the ecological niches, species of both flora and fauna tend to be limited to restricted altitudinal distribution. For example, in the case of the almost 340 species of vascular plants known to exist in the moist high grassland ecological zone, the majority have been recorded at altitudes in excess of 3000 meters. Altitudinal restrictions are reflected in the interactions between flora and other biological components.

Among the plants of particular interest in terms of the restricted distribution they exhibit are populations that are only found to grow in Peru or within the PNRA. The contribution of the park's flora to new records for Peruvian flora is estimated to be 2% (20) of the total species recorded within the PNRA. This flora includes examples of national and regional endemism, particularly within montane forest zones. In the case of the PNRA, this includes a total of 103 endemic species, of which 85 are found in the upper reaches of the park and 18 are found in neighboring areas (Young, 2010).

Peru's national parks contribute to the conservation of rare species of vascular plants by providing a refuge for the majority of endemic taxa within the nation's National System of State-Protected Areas (León *et al*., 2007). The PNRA contains 10% of the endemic flora protected within the national park system.

The complexity of biological components is reflected in the multitude of biological interactions and the consequences of these for the ecology of the area. Symbiotic interactions have been identified across a number of species present in the PNRA, as in the case of cyanobacteria, with members of the *Gunnera* genus, or with the aquatic fern *Azolla*. Parasitic interactions have been identified among different plant components, such as *Bartsia* and *Castilleja*, in Andean grasslands, or *Tristerix*, with different species of trees in montane forests.

The best known biological interaction is almost certainly pollination. One example associated with an unpleasant odor is that of species from the genus *Valeriana*, which attract flies to pollinate them. Other plants with bright red flowers, such as species of *Centropogon*, *Fuchsia* and *Siphocampylus*, are pollinated by the birdlife of the park, in the form of hummingbirds. Many species of orchid are pollinated by certain insects that specialize in their particular flower types. Bats are also associated with the pollination of some species of plants, as well as the seed dispersal of other species. The majority of flowering plants depend upon animals for seed dispersal, to which end they produce seeds wrapped in fruits intended to attract symbiotic species. In general, species interact in a mutualistic manner; in other words, their existence is dependent upon other species.

Environmental changes over time

Recent plant ecology work conducted in the park (Young, 1993a, 1998), including satellite detection of changes in the western zone (Kintz *et al*., 2006), as well as studies of the past (Hansen & Rodbell, 1995; Bush *et al*., 2005), have provided new insights into the biological and environmental processes associated with eastern Andean montane forest, particularly forest edges. Such studies have highlighted the dynamism of the processes associated with changes in plant communities. Young & León (2007) have noted the heterogeneity of the upper limit of Andean forest, associated with a species richness the components of which exhibit their own characteristic responses to biophysical limitations.

To some degree, virtually all aspects of the composition and structure of vegetation change constantly. Young (1991a) was able to determine mortality rate by species and by tree species group. The rate of 1.5% mortality per year of all large plants (with diameters greater than 2.5 centimeters) is similar to the rate for lowland forests. This result indicates that the forest studied in the park is as -or more- dynamic than an Amazonian forest situated 3000 meters lower. The montane forest studied also exhibits several annual changes within a spatial scale of a few meters. It should be noted that each species exhibited a different population biology; many of the big trees displayed no mortality over two years, while other species (*Gynoxys* sp., *Myrsine dependens)* displayed high rates, interpreted as a sign that they were disappearing from the stands being studied.

Studies designed to reconstruct the last 20,000 years of history within the PNRA have proved important by emphasizing that neither climate nor vegetation have remained constant over time (Hansen & Rodbell, 1995; Bush *et al*., 2005). The authors of these studies have shown that during the Pleistocene glaciers may have advanced to altitudes of around 3200 meters, as in the case of the Chochos valley (Rodbell, 1992). Glaciers began to retreat in the area now occupied by the park around 13,000 years ago (Rodbell, 1991; 1992).

Studies incorporating data on pollen and carbon deposits in the sediment of Lake Chochos (Bush *et al*. 2005) confirm that the deglaciation period was marked by intense climatic variation associated with warming, most notably around 9000 years ago. The information compiled by Bush *et al*. (2005) also points to two cycles of climatic fluctuation: one lasting 216 years, and the other 750 years. Given that, in theory, the evolution of a new species requires hundreds of thousands of years, the dominant processes during such time scales would not have included speciation, but rather the altitudinal migration of flora and vegetation, as well as the arrival of species from the Huallaga and Marañón river basins.

The environmental conditions described as part of the climatic and geological history of the PNRA have had consequences beyond the limits of the park. They offer a biophysical context for our understanding of northern Peru and the contact of the eastern slopes of the Andes with the Amazon basin, and they indicate that climate change may have been a factor in the history of human habitation in the region.

Human influence

The lakes and rivers of the PNRA offer a setting characterized by beautiful scenery, particularly in those natural areas least affected by human influence and home to unique biodiversity. However, rivers situated above 2200 meters contain populations of rainbow trout (*Oncorhynchus mykiss*), an exotic species introduced from North America some five decades ago. This species is now the main predator of other fish and aquatic organisms, and can therefore be considered a negative modifier of the environment it inhabits. These trout may have entirely eliminated certain native species of fish and amphibians, which are particularly vulnerable during their aquatic larval stages. This case highlights the fact that even when it is indirect, human influence can be significant.

