Preserving the Unique Puna Ecosystems of the Andean Altiplano

Authors: Rundel, Philip W., and Palma, Beatriz

Source: Mountain Research and Development, 20(3) : 262-271

Published By: International Mountain Society

URL: https://doi.org/10.1659/0276-4741(2000)020[0262:PTUPEO]2.0.CO;2

Mountain Research and Development Vol 20 No 3 Aug 2000: 262–271

Philip W. Rundel and Beatriz Palma

Preserving the Unique Puna Ecosystems of the Andean Altiplano

A Descriptive Account of Lauca National Park, Chile

Lauca National Park forms a unique area of puna and prepuna ecosystems in the high Altiplano of northeastern Chile. Its extensive puna steppe shrublands lying above 4000 m and high volcanoes reaching above 6000 m provide some of many strong justifications for its designation as a UNESCO International Biosphere Reserve in 1983. The park also contains Lago Chungará, the highest lake in the world at 4518 m elevation, and a rich variety of fauna and flora. The mammal fauna of the park includes notable populations of large herbivores such as vicuña, guanaco, and huemul, and a rich diversity of rodent species. More than 140 species of birds, one third of the total Chilean bird fauna—with many rare wetland species— and more than 400 species of vascular plants occur within the park. Despite its relatively pristine natural environment, Lauca National Park faces numerous management challenges. These include the management of critical and limited water resources, the impacts of human population and tourism, management of rare and endangered species, and pressures from mining and agricultural interests to decertify areas currently within park boundaries. Expansion of the park boundary westward to include ecologically significant prepuna habitats should be a high priority of park management.

Keywords: *Parinacota; Lago Chungará; bofedales; Polylepis; Azorella; park management; Lauca National Park; Chile.*

Peer reviewed: *April 2000.* ***Accepted:*** *May 2000.*

Introduction

Lauca National Park, positioned in the high Andean Altiplano of northern Chile, provides an unparalleled example of a pristine, arid puna ecosystem. The Lauca Basin within which the major area of this large park lies forms a portion of the Altiplano Plateau shared by southern Peru, western Bolivia, northern Chile, and Argentina. Included within the park boundaries are spectacular vistas of extensive puna landscapes, large Andean lakes and wetlands, and a series of snow-capped volcanoes. Three volcanic cones rise above 6000 m elevation—Parinacota (6342 m), Ponerape (6240 m), and Guallatire (6063 m)—and numerous peaks reaching above 5000 m ring the Lauca Basin in which the park lies. Lago Chungará is situated at an elevation of 4518 m. It is the highest lake of significant size in the world. Beyond these scenic attributes are rich and unique flora and fauna exhibiting remarkable adaptations to the high elevations of Lauca. Vicuña, guanaco, huemul, viscacha, rhea, and flamingo are among the notable wildlife readily visible and protected in this park.

Associated with Lauca National Park, which comprises 137,833 ha, are Las Vicuñas National Reserve (209,131 ha) and the Salar de Surire National Monument (11,298 ha). The former was established to protect and manage populations of the endangered vicuña, while the latter protects a relatively small saline lake that is of international significance for its large and diverse populations of resident birds. Lauca Biosphere Reserve (including Lauca National Park, Las Vicuñas National Reserve, and Salar de Surire National Monument) was declared a UNESCO International Biosphere Reserve in 1983, 1 of only 7 reserves in Chile so designated.

Lauca National Park is situated at about 18°10'–18°25' S latitude along the Bolivian border in Region 1 of northern Chile (Figure 1). Despite its very high elevation, the entrance to the park lies only 160 km east of the coastal city of Arica. The area of Lauca National Park was first set aside as a portion of a large forest reserve in 1965 and then redesignated as a national park in 1970 by a decree of the Chilean Ministry of Agriculture. Its present boundaries were set in 1983, along with those of Las Vicuñas National Reserve and Salar de Surire National Monument. It is 1 of only 2 national parks existing in the puna region of the northern Chilean Andes. The other, Volcán Isluga National Park, lies 120 km to the south.

The summer rainfall regime in the puna region is unique in Chile and different from the Mediterranean-like climate in most of the country (Table 1). This climatic regime represents the most arid extension of a tropical alpine ecosystem that occurs from central Peru southward through western Bolivia into northern Chile and Argentina. Tropical alpine climates create extreme conditions for survival, with freezing temperatures occurring almost every night of the year. Daily ranges of temperature extremes from high to low may be as much as 25–30°C. The puna as represented at Lauca thus represents a unique bioclimatic and biogeographic region of Chile, with strong floristic and faunistic relationships to Peru and Bolivia rather than to other parts of Chile.

