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An unexpected record of the endemic species *Polylepis albicans* Pilger (Rosaceae) in Huancavelica, Peru, with notes on its conservation and complex geographic distribution pattern

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Abstract. *Polylepis albicans* Pilger (Rosaceae) is restricted to the Cordillera Blanca in Ancash and La Libertad, northwestern Peru. Here, we report the occurrence of a new population of the species in Huancavelica, central Peru. We analyzed its morphology and compared samples of the new record with samples collected from the Cordillera Blanca, where the main populations of the species are concentrated. We discuss the complex patterns of the geographic distribution *P. albicans* and the implications for its conservation.

Keywords. Biogeography, conservation, endangered species, high-Andean forest, protected natural areas, range extension

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Introduction

The genus *Polylepis* Ruiz & Pavón (Rosaceae) is distributed throughout the mid- and high-elevation tropical Andes from Venezuela to northern Chile and the Sierras Grandes de Córdoba in Argentina. Individuals of the genus may occur at elevations as high as 5000 m a.s.l.; therefore, they are considered the highest growing forest-tree species in the world (Fjeldså and Kessler 1996; Kessler 2006; Boza Espinoza and Kessler 2022). This genus includes tree and shrub species that inhabit rocky areas with steep slopes and difficult

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access in the high Andes (Boza Espinoza and Kessler 2022). The forests of this genus provide suitable habitat for endemic and endangered flora and fauna species (Fjeldså and Kessler 1996; Kessler et al. 2001; Gareca et al. 2010; Sevillano-Ríos and Rodewald 2017). The most recent taxonomic revision of the genus reported 45 species, with 23 species occurring in Peru, of which 15 are endemic. Indeed, Peru is the country with the greatest *Polylepis* richness and is the center of diversification for the genus (Boza Espinoza and Kessler 2022).

Polylepis albicans Pilger (Rosaceae) was originally described by Pilger (1906) from the Cordillera Blanca in Peru. Later Simpson (1979) lumped it as a synonym with *Polylepis sericea* Wedd., based on a biological species concept and considering the morphological plasticity of the genus. Nevertheless, based on a more detailed review of morphological traits and climatic niche differences, Boza Espinoza et al. (2019) split the *P. sericea* complex into five species: *P. canoi* W.Mend., *P. ochreata* Bitter, *P. argentea* T.Boza & H.R.Quispe, *P. sericea* Wedd., and *P. albicans* Pilger, with the last species reinstated as a species. Populations of *P. albicans* are restricted to the Cordillera Blanca in Ancash and La Libertad in northwestern Peru (Boza Espinoza et al. 2019; Boza Espinoza and Kessler 2022) (Fig. 1).

Boza Espinoza and Kessler (2022) proposed that 41 species of *Polylepis* have some degree of threat following the IUCN criteria. *Polylepis albicans* was categorized as Vulnerable. Illegal mining is one of the main threats to the most representative populations of *P. albicans*, which are located in Huascarán National Park. Other factors that negative affect these forests include the expansion of the agricultural frontier, logging, fires, and cattle ranching. All of these activities restrict the regeneration of these forests and increasingly reduce their area (Fuentealba and Sevillano 2017). Therefore, research has been proposed that will generate information useful for conservation of these ecosystems (Segovia-Salcedo et al. 2021); this research should be given priority in the agendas of researchers and conservation practitioners.

The Peruvian central Andes are home to eight *Polylepis* species: *P. racemose* Ruiz & Pavón, *P. incana* Kunth, *P. flavipila* (Bitter) M.Kessler & Schmidt-Leb. (Kessler and Schmidt-Lebuhn 2006), *P. canoi* W.Mend. (Mendoza 2005), *P. rodolfovasquezii* L.Valenzuela & I.Villalba (Valenzuela and Villalba, 2015), *P. argentea* T.Boza & H.R.Quispe (Boza Espinoza et al. 2019), *P. pilosissima* T.Boza & M.Kessler and *P. sacra* T.Boza & M.Kessler (Boza Espinoza and Kessler 2022). Of these species, five are endemic to the country. In recent years, research of high-Andean forests in central Peru has increased. The results show that this area of the Andes is highly diverse, with a unique species composition of taxa (Ames et al. 2019; Navarro et al. 2020; Quispe-Melgar et al. 2018, 2020, 2022), which suggests that conservation and restoration efforts should be increased in this area.

