The World's Highest Forest

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Abstract (summary)

Purcell et al study the properties and the preservation of the Andean quenua. Quenua are members of the genus Polylepis, which are the highest growing trees in the world, and their distinctive appearance highlights the many adaptations necessary to survive at considerable altitude in the cordilleras of South America.

Full Text

Headnote

A better understanding of the properties of Andean queñua woodlands has major implications for their conservation

In and out of mists and clouds of the high Andes of Bolivia appears an unexpected sight: patches of otherworldly trees and bushes surviving the harsh climate 4,000 meters above sea level. Called queñua by Andean natives, these members of the genus Polylepis are the highest growing trees in the world, and their distinctive appearance highlights the many adaptations necessary to survive at considerable altitude in the Cordilleras of South America. Species of Polylepis differ markedly from one another having specialized for very different habitats: Some grow on the cold and wet eastern flank of the Andes above the expansive Amazon Basin, whereas others eke out an existence in the high and arid western side, which slopes down into the Atacama desert. Because of the isolation of this amazing ecosystem, a wide range of animals, particularly birds and insects, has evolved close connections with the Polylepis trees, creating a fascinating and distinctive community.

Despite the uniqueness and fragility of the Polylepis ecosystem, it long remained poorly studied because early investigators believed that the patchy occurrence of Polylepis groves was a natural phenomenon, thus raising no alarms for its longevity. The German botanist Heinz Ellenberg challenged this notion in the 1950s. He claimed that much of the high Andes would naturally be covered with Polylepis and that the current restricted distribution of the Polylepis forests was the result of thousands of years of human activities. Other scientists refused to accept this view until the late 1980s, when Danish ornithologist Jon Fjeldså and one of us (Kessler) launched several wide-ranging expeditions to find areas of Polylepis and to catalogue the plant and bird species in each. These studies obtained conclusive evidence that in Ecuador, Peru, Bolivia and northern Argentina, Polylepis is the natural vegetation on mountain slopes at elevations up to 4,400 meters in humid regions and up to 5,000 meters in the arid volcanic soils of northwestern Bolivia. In Colombia and Venezuela, the situation may be different because these countries harbor only two Polylepis species specialized to live in humid cloud-forest conditions, as opposed to the 19 species farther south.

The finding that once-extensive natural Polylepis forest has been artificially fragmented by occupants of the Andes for 5,000 years-and is, in fact, highly threatened-has completely changed the perception of researchers and conservationists. Early investigators predicted that Polylepis would grow only on boulder fields and steep slopes because of some advantageous ecological conditions, such as warmer ground temperatures or decreased wind. Further study has shown that the remaining patches are not restricted to any single type of terrain, but rather have survived in sites that are less accessible to brush fire and grazing animals. The initial studies by Fjeldså and Kessler were successful in bringing attention to this increasingly endangered ecosystem. As a result, biologists have now fully documented the 20 types of queñua and continue to discover among them new bird and insect species. Currently, several research and conservation projects focus on Polylepis throughout the tropical Andes, many of them being carried out by local investigators rather than by foreigners.

The Thick and Thin of Survival

Many of the distinctive features of Polylepis seem to be adaptations for high-elevation living in a habitat that can vary dramatically from extremely wet to water-stressed, is often windy and has high levels of sun exposure because of both elevation and proximity to the equator. The trees are marked by red, shiny bark, which peels off in paper-thin sheets much like the bark of paper birch trees. The many layers of bark protect the trees from damaging frosts and fires but may have originally evolved to shed moss and epiphytes (smaller plants that grow on the trunk and branches of trees), which would have been abundant in the comparatively balmy habitat of ancestral Polylepis. These trees are covered with small, thick leaves, which cluster in groups of between three and seven, depending on the species. The leaves survive the dry air and strong wind by growing thick and sturdy, thus conserving moisture, and by developing a covering of waxy hairs to protect them from intense sun exposure. The trees often appear stunted, with many branches spreading umbrella-like from a stubby trunk. Most are 3 to 10 meters tall, but exceptional individuals can reach 36 meters with a diameter of more than 2 meters.

Polylepis hosts a variety of creatures. Insects live inside the loose layers of bark, finding protection from the cold air and (in some places) frequent rain, although not from the many kinds of insectivorous birds that also make these woodlands their home. The small trees provide nesting sites for these and other birds and for small mammals. Some of these birds and insects are specialists found only in Polylepis ecosystems. The ongoing transformation of these sheltered, richly structured forests to monotonous, wind-swept grassland (puna) thus threatens many kinds of fauna.