Despite its many attributes, Lauca National Park continues to face significant issues of resource management and protection that are critically important for its future. The present article briefly reviews the natural attributes of Lauca and discusses issues of resource management and external forces impacting the park.

FIGURE 1 Map of Lauca National Park showing the primary geographical features and vegetation formations. The transitions from pre-puna shrublands to puna shrub steppe and from puna shrub/steppe to high Andean occur at elevations of roughly 4000 and 5000 m, respectively.

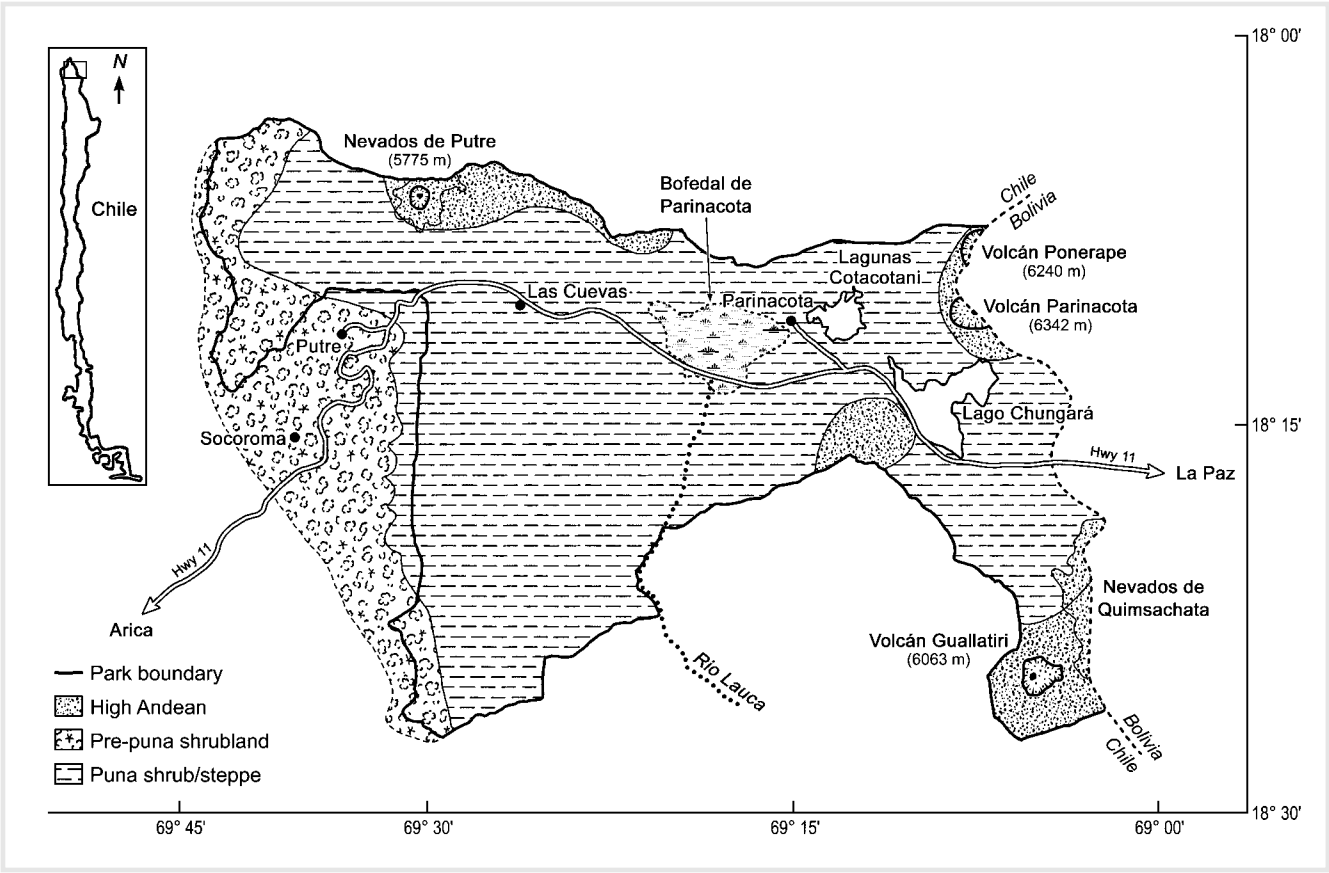

TABLE 1 Mean monthly maximum and minimum temperatures and rainfall at Parinacota (4390 m asl). Data from Novoa and Villaseca (1989) for temperatures and wind speed and CONAF (1986) for rainfall.