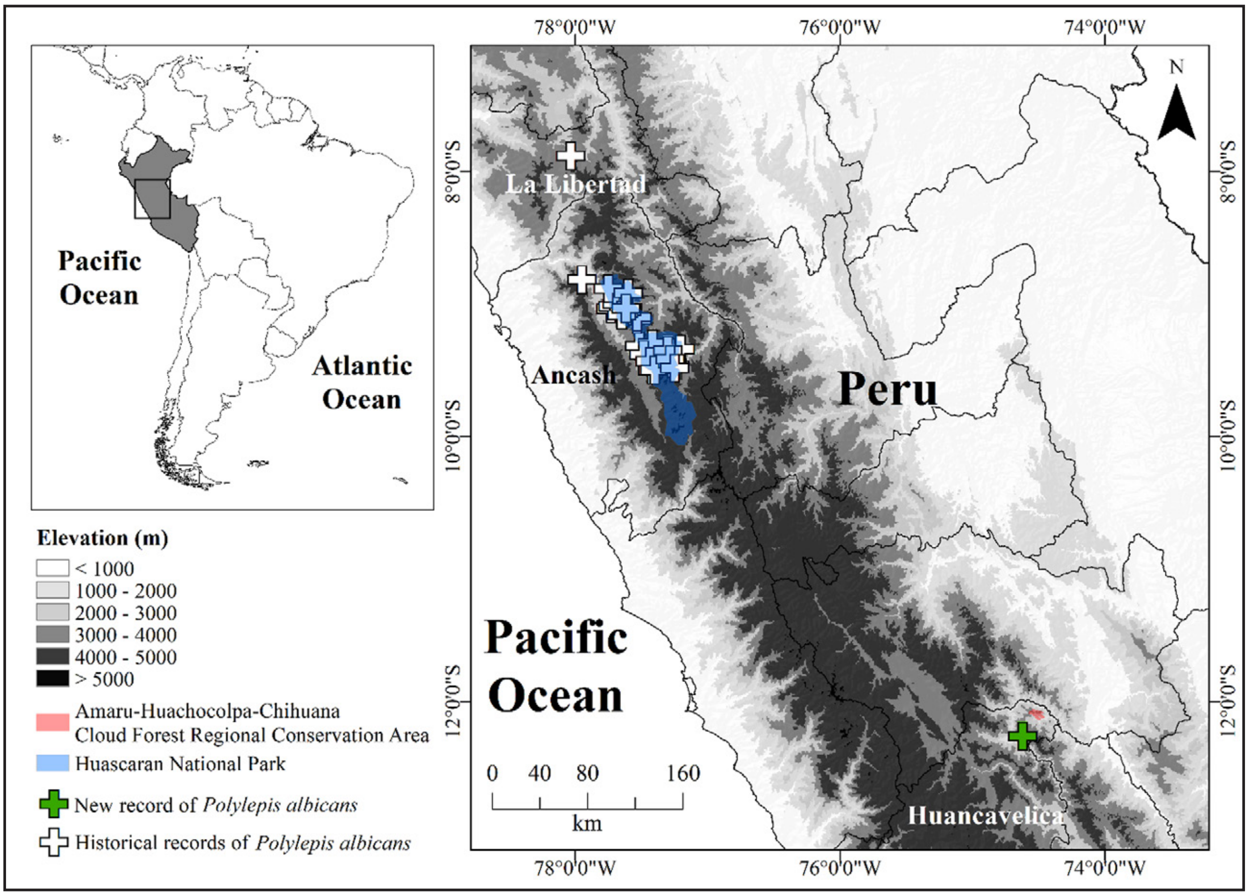

Figure 1. Records of *Polylepis albicans*. White crosses indicate known records of the species in Ancash and La Libertad, while the green cross indicates the new record in Huancavelica. The presence of records was taken from Boza Espinoza et al. (2022).