Investigators are particularly interested in the fate of the birds, in part because the interactions of avian specialists with their habitat provide a fascinating field of study, one that is only now beginning to take off in Polylepis woodlands. Research groups led by Isabel Gómez of the Universidad Mayor de San Andrés in La Paz and Jennifer Cahill of Universidad Mayor de San Simón in Cochabamba, Bolivia, are currently working to learn more about the diminished populations of Polylepis-specialist birds.

In an effort to contribute to that mission, two of us (Purcell and Brelsford) spent one year mapping Polylepis sites and the range of one such avian specialist, the giant conebill (Oreomanes frasenri), in an understudied part of the Cordillera Real, in the La Paz department on the northeast edge of Bolivia's highlands. This bird, a member of the honeycreeper family, makes its living stripping back the bark from Polylepis trees and eating the insects hiding within. Although it is one of the most widespread of the Polylepis specialists, the giant conebill seems to require relatively large areas of forest to flourish and thus offers insights to the effects of quenua fragmentation. We found this particular avian species in 7 of 23 Polylepis woodlands that we surveyed: The smallest was about 6 hectares, the average size was 26 hectares, and we found these birds only in areas with several Polylepis patches in the immediate vicinity.

Isabel Gómez and her team are conducting a similar study on the endangered ash-breasted tit-tyrant (Anairetes alpinus) in an attempt to establish the extent of the Bolivian population. This small bird forages insects from the outer branches of Polylepis trees. We and the La Paz-based Bolivian group have also been able to explore the range of a recently discovered population of a third specialist, the royal cinclodes (Cinclodes aricomae), which forages in the debris that builds up on the floor of these woodlands. This species is among the most threatened Polylepis specialists, with an estimated world population of fewer than 250 individuals.

Two-Toed Terrors

Mapping the distribution of the giant conebill and the royal cinclodes in the high, humid valleys of the Cordillera Real was first and foremost a problem of finding Polylepis

stands. As we did our field work, it became apparent that many of the locations in this region that Fjeldså and Kessler studied in the 1980s and early '90s had been completely deforested in the intervening years. Thus, in addition to documenting previously undescribed sites, Brelsford and Purcell returned to all of the recently surveyed areas in a part of the northern Bolivian Andes to evaluate their current condition. Seven out of 17 places that we visited had been totally deforested in the past 12 years; these seven sites accounted for a massive 87 percent of the previously documented Polylepis area. To put this in perspective, the total deforested area (about 204 hectares) was about 40 percent as much as the 520 hectares of newly described sites in that section of the Cordillera Real documented by Brelsford, Purcell and the La Paz university group.

During a 2000 conference focusing on the dangers to these forests, a group of international ecologists came to the consensus that Polylepis has the most dramatically reduced range and is the most threatened ecosystem in both Bolivia and Peru. Only an estimated 1 percent of quenua remains intact in the eastern Bolivian Andes (around 50 percent survives in the very inhospitable and dry western cordillera), whereas the figure is about 3 percent in Peru. (Fjeldså and Kessler estimated the original extent of Polylepis based on land area having the genus's elevational range and annual rainfall tolerance.) Because of these severe losses, and because of the large numbers of endemic plants, birds and insects that live there, Polylepis woodlands are becoming a top priority for further protection and study.

What forces exactly are threatening these places? Local residents have exploited Polylepis throughout history. There is evidence suggesting that huge tracts of Polylepis woodlands were degraded in the pre-Inca days, probably to clear land and for use as firewood. Inca leaders then decided that conserving remaining quenua fragments was an important priority and banned the cutting of these trees. This edict presumably slowed the disappearance of Polylepis woodlands dramatically, but the destruction resumed en force with the arrival of the Spaniards and has been continuing at varying rates since then. In modern times, the rate of Polylepis destruction seems partly tied to the price of fuel, increasing whenever charcoal is in higher demand as a fuel source.

Major changes in the livestock of choice and in land-use practices have also compromised the long-term health of Polylepis woodlands. The introduction of new grazers, predominantly cattle and sheep, to high Andean communities has led to massive erosion. There were fewer such problems before because traditional herd animals, camelids including llama and alpaca, have several very important adaptations to montane life. First of all, their feet are soft and flat, as opposed to the solid, sharp hooves of cows and sheep. Llamas, therefore, can travel across steep hillsides without displacing much soil, whereas hard-hooved animals churn up the earth, damaging vegetation and triggering dramatic erosion. The loss of nutrient-rich soils in turn can cause the slow devastation of Polylepis ecosystems. We found very few sites in the Cordillera Real without some recent evidence of this destructive chain of events.