Month	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean rainfall (mm)	Mean wind speed (km/h)
January	7.9	0.3	90.0	5.3
February	7.8	0.2	99.3	4.9
March	7.5	-0.1	55.9	4.7
April	6.1	-1.1	9.5	4.9
May	3.9	-2.9	3.0	4.9
June	1.1	-5.1	1.7	5.9
July	0.0	-6.0	0.6	5.7
August	3.1	-3.5	1.4	5.9
September	3.7	-0.1	2.7	6.0
October	5.9	-1.3	2.9	6.1
November	6.7	-0.7	14.2	6.0
December	7.3	-0.3	39.8	ND
Mean	5.1	-2.0	321.6	5.5

Geomorphology and hydrology

Lauca National Park lies largely within the northern Lauca Basin, which is the westernmost extension of a series of fluvio-lacustrine basins that stretch over more than 800 km from Lago Titicaca across the Bolivian Altiplano to the Salar de Uyuni. This basin is drained by the Rio Lauca, which flows eastward into the Copiasa Basin of Bolivia. The eastern margin of the basin is formed by a line of active volcanoes extending from Parinacota and Ponerape to Cerro de Quisiquisini, Guallatire, and south to Puquintica (5780 m). The western hydrologic boundary of the basin is formed by a chain of deeply eroded Miocene volcanoes, which are sometimes termed the Chilean Western Cordillera. Geologically, this chain consists of folded and faulted Cretaceous and Tertiary sediments mixed with former volcanic centers of activity. The most prominent peaks are the Nevados de Putre (with the Cerro de Taapaca at 5775 m) and Cerro Belén, Cerro Tallacollo, Cerro Orotunco, and Cerro de Anocarire, which all reach above 5000 m. Beyond this chain to the west, the Altiplano plateau exhibits a sharp staircase drop of more than 2500 m along two north–south striking normal faults (Kött et al 1995).

FIGURE 2 Volcán Parinacota (6342 m) with Lago Chungará, the highest elevation lake in the world, at its base. In the right foreground are dwarf woodlands dominated by *Polylepis tarapacana*, and the left foreground shows wetland habitats termed bofedales with grazing vicuñas. (Photo by authors)

The relatively gentle topography within the Lauca Basin averages about 4100 m in altitude, giving it an elevation about 500 m higher than Lago Titicaca. Geological evidence and climate indicators such as pollen, evaporites, and sedimentary facies indicate that an arid climate has existed in the Lauca Basin over the past 6.2 million years (Kött et al 1995; Gaupp et al 1999).

Volcán Parinacota (Figure 2) and the adjacent Volcán Ponerape are jointly known as the Nevados Payachata. These volcanoes have been the subjects of relatively detailed vulcanological and geochemical studies. Ponerape is extensively glaciated and therefore pre-Holocene in age, while Parinacota is younger and consists of an older dome and flow complex capped by younger andesite flows. This volcano possesses a well-preserved summit crater about 300 m in depth and a large glacier on its southern slope. Volcán Guallatiri, the youngest of a trio of volcanoes forming the Nevados de Quimsachata, is one of the most active volcanoes in northern Chile. It has the distinction of being the southernmost volcano in the Central Andes to retain a perennial thick ice cap.

At 4518 m, Lago Chungará (Figure 2) is the highest natural lake of moderate to large size in the world and covers about 2100 ha (CONAF 1986; Andrew 1987). It was formed when an avalanche of rocky debris from Volcan Parinacota 13,500 years ago dammed existing westward drainages at Lauca. Water seeping slowly through the remains of this avalanche deposit supply water for Lagunas Cotacotani, which itself serves as the source of the Río Lauca.

Hydrologic studies in the Lauca Basin and adjacent basins have indicated that ongoing hydrologic recharge of groundwater aquifers is relatively limited

FIGURE 3 Volcán Ponerape (6240 m, left) and Volcán Parinacota (6342 m, right) tower over rocky lava ridges with stands of *Polylepis tarapacana* growing with *Parastrephia lucida* and *Azorella compacta*. (Photo by authors)

(Messerli et al 1997). Thus, many of the existing pools of groundwater likely date from more humid periods about 13,000–12,000 BP, with evidence for maximum lake levels from the period about 10,000–9200 BP (Gehy et al 1999).

Terrestrial communities and biodiversity

Vegetation and flora

The plant communities of Lauca National Park can be divided into three formations, or alliances, as they are termed in the phytosociological literature. The lower prepuna elevations at about 2900–3900 m on slopes leading up to the Altiplano plateau are dominated by shrublands of varying height and densities that can be characterized as prepuna shrublands. This relatively diverse shrubland commonly has a woody plant cover of 40% or more. Various authors have distinguished a number of associations within these shrublands on the basis of dominant shrub species (Cabrera 1957; Hernández 1980; Gajardo 1994).