Here, we report the first record of *P. albicans* in the central region of the Peruvian Andes. We morphologically compare the new sample with those from Ancash and provide comments on the complex geographical distribution pattern. Management and conservation actions of these high-Andean forests need to be enhanced.

Methods

As part of a research project implemented by ANDINUS Association, we conducted a field trip to verify the presence of *P. canoi* and *P. rodolfovasquezii* in Huancavelica. Areas with the most suitable habitat for those species were previously identified and mapped using Google Earth Pro. As a result of this preliminary work, the area surrounding the Amaru-Huachocolpa-Chihuana Cloud Forest Regional Conservation Area was one of the areas selected for further exploration. Once in the field, we asked local people about the presence of *Polylepis* forests (known as "Quinuales", "Queñoas", or "Inguas"). Whenever the forests presence was confirmed, we made an exploration trip. In the forests, we photographed landscapes and *Polylepis* species, and we collected botanical samples for subsequent identification when we were not sure of the species identity; these samples were deposited at Herbario Selva Central Oxapampa HOXA.

Botanical samples were collected from the Llanganuco and Quillcayhuanca ravines of Huascarán National Park in Ancash for detailed morphological comparisons with the samples collected in Huancavelica. We measured leaf size (length and width) and size of the largest leaflet (length and width), and counted the flower number, following Boza Espinoza et al. (2019). For statistical comparisons, we performed normality tests (Shapiro Wilk), ANOVA analysis, and a Tukey's post hoc test.

Finally, we characterized the ecological niche in the environmental space (Soberón et al. 2017), based on the historical records and the new records, to determine whether the environmental conditions of the population present in the central region were similar to those of the populations present in northwestern Peru. We used environmental layers obtained from the CHELSA v. 2.1 database (Karger et al. 2017). Data processing and plotting were performed with the packages nortest (Gross 2022), moments (Komsta 2022), magrittr (Bache 2022), ggplot2 (Wickham et al. 2022), cowplot (Wilke 2022), and the basic functions of the R-Project (R Core Team 2022).

Results

***Polylepis albicans* Pilger**, Bot. Jahrb. Syst. 37(5): 535 (1906). (Pilger 1906)
Figures 2A–G, 3

Type. PERU. Ancash, Cordillera Blanca above Caraz, Jun 1903, Weberbauer 3229 (holotype: B destroyed, photograph in F!, GH!, NY!). Taken from Boza Espinoza et al. (2019).

New records. PERU – **Huancavelica** • Tayacaja province, Andaymarca district, Sune, near Judas Lagoon; 12°15′44″S, 074°37′22″W; elev. 3900 m a.s.l.; 29.VIII.2021; semihumid, high-Andean forest dominated by *P. albicans* and accompanied by *Gynoxys* Cass., *Lupinus* L., *Baccharis* L., and *Rubus* L., with abundant mosses on ground and surrounded by a grassland matrix, collection number 10; HOXA 078819.

The morphological comparison (flower number, leaf, and leaflet measurements) showed that leaf length was greater in samples from Ancash than in those from Huancavelica, whereas leaf width and leaflet length were greater in samples from Huancavelica than in those from Ancash (Table 1). There were no significant differences in leaflet width or flower number between samples from both populations (Fig. 4A–E). Furthermore, the ecological niche environmental values of the new record are similar to those obtained from the species historical records (Fig. 4F).

Identification. *Polylepis albicans* differs from other *Polylepis* species mainly in the number of leaflet pairs (4 or 5), elliptical leaflets, the slightly crenulate apical margin of leaflets, with 4 or 5 teeth, and the number of flowers (18–21) per inflorescence. Other distinguishing features are the presence of ferruginous resin released from glands located at the insertion point of the leaflets and the densely sericeous indumentum on the rachis and leaves. The most similar, geographically close species are *P. argentea* (number of leaflets: 3; narrowly elliptical leaflets; 5–6(9) flowers), *P. canoi* (3–4(5); obovate leaflets; 12–17(26) flowers), and *P. ochreata* (5–8; narrowly elliptical leaflets; (16)21–43 flowers).