Clearly, human influence within the area occupied by the park is not a recent phenomenon, but it has continued apace in the upper reaches, while not being limited to that zone. Studies of plant ecology have included analysis of this type of impact (Young & León, 1988; Young, 1993b, c). The high grassland (tropical alpine zone) of the park is probably the area where the greatest continuous impact has been felt, and studies have been conducted on the effects of changes in the composition of grassland communities resulting from fires and grazing (Ponette-González *et al*., 2016). Recently, a time scale of decades has been established for ongoing observation of the effects of climate change, with the establishing of Global Observation Research Initiative in Alpine Environments - GLORIA (Pauli *et al*., 2004) inventory plots.

The composition of flora within the PNRA reflects the history of human intervention, as well as the dynamics of geomorphological processes. In the past, one of the most damaging activities for the flora and vegetation of the western sector was intensive grazing and associated burning.

In the western part of the park at altitudes where grassland predominates, and particularly in the southern sector of the PNRA, where there was intensive grazing in the past *Werneria nubigena* or *Alchemilla* spp. have been found to dominate. These species are not palatable to livestock, and have therefore survived and spread into areas where more palatable species are found. At the same time, there is evidence that fires have fragmented and reduced the upper limit of the forest, resulting in isolated arboreal species or reduced stands, as in the case of *Buddleja incana* or *Escallonia resinosa*. The flora at landslide and riverbank sites has not been extensively documented, but we do know that it includes elements of pioneer species and others tolerant of fluctuating environmental conditions.

The flora of the PNRA includes several species of local interest by virtue of their use in traditional medicine or other traditional practices. In some cases, these species are subject to extraction, but the impact upon their populations of extraction on a scale sufficient to satisfy local requirements has not been evaluated, and nor do we know if these plant populations have been assessed in terms of their importance to genetic diversity. For example, *Laccopetalum giganteum*, employed in traditional medicine (Rodríguez *et al*., 2007), is present in the PNRA, but as far as we know its populations throughout its range within Peruvian territory are extremely localized (Young, 1991b; León *et al*. 2010).

The presence of archaeological sites in what is today forest (Church, 1988, 1991, 1996) indicates that this forest is the product of historical deforestation (more than four centuries ago), followed by the gradual recovery of the forest biomass. The structure and composition of these recovered forests, therefore, may have been influenced by that history of landscape use.

On a different timescale, we also have the selective extraction of timber in the southern part of the park dating from the 1960s. Today, these areas, situated in the montane forest ecological zone of the Abiseo river basin, are composed of recovering forest and offer an opportunity to study and replicate such ecological restoration.

The PNRA requires a comprehensive approach to its challenges and issues, particularly those associated with the presence of neighboring human settlements. This implies a dynamic perspective like that proposed by Young (2010). The consequences for the park's ecosystems of processes and factors associated with human impact are multiple. Such impacts include those derived from the burning of grasslands and forests, the grazing of non-native animals, the building of roads (Leo & Ortiz, 1982; Young *et al*., 1994), and the potential influence of historical extractive activities. One possible risk requiring evaluation is the introduction of flora, particularly in areas that experience the intensive transit of people and livestock, given the risk that the colonization processes of such species might supersede native flora. Poaching within the park constitutes another impact requiring further study. Barrio (2013) described the deer present in Peru, including the PNRA, which is home to white-tailed deer (*Odocoileus virginianus*) and north Andean deer (*Hippocamelus antisensis*).

Further conservation and protection measures are required in northern Peru. Environmental deterioration beyond the park endangers the habitats within the protected area. It is important to understand the dynamics of deterioration and the interaction of the processes underlying such deterioration with the conditions within the park, so that risks can be evaluated and mitigating measures adopted.

Conclusions and next steps

Peru is a megadiverse country, the product of the evolution of a host of species over millions of years, together with the presence of a biophysical diversity characterized by many distinct climate zones spread across considerable altitudinal ranges. Such diversity calls for a responsible approach to its conservation and the sustainable use of natural resources.

In Peru, the concentration of biological wealth is greatest on the moist Andean slopes situated within the Amazon basin (Young, 1992). The biophysical factors that make such wealth possible include the isolation of populations due to physical barriers, the presence of altitudinal corridors that facilitate the movement and exchange of biota, and environmental gradients. The geology of the Andes and the geomorphological processes within Peruvian territory produce an environmental dynamic that influences the evolution of the Andean biota. In this context, protected areas function as natural laboratories in which ecological and evolutionary processes produce changes in ecosystems and species, typically over centuries or millennia. Human activity in such areas can be considered minimal, although in many cases the influence of the past may persist.

The creation of the Río Abiseo National Park (PNRA) was made possible by the efforts of the Peruvian Association for the Conservation of Nature (APECO), and specifically by the work of the biologist Mariella Leo (Leo & Ortiz, 1982), who together with neighboring communities, particularly those of Alisos and Piás, promoted a number of natural resource conservation programs that other organizations and individuals would do well to replicate. These efforts were supported by recognition of the PNRA on the part of UNESCO as a World Heritage Site of global significance.

Given that the environment and climate have changed in the past, it should come as no surprise that they might change in the future (Young & Lipton, 2006; Sarkar *et al*., 2009). From the perspective of biological conservation, the park exists not only to protect the plants and animals that live there now, but also to protect future generations of flora and fauna. In order to achieve adequate protection of the biota, measures will be required based upon timescales far beyond those normally considered by policymakers.

Based upon the information gathered by studies already conducted, we can conclude that its biological and historical heritage mean that the PNRA should be viewed as both an object of pride and a responsibility. At the same time, it is clear that the areas bordering the park must be included in its management and protection programs. And, finally, we must never forget that biota and vegetation have never existed, do not exist, and can never exist in a vacuum.