The plateau of the Altiplano, which forms the major area of Lauca National Park at 4000–4500 m elevation, is a steppe shrubland. The bunchgrasses *Festuca orthophylla* and *Deyeuxia breviaristata* are the dominant species (see Figure 4), together with two widespread evergreen shrubs, *Parastrephia lucida* and *P. quadrangularis* (Asteraceae). Two additional steppe shrubland communities can be distinguished at Lauca. Rocky slopes above 4000 m commonly support a cushion plant shrubland characterized by the presence of *Azorella compacta* (Apiaceae), a large woody cushion reaching up to 1 m in height and 4 m in diameter. Its unusual lemon-green color is visible at great distances. *Polylepis* woodlands dominated by *P. tarapacana* form the final distinctive community on north-facing slopes at 4400–4900 m (Figure 3). Individual trees of *P. tarapacana* reach 3–4 m in height and more than 40 cm in diameter at Lauca.

The final puna communities at Lauca are the wetlands of the *bofedales* (see Figure 2). These wetland communities cover 10,170 ha of the park and are a keystone habitat for wildlife. Woody cushions of *Oxychloe andina* (Juncaceae) form the dominant cover of the *bofedales,* with a diverse assemblage of associated plant species (Ruthsatz 1995).

No thorough field study of the flora of Lauca National Park has been carried out, but it is possible to estimate the approximate size of this flora from literature surveys carried out in Region 1 of northern Chile. Combined records from all available surveys and biogeographic studies of Parinacota Province suggest that the expected number of vascular plant species within the present boundaries of Lauca National Park is between 400 and 450.

The biogeographic affinities represented in the flora of Lauca National Park and adjacent areas of Parinacota Province show differing patterns between zonal and wetland floras. The flora of zonal habitats of the prepuna and puna show stronger floristic links to a regional puna flora extending from southern Peru and western Bolivia into northern Chile and Argentina. This puna flora in the Andean puna habitats of northern Chile is markedly distinct from that of the Andean flora characteristic of the central and south-central Andes, where winter rainfall regimes exist (Arroyo et al 1988). There is a stronger floristic similarity, however, between the puna wetland flora of northern Chile and the Andean wetland flora of central and southern Chile, and little local endemism is present in this group (Arroyo et al 1982, 1988; Ruthsatz 1993).

FIGURE 4 Grazing vicuñas on one of the roadside bofedales near Las Cuevas in Lauca National Park. The rocky hillside slopes behind are dominated by perennial bunchgrasses, particularly *Festuca orthophylla* and *Deyeuxia breviaristata*. (Photo by authors)

Mammals

The mammal fauna of Lauca National Park is relatively small, including approximately 31 species, not considering bats, which are poorly studied and collected. The most charismatic of the large mammals at Lauca is the vicuña, *Vicugna vicugna* (Figure 4). These large cameloids, once threatened with extinction due to hunting for their valuable fur, numbered less than 1000 individuals in the early 1970s; their populations have recovered remarkably under park protection. Vicuñas are commonly found grazing on the wetlands of the bofedales at Lauca, where their territorial habits give rise to competition for food and water.

Guanacos (*Lama guanicoe*), once extremely wide ranging in southern South America, are now relatively rare in the northern half of their former range. Guanacos are common around and above Putre at the lower margins of Lauca National Park in prepuna shrublands and grasslands up to about 4200 m (see Figure 6). Although there is overlap in habitat range between vicuñas and guanacos at 4000–4200 m, minimal competition for food is thought to occur.

The third large ungulate present at Lauca is the Andean huemul or *taruca, Hippocamelus antisensis*. The distribution of the Andean huemul in Chile is highly restricted, occurring only in the northernmost prepuna and puna areas. Populations of Andean huemul at Lauca are most common in prepuna grasslands and shrublands below about 4000 m in western areas of the park. Once threatened with extinction by hunting, populations of Andean huemul at Lauca are increasing.

Six species of carnivores are also present at Lauca. The largest but rarest of these is the puma, *Puma concolor*. This extremely wide-ranging predator has been eliminated over much of its former range in southern South America but once occurred throughout Chile. The most notable other carnivores are the Andean cat (*Felis jacobita*) and the pampas cat (*Felis colocolo*).

The most abundant, diverse, and locally distributed group of mammals at Lauca is certainly the rodent family, with 22 species present. High Andean areas of northern Chile fall within the range of a remarkably diverse assemblage of puna rodents, and the puna region of the Altiplano has been an area of active speciation among rodents (Reig 1986; Marquet 1994). The diversity of rodents within Lauca is as great or greater than in any other part of Chile. The ability of many of these rodent species to survive at the extreme upper limits of vegetation is remarkable, with 9 rodent species known to occur at elevations up to 5000 m or more, the typical upper limit of occurrence for vascular plants in the puna.