Discussion

To date, the geographic range of *Polylepis albicans* has been considered to be restricted to Ancash and La Libertad in northwestern Peru (Boza Espinoza et al. 2019). Our finding extends the species' geographic range by more than 400 km to the south-east, at the edge

Table 1. Quantitative characters of *Polylepis albicans*.

Character	Huancavelica	Ancash
Leaf length (cm)	4.75 ± 0.55	5.24 ± 0.71
Leaf width (cm)	3.86 ± 0.51	3.48 ± 0.61
Leaflet length (cm)	2.36 ± 0.28	2.16 ± 0.22
Leaflet width (cm)	0.66 ± 0.11	0.61 ± 0.11
Number of flowers	19 ± 3	18 ± 2

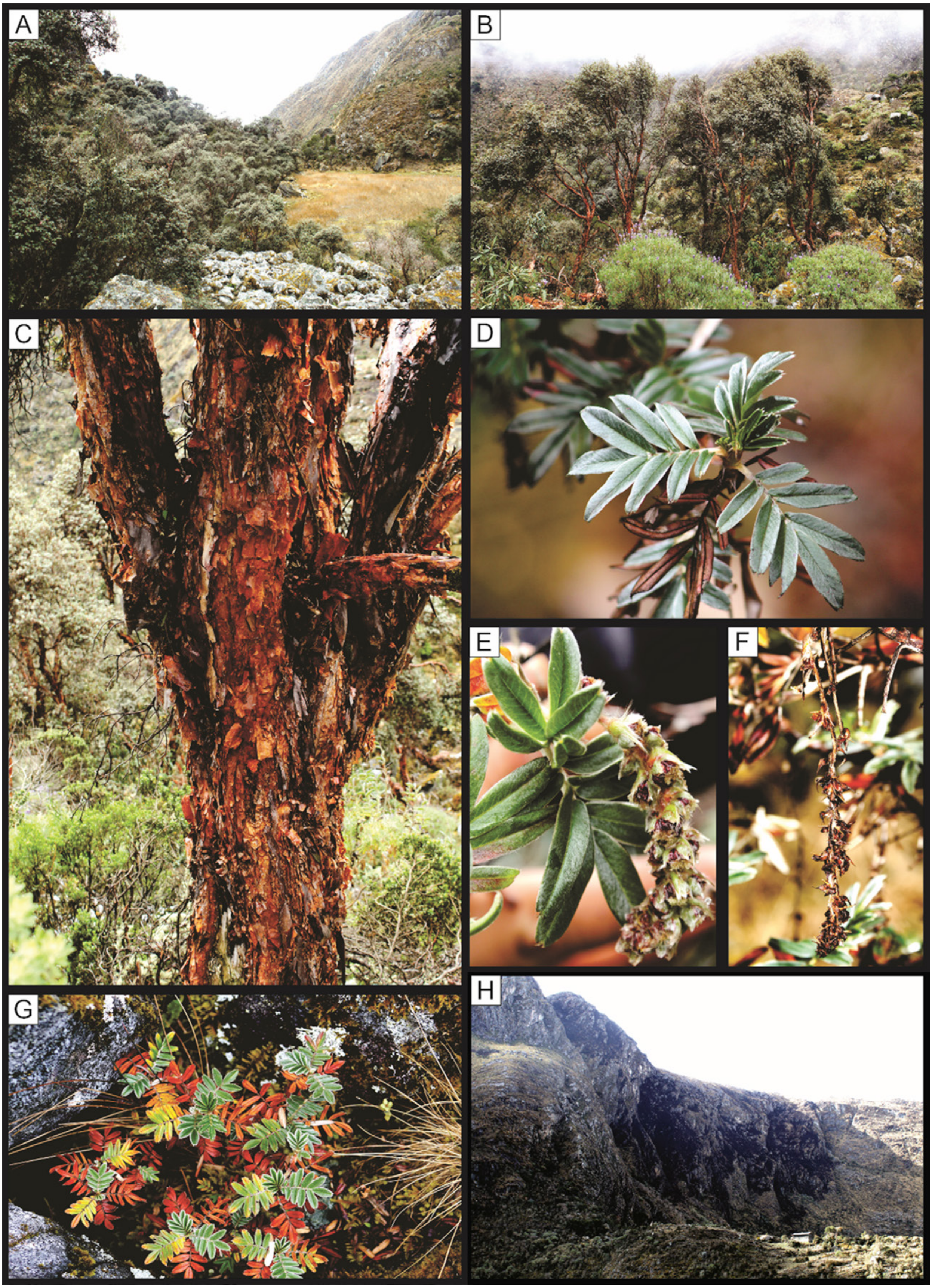

Figure 2. *Polylepis albicans* Pilger. **A.** Panoramic view of the forest. **B.** Adult individuals. **C.** Trunk detail. **D.** Leaves. **E.** Inflorescence. **F.** Fruits. **G.** Natural regeneration. **H.** Burned grassland around the forest. Photographs by Harold Rusbelth Quispe-Melgar (A, C-H) and Katherine Lucero Lagones Poma (B).