Another difference in the grazers is their foraging capabilities: Camelids, especially llamas, can survive on small amounts of dry grass, which they digest very efficiently, whereas cattle require fresh, green shoots in higher quantity. As a result, herders burn large sections of dry puna bunchgrass to stimulate new growth for their livestock. Mature Polylepis are somewhat resistant to these large-scale brushfires, but young trees are readily destroyed. These fires also damage other Andean plant life and tend to produce a homogeneous bunchgrass ground cover. Despite these enormous problems, owning large herds of cattle and sheep has become increasingly popular: It serves as a sign of prestige among rural people as well as economic insurance for emergencies. The number of domesticated camelids has, as a consequence, fallen well below that of exotic herd animals, with llama and alpaca now primarily being raised in places that are too rugged or cold for sheep and cattle.

Burning (or cutting) may also be used to clear new areas for pasturage or cultivation. Indeed, several of the sites we visited in 2003 showed signs of recent burning and cutting to clear the forest underbrush. Premature cutting of limbs leaves Polylepis with the stunted appearance of a low bush, and reduces the future utility of the wood. Although long-term degradation is clearly a major threat to Polylepis, as previously noted, outright elimination through cutting and burning is also occurring in a few areas. all of the former Polylepis stands we surveyed were near roads, and five were in the vicinity of mining or hydroelectric projects mounted in recent years. These activities drew job- seekers from elsewhere, swelling the population with shortterm residents, who may not have been aware of or willing to observe local conventions that have preserved intact Polylepis forest. These people appear to have used the trees as an expendable one-time source of firewood.

Raising Consciousness, Raising Trees

The question of how to conserve Polylepis is hard to answer. The traditional approach of setting aside one or a few protected areas will not, for the most part, work because of queñua's extensive fragmentation. In other places, the best strategy is educating local people to the value of maintaining a large, intact ecosystem (a park) to foster tourism. This is not the case for small, remote Polylepis woodlands: Although they are extremely interesting and beautiful places, few tourists are likely to visit any other than readily accessible ones such as Sajama National Park of western Bolivia. And because the remaining Polylepis forest is so fragmented, conservation efforts targeting just a few sites would be inappropriate. Indeed, a comprehensive campaign would require the preservation of hundreds of forest patches.

Instead, the key to Polylepis conservation is involving and educating the people living in the Polylepis zone so that they come to appreciate the material (and ecological) benefits of sustainable management of their nearby Polylepis woodlands. If that can be done, queñua will cease to be such a threatened habitat.

But will the natural fauna have survived and be able to recover as the forest expands? The answer probably depends on local circumstances. Our current research suggests that even in many cut-back or partially burned forest fragments, some Polylepis bird specialists are still able to make a living, at least in the short term. This phenomenon seems to depend on the size of the site in question. In larger fragments, even those located near villages (such as one stand of more than 200 hectares at Pelechuco in the Cordillera Apolobamba), avian specialists are still present and even abundant. In contrast, the many small, isolated patches of Polylepis we visited in the Lake Titicaca basin (mostly places in or near settlements where a few trees were cultivated to block the wind) were all devoid of these species. At these sites, Polylepis specialists are outcompeted by human-adapted birds. This observation implies that Polylepis forest and the plants and animals that it houses can survive adjacent to farming or with branch cutting, so long as large patches or networks of smaller ones remain. Tiny fragments and individual trees, however, are not enough to sustain Polylepis biodiversity. The latter two categories constitute a large number of the known quenua sites in our study area in northern Bolivia.

The challenge, then, will be to help communities find a sustainable compromise between use and conservation, so that Polylepis ecosystems are not stressed too much. Finding this balance will require a number of complementary approaches: Raising awareness of local people to the potential economic value of intact ecosystems will be only the first step. It will be even more important to establish husbandry programs through which the people can continue to use the wood as a resource by cutting an amount that allows the trees to regenerate and reproduce quickly.