The most apparent and charismatic of the Lauca rodents is the viscacha (*Lagidium viscaria*). These large rodents collect considerable amounts of plant material for their nests and thus build up middens of significant size. These middens remain for thousands of years and are now being used to develop a 40,000-year chronology of vegetation change in areas of the Chilean puna.

Ctenomys opimus, the tuco-tuco of the puna, is another abundant rodent at Lauca. This species inhabits open areas on sandy, gravelly, or cindery soils up to 5000 m. It is their burrowing and feeding activities rather than tuco-tucos themselves that are readily apparent on the puna landscape. Tuco-tucos build burrow systems consisting of main and lateral tunnels. They forage for roots, stems, and leaves in the immediate area of the mouths of their burrows, producing large open areas where vegetation has been removed.

Birds

Bird populations in Lauca are surprisingly rich and diverse for such an extreme environment. About 148 species are reported from the park, accounting for nearly a third of the total Chilean bird fauna. The open *Festuca* grassland areas of the park are home to several interesting bird species, including the lesser rhea (*Pterocnemia pennata*). These large flightless birds reach 1 m in height and 20 kg in weight. Other common flightless birds of the open grasslands at Lauca are the puna tinamou (*Tinamotis pentlandii*) and ornate tinamou (*Nothoprocta ornata*), which reach 35–40 cm in height.

The largest and most spectacular populations of birds at Lauca are found in wetland habitats in the bofedales around Parinacota and at Laguna Cotacotani and Lago Chungará. Aquatic bird populations are particularly rich at Lago Chungará, with thousands of birds present. The most abundant species are the giant coot (*Tagua gigante*), silvery grebe (*Podiceps occipitalis*), and Chilean teal (*Anas flavirostris*). Large mud nests built by the giant coot form prominent small islands 5–10 m from the shore. These nests are a protection against predators. Among the diverse wetland birds present is the diademed sandpiper-plover (*Phegornis mitchellii*), one of the rarest shorebirds in the world.

Lauca is one of the very few places in the world where one can observe three species of flamingo together. These are the Chilean flamingo (*Phoenicopteris chilensis*), Andean flamingo (*Phoenicopteris andinus*), and puna, or James', flamingo (*Phoenicopteris jamesi*). The Andean condor (*Vultur gryphus*), puna hawk (*Buteo poecilochrous*), the red-backed hawk (*B. polyosoma*), and the mountain caracara (*Phalcoboenus megalopteris*) are present as carrion feeders and predators at Lauca.

Human history

Human history in the Lauca region of Parinacota Province extends back thousands of years. Hunter-gatherers are thought to have inhabited this region at least 7000 years ago and perhaps as far back as 10,000 BP. Agricultural and herding centers began to develop

FIGURE 5 Village of Parinacota at 4400 m elevation in Lauca National Park. The church was originally constructed by the Spanish conquistadors in the 17th century, and rebuilt in 1789. (Photo by authors)

about 3000 years ago. One thousand years ago, the Parinacota region came under the control of the Tiawanaku Empire centered at the edge of Lago Titicaca and 500 years later under the control of the Incan Empire. Numerous archeological sites representing these eras have been identified within the park, but have not been carefully excavated or studied. The most significant archeological sites are the Tambo de Chungará, Refugio Rocoso Las Cuevas, and the Chacus Incaico Las Cuevas.

Although the village of Parinacota dates from pre-Columbian times, the Spanish rebuilt the town as a center along a herding trail connecting Arica with the silver mines of Potosí in Bolivia. The church of Parinacota was first constructed in the 17th century and then rebuilt in 1789 in its present form (Figure 5). The wall paintings and statuary inside date from the 17th century.

The human inhabitants of the Lauca National Park today are largely Aymara Indians, whose ancestors have lived in the Altiplano for thousands of years. However, there has been significant migration of Aymara into the park from Bolivia in relatively recent decades. There are two primary population centers within the park. These are at Parinacota and at Chucuyo, a newer village that arose as a separate center from Parinacota.

Management issues and threats

Despite the remoteness of the Altiplano region of northeastern Chile, Lauca National Park is facing serious management issues. These include both internal management of natural resources and outside pressures on these same resources. Potential human impacts on park ecosystems are at the center of both of these management concerns. The management issues and natural resources of Lauca were described in some detail in a *Plan de Manejo* prepared by Corporación Nacional Forestal (CONAF) in 1986. This plan, however, was meant to have a 10-year lifespan and is now under revision. Related to this re-evaluation of management plans for Lauca is a broader evaluation of priorities for conservation in the surrounding Parinacota Province, including Las Vicuñas National Reserve and Salar de Surire National Monument. There are five areas of particular concern for resource management, and these are highly interrelated in many respects:

(1) Management and protection of water resources.
(2) Human population impacts.
(3) Ecotourism.
(4) Management of rare and endangered species.
(5) Re-evaluation of park boundaries.