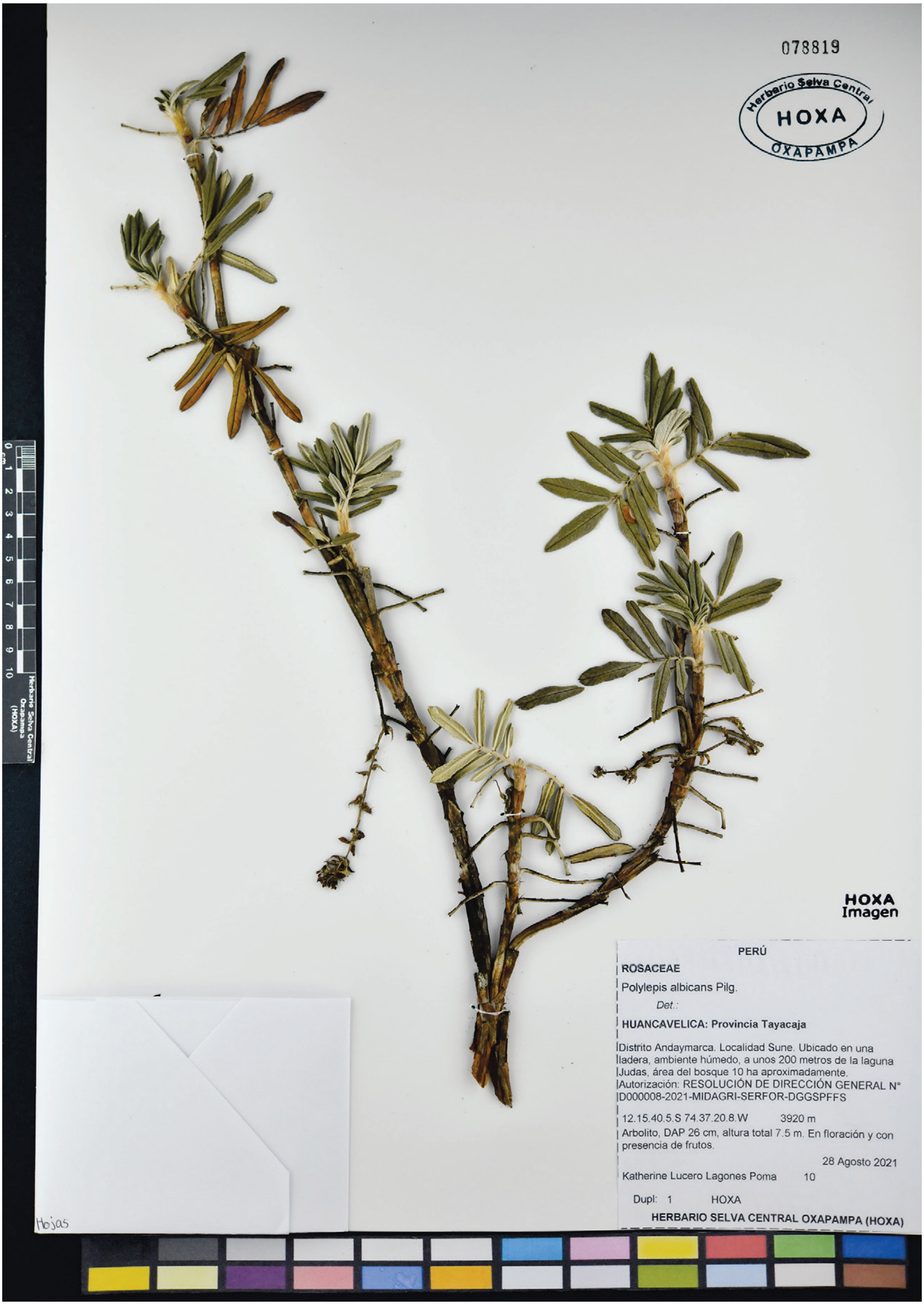

Figure 3. *Polylepis albicans* Pilger. Specimen deposited in the HOXA Herbarium.