This plan could profit from and expand on the existing base of traditional knowledge and community pride in Polylepis. Even on the tree-less altiplano, people asked where the nearest quenua is will invariably answer with something like, "Oh, there's some about 50 kilometers north of here in the village of Pelechuco...." They will then proceed to explain what Polylepis can be used for and sometimes recount the recent history of Polylepis in the area; most often, they mention charcoal. In one case, an elderly gentleman from Estancia Kakapi explained that there had been abundant Polylepis in the valleys around his home, but that the men from the area had cut it all down in the 1940s, when charcoal was fetching a particularly high market price. He then explained that there was still queñua growing in the less accessible valleys more than a day's walk away. He said it was a shame that there was no more Polylepis close by. In villages with abundant Polylepis, people are proud of the presence of the trees, and they emphasize how useful the forest is as a source of strong timber and firewood and as an agricultural windblock. Several rural women also explained that Polylepis extracts are often utilized as a traditional herbal remedy.

We would add two other reasons to want to keep Polylepis forest around: It serves an important role in stabilizing soil, and it provides habitat for a number of specialist species. We would hope, too, that local residents become more aware that grazing animals, especially exotic livestock, harm Polylepis forests and that the non-native Eucalyptus, which is grown as an alternative to queñua in many areas, actually causes long-term problems, as its high water consumption leaves little groundwater for nearby plants.

In gearing conservation action toward sustainable use of resources, the benefits of reforesting native Polylepis rather than planting an exotic tree like Eucalyptus should be emphasized, and seedlings should be made available to the community. Plantations of Polylepis trees could, in the long run, protect the naturally occurring woodlands by providing an easily accessible alternative source of wood, thereby reducing the pressures on forests that harbor endemic birds. Eventually, replanted queñua patches might also become habitat in their own right. The communities in which such plantations have been encouraged have enjoyed tremendous success, with the Polylepis woodland providing shade, protection against erosion, and a resource for firewood and timber.

There are several potential difficulties with reforestation schemes, however. First of all, reforestation is a long-term process, and many Andean villagers have an immediate need for fuel and productive agricultural space. Moreover, these are very poor people with extremely limited resources to devote to conservation projects. Although Polylepis reforestation should pay off within a generation by maintaining valuable topsoil, recharging the water table and providing wood resources, many villagers have more immediate unmet needs and may legitimately view ecological restoration as a lower priority than subsistence or cash-crop agriculture. Indeed, long-term community-development programs have already been tried in some areas, with mixed success. Pierre Ibisch of the Botanical Institute of the University of Bonn, an organizer of one project in Cochabamba department, Bolivia, cited the too-short time span of the project (10 years) and the difficulties encountered by foreigners trying to advise local initiatives among the main problems.

Thus plans for Polylepis conservation or its sustainable development will need a long introductory period. Most likely, the local residents would need to observe tangible benefits of reforestation before external support could be withdrawn. Moreover, any type of stewardship is unlikely to be effective unless the villagers themselves are involved in organizing and managing the projects. Perhaps a good way to start at any given place would be to enlist the aid of people from communities with healthy Polylepis stands nearby, who can pass on their hands-on experience to their neighbors. Residents are more likely to trust the advice of people from neighboring villages than of people from faraway cities or from abroad. On the other hand, foreign organizations can play an essential role in organizing and funding these cooperative projects and exchanges, as well as providing the means for executing the projects, including an initial supply of Polylepis seedlings.

Preservation and Further Study

Scientists are also working to save Polylepis forests by creating small, private reserves in remote places where existing stands retain the dynamics of the untouched ecosystem. But this effort is in its infancy. Prioritization of sites and regions for conservation should be based on several factors, including ecological value and the extent to which they are at risk. Rating ecological value of existing forests is tricky, however, as there are many components involved. Sites harboring greater levels of biodiversity should be a major priority, and among those, sites with the highest number of rare endemic species should be protected first. Jon Fjeldså documents seven of these "centers of endemism" based on spatial analysis of bird ranges, and these regions in Ecuador, Peru, Bolivia and Argentina should be early targets of conservation efforts.

Finally, more research is needed into the ecology of Polylepis-specialist birds, particularly the sizes and spatial arrangements of forest fragments necessary to support viable populations. Knowing more about the needs of the animals and ecosystem that we are trying to protect will make conservation plans more effective.

We believe that the time, effort and resources needed to conserve Polylepis are well worth the investment. Polylepis is one of only two tree genera in the world that have adapted to grow at elevations of up to 5,000 meters above sea level (the other is Juniperus in Tibet, where it is similarly threatened). Further, many of the fascinating characteristics of the evolution and the ecology of queñua are not fully understood and are likely to provide further information of ecological importance. Polylepis systems have also evolved a rich endemic fauna, which will be lost with the destruction of their habitat. Finally, scientific interests aside, Polylepis has served and continues to serve as an indispensable resource to rural people.

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