Management and protection of water resources

Water resource issues lie at the core of many management concerns that have faced Lauca from a period long before its establishment as a national park (Andrew 1987). International controversies between Bolivia and Chile over legal rights to water from the Río Lauca have continued for decades. The basin of the Río Lauca drains Lago Chungará, Lagunas Cotocatani, and the Parinacota bofedales but then flows eastward into Bolivia. A concrete canal to tap the Río Lauca for agricultural water was considered as early as 1856 (Keller 1946) and was finally built during the 1960s. This canal sends water through a nearly 4-km tunnel to a hydroelectric plant at Chapiquiña and then into the Río San Jose, where it flows westward to irrigate the fertile Azapa Valley near Arica. No evidence exists to suggest that this channelization of flow from the Río Lauca has had a significant impact on the water resources of the important Parinacota bofedal and the lakes that feed this wetland. Records of the water level in Lago Chungará show remarkable stability, with little interannual change from 1962 to 1998. Nevertheless, there have been efforts in the past to directly tap water resources from Lago Chungará. A water-pumping facility was once built on the western margin of the lake but was never operated because of public outcry over the potential impact of lowered lake levels. Strong economic pressures to allow groundwater withdrawal from within Lauca National Park continue today and generate some of the political pressure to re-evaluate park boundaries. Scientific evidence has shown that only limited hydrologic recharge of groundwater is occurring today. Using wells to tap this resource for agricultural use in the Azapa Valley on the coast would amount to mining a nonrenewable resource and would therefore have a potentially significant ecological impact.

Human population impacts

Human populations living or working within Lauca National Park have the potential to make significant impacts on the puna landscape and ecology. Resource management issues, however, are complicated by controversies related to the level of political control granted to the Aymara, whose ancestors have lived in this region for thousands of years. The economic and political agendas of rural Aymara, urban Aymara, private companies, and the government are often vastly different.

Human impacts became dramatic across much of the puna region in Chile in the late 19th and early 20th centuries, with the development of the nitrate mining industry. Fuel and timber were in great demand in the mining areas of the Atacama Desert, leading to extensive harvesting of both queñua (*Polylepis* species) and llareta (*Azorella compacta*). Dried llareta burns well, with half of the energy content of coal, and remains a common source of fuel today for rural Aymara populations. As recently as the 1940s, huge quantities of llareta were harvested annually in Parinacota Province. Keller

(1946) gives annual harvest figures of 20,000 tons of llareta used in the nitrate mining industry, 12,000 tons used as fuel for steam locomotives along the railway line connecting Arica with La Paz, and 2400 tons for domestic fuel in Arica. During this same period, an average of about 1000 tons of queñua firewood and charcoal was used annually by the railroad. Fortunately, both *Polylepis* and *Azorella* appear to be aggressive colonists and have made a rapid recovery in revegetating much of the area from which they were once harvested in Parinacota Province. Existing population centers at Parinacota and Chucuyo do not appear to be having strong negative impacts on these species.

Both vicuña and chinchilla were hunted extensively in the past throughout the Chilean puna for their valuable fur. Once highly endangered, the vicuña has made a remarkable recovery in the bofedales at Lauca, which offer protection and good grazing. Vicuña populations have recovered less well in unprotected bofedales outside the park, where they compete with domestic animals. The chinchilla population has likely always been low at Lauca. These animals are more common to the south in semiarid mountain regions of Chile with a Mediterranean climate regime.

One component of human impact at Lauca is related to large numbers of domestic animals grazing on the bofedales. Domestic animals have probably existed in the puna region for thousands of years but much more intensively over the past 400 years since the introduction of goats and sheep by the Spanish in the 16th century. Keller (1946) reported a population of 10,461 llamas and alpacas and 1836 sheep in the region of Putre and the present national park in the 1940s. Smaller numbers of domestic animals are present today. Large populations of llamas and alpacas, however, graze on the Parinacota bofedal near settlements at Chucuyo and Parinacota. Small numbers of sheep, goats, and horses are also present.

Domestic animals have been shown to have a significant impact on the structure and diversity of the puna wetland communities where they graze (Ruthsatz 1995). Their feeding preference for grasses and rushes reduces the cover of these species and expands the dominance of less palatable cushion plants such as *Oxychloe andina*. The net effect is a reduction of diversity in grazed bofedales. Vicuñas are able to graze cushion species and thus maintain the species richness of the bofedales.