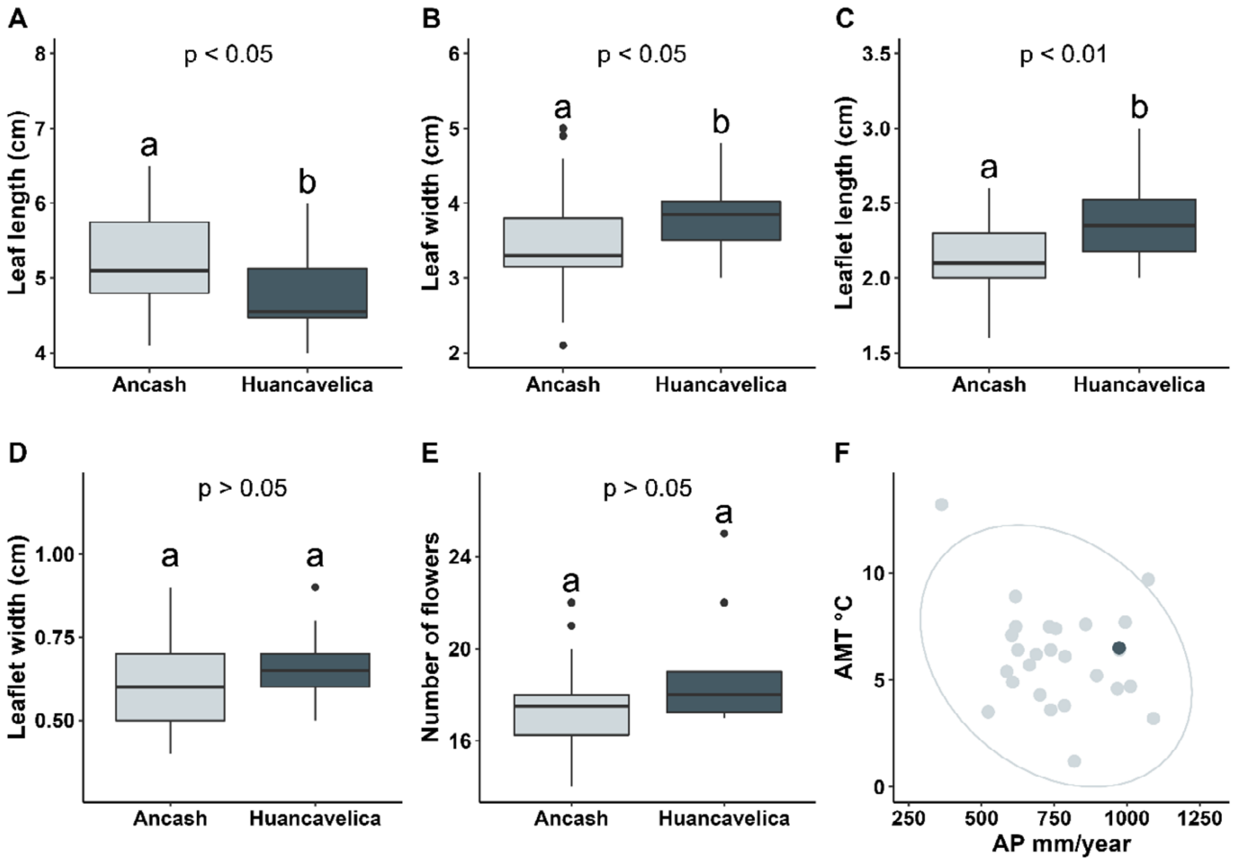

Figure 4. Comparison of morphological traits and ecological niche between PCP and PNP. **A–E.** Comparison of botanical characters. **F.** Niche characterization in the environmental space based on annual mean temperature (AMT °C) and annual precipitation (AP mm/year). Box plots with different letters (a or b) are significantly different based on a *post-hoc* Tukey test.

of the eastern central Andes cordillera in Huancavelica. Hereafter, the new record will be referred to as the "Population from central Peru (PCP)", since the finding implies the presence of a relict population in ~20 ha of dense forest rather than isolated and scarce individuals. Likewise, the already known populations will be referred to as "Populations from northwestern Peru (PNP)".

From a biogeographical perspective, the presence of the PCP is completely unexpected, which led us to ask the following questions:

Are there any undetected forests of the species in the area between the PCP and PNP? From the 1980s onwards, important expeditions have been carried out to document the biological diversity associated with *Polylepis* forests along the Andes (Fjeldså and Kessler 1996). Although there are areas that have not been explored, we consider that the presence of *P. albicans* populations in intermediate areas is unlikely. However, further expeditions in intermediate areas would help to corroborate this assumption. A more feasible possibility may be the presence of more populations near the new record; if this were true, there would be two core populations of the species, as with *P. australis* in Argentina and *P. sericea* in Venezuela and Colombia (Boza Espinoza and Kessler 2022). Therefore, we consider it is important to carry out further field trips near the PCP area in Huancavelica. This Andean region has been found to harbor a unique species diversity (Collantes 2014; Gobierno Regional de Huancavelica 2016; MINAM 2021; Quispe-Melgar et al. 2022).