Tourism

Tourism is beginning to expand within Lauca National Park. Much of this tourism could be classified as ecotourism, with individuals and organized groups arriving in increasing numbers to observe wildlife and photograph park landscapes. Ecotourism services now operate out of Arica and Putre and provide guided tours of the park. The total number of visitors to the park remains relatively modest, however. CONAF currently estimates a monthly mean number of about 2400 park visitors. Most visits occur in the summer months of January– March, and most visitors spend 1–3 days in the park. Three quarters of the visitors are Chilean, with Europeans comprising two thirds of the foreign visitors. The adjacent Las Vicuñas National Reserve and Salar de Surire National Monument are virtually unvisited, having only an average of 22 and 37 monthly visitors, respectively (CONAF, unpublished data). Facilities for park visitors include a *refugio,* campgrounds, and nature trails; these facilities have been improved significantly in recent years. A newly remodeled CONAF *refugio* in Parinacota provides an excellent introduction to the ecology and natural resources of the park and its puna habitats.

The road traversing Lauca National Park is busy Highway 11, which connects Arica with La Paz. Literally hundreds of large trucks pass this route daily, providing a potential for pollution impacts from material spills, air pollution, and wildlife disturbance. Lago Chungará and the Parinacota bofedal would be potentially highly sensitive to major point-source pollution since they are directly adjacent to the highway. Thus, it is important that consideration be given to regulating the transport of hazardous materials along this route and to developing emergency response plans for possible toxic spills.

Management of rare and endangered species

Lauca National Park is home to a significant number of rare and endangered species of vertebrates and vascular plants and undoubtedly to invertebrates as well, though these groups are not known well enough. The conservation and preservation of these rare and endangered species is best considered not on a species-by-species basis but through a policy of protecting the habitats and ecosystem processes that allow their survival. Of particular concern are the large charismatic vertebrates such as the vicuña, Andean huemul, and rhea as well as the diverse assemblage of bird species.

A key element in managing these rare and endangered species is an improved knowledge of their population structure and dynamics, resource requirements, and important species interactions. Basic ecological research should be integrated into the management plans of the park, with cooperative interactions between resource managers and scientists.

For the vicuña, protection of the bofedales has been the key element in the spectacular recovery of this species since the establishment of the park. This success, however, has led to a new management issue of determining the potential carrying capacity of the bofedales for populations of vicuñas. A proactive policy of preparing for this issue was important in the decision

FIGURE 6 Grazing guanacos in pre-puna shrubland about 30 km southwest of Putre, outside of Lauca National Park. This habitat is poorly represented within the park. (Photo by Karen Esler)

leading to the creation of Las Vicuñas National Reserve adjacent to Lauca as an area where more active management can take place. Careful consideration is now being given to how herds of vicunas can be managed so that an industry can be developed by indigenous populations to harvest valuable vicuña fur in a sustainable manner and without violating the restrictions of CITES for this endangered species. Management and protection of Andean huemul, guanacos, and a variety of rare plant species in prepuna habitats can best be implemented by adding larger areas of these habitats to the existing park (Figure 6). This issue is discussed in more detail below.

Re-evaluation of park boundaries—issues and concerns

There is an obvious need to consider additions to the area of Lauca National Park so that representative prepuna habitats of the puna region of northeastern Chile can be preserved. Of primary concern here are prepuna shrubland communities of Parinacota Province, which are poorly represented within the current boundaries of Lauca. This zone west of Putre at elevations of 3000–3600 m includes significant stands of the rare *Polylepis besseri* (Rosaceae), growing in a relatively species-rich shrubland matrix. Much of the primary habitat for Andean huemul, as well as for guanacos, lies in this prepuna shrubland. Arid areas at lower altitudes of 2200–3000 m dominated by the candelabra cactus (*Browningia candelaris*) have only modest diversity, but addition of this area to the park would protect this unique habitat and species (Gibson and Rundel, in press).

It has been argued in recent months that the addition of new prepuna areas to Lauca National Park should be accomplished as part of a re-evaluation of the conservation significance of lands presently protected within the park and within Las Vicuñas National Reserve and Salar de Surire National Monument. The implicit basis for these arguments has been that an addition of new protected areas may be appropriately balanced against a decertification of some existing protected areas of lesser conservation value. Driving these pressures for re-evaluation of park boundaries have been strong economic forces that seek to open new areas for mining and for tapping groundwater pools for agriculture in the coastal Azapa Valley below. Economically significant deposits of a number of minerals are known to exist near or within the boundaries of Lauca.

These include sulfur, borax, gold, silver, and zinc (Keller 1946). Pressure has existed in the past, and will no doubt continue in the future, to allow selective exploitation of these mineral resources. It is these pressures, along with interests in mining groundwater as described above, that have led to proposals to re-evaluate the boundaries of Lauca National Park.

Any consideration of decertification of national park lands—particularly within an area such as Lauca National Park—that are internationally recognized as a UNESCO Biosphere Reserve should only be accomplished with the strongest justification and opportunity for extended public review. Decertification on the basis of a quid pro quo to allow new areas to be included should never be a justification for such a step. While detailed evaluations of conservation value for Lauca National Park and adjacent conservation lands were completed in 1999 as a portion of a resource evaluation project, the rating systems used for evaluating conservation value were indices based on evaluations of habitat type and species presence. Little consideration was given to evaluating critical ecosystem processes that support species richness and habitat distribution. The maintenance of basic ecosystem processes at the watershed and landscape level is critical to the sustainability of natural resources and the species richness of Lauca National Park.

AUTHORS

Philip W. Rundel
Department of Organismic Biology, Ecology and Evolution, University of California, Los Angeles CA 90095 USA and White Mountains Research Station, Bishop CA 93514 USA.
rundel@protos.lifesci.ucla.edu

Beatriz Palma
Division of Agronomía, Universidad de las Americas, Santiago, Chile.
bpalma@uamericas.cl

REFERENCES

Andrew TE. 1987. Biological implications of lake management with reference to Lago Chungará, Chile. *Archivos de Biología y Medicina Experimentales* 20:131–134.

Arroyo MTK, Squeo FA, Armesto JJ, Villagrán C. 1988. Effects of aridity on plant diversity in the northern Chilean Andes: results of a natural experiment. *Annals of the Missouri Botanical Gardens* 75:55–78.

Arroyo MTK, Villagrán C, Marticorena C, Armesto J. 1982. Flora y relaciones biogeográficas en una transecta altitudinal en los Andes del Norte de Chile (18–19ºC). *In:* Veloso A and Bustos E, editors. *El Ambiente Natural y las Poblaciones Humanas de los Andes del Norte Grande de Chile (Arica, Lat. 18º28'S).* Santiago: UNESCO, p 71–92.

Cabrera AL. 1957. La vegetación de la Republica Argentina. VI. La vegetación de la Puna Argentina. *Revista de Investigaciones Agrícolas* 11:317–412.

CONAF (Corporacion Nacional Forestal). 1986. *Plan de Manejo del Parque Nacional Lauca*. Documento de Trabajo No. 82. Santiago: Corporacion Nacional Forestal.

Gajardo R. 1994. *La Vegetación Natural de Chile: Clasificación y Distribución Geographica*. Santiago: Editorial Universitaria.

Gaupp R, Kött A, Wörner G. 1999. Paleoclimatic implications of Mio-Pliocene sedimentation in the high-altitude intra-arc Lauca Basin of northern Chile. *Paleogeography, Paleoclimatology, Paleoecology* 151:79–100.

Gehy MA, Grosjean M, Nuñez L, Schotterer U. 1999. Radiocarbon reservoir effect and timing of the late-glacial/early Holocene humid phase in the Atacama Desert (northern Chile). *Quaternary Research* 52:143–153.

Gibson AC, Rundel PW. 2000. *Browningia candelaris* in the Andean prepuna of northern Chile. *Cactus and Succulent Journal* (in press).

Hernández S. 1980. *Zonificación con Fines de Manejo de las Formaciones Vegetales Presentes en la Parque Nacional Lauca (1ª Región)* [tesis ing. Forestal]. Santiago: Facultad de Ciencias Forestales, Universidad de Chile.

Keller C. 1946. *El Departamento de Arica*. Santiago: Zig-Zag.

Kött A, Gaupp R, Wörner G. 1995. Miocene to Recent history of the western Altiplano in northern Chile revealed by lacustrine sediments of the Lauca Basin (18º15'–18º40'S/69º05'W). *Geologische Rundschau* 84:770–780.

Marquet PA. 1994. Diversity of small mammals in the Pacific Coast desert of Peru and Chile and in adjacent Andean area: biogeography and community structure. *Australian Journal of Zoology* 42:527–542.

Messerli B, Grosjean M, Vuille M. 1997. Water availability, protected areas, and natural resources in the Andean desert Altiplano. *Mountain Research and Development* 17:229–238.

Novoa R, Villaseca S. 1989. *Mapa Agroclimático de Chile.* Santiago: Instituto de Investigaciones Agropecurias.

Reig OA. 1986. Diversity patterns and differentiation of high Andean rodents. *In:* Vuilleumier F and Monasterio M, editors. *High Altitude Tropical Biogeography*. Oxford: Oxford University Press, pp 404–439.

Ruthsatz B. 1993. Flora und ökologische Bedingungen hochandiner Moore Chiles zwischen 18°00' (Arica) und 40°30' (Osorno) südl. Br. *Phytocoenologia* 23:157–199.

Ruthsatz B. 1995. Vegetation und Ökologie tropischer Hochgebirgsmoore in den Anden Nord-Chiles. *Phytocoenologia* 25:185–234.