Were there populations in the area between PCP and PNP that became extinct? Although the presence of populations in the area between PCP and PNP is unlikely, we do not discard the possibility that the species had a wider range and that populations in other areas have become extinct for diverse reasons. *Polylepis* forests are considered to be one of the ecosystems most threatened by the effects of climate change (Tejedor et al. 2012, 2015). Although their fragmented distribution has been shown to be naturally caused by the effects of global climatic change, it is also known that over the last 1000 years these forests have become hyper-fragmented due to pressures from human activities (Valencia et al. 2018). In less than four decades, the range of some populations have been reduced by half (Ames-Martínez et al. 2021). Therefore, it could be hypothesized that populations of this species may have become extinct, but where this might have occurred is unknown. Palynological studies could help to answer this question.

Thus, *P. albicans* would have colonized several areas in the central Andes, at sites where there were optimal environmental conditions, and after the last glaciation its populations would have declined without leaving obvious evidence of their presence or consistent geographic distribution patterns. This process, along with the pressure from human activities, would have generated separate population cores.

Kessler (2002) proposed that the high-Andean region might have been covered by *Polylepis* forests and that currently only 5% of its total extent remains. However, it is now known that the high-Andean forests were naturally fragmented prior to intensive human activities (Renison et al. 2006, 2010; Valencia et al. 2018). It is possible that PCP and PNP may have not been directly (physically) connected. However, possibly extinct populations nearby may have had gene flow, via pollination. We consider that PCP is currently isolated (disconnected) from PNP, both physically and genetically.

Are there other species of the *P. sericea* complex between the locations of the disjunct populations of *P. albicans*? The most recent taxonomic revisions of the genus provide detailed maps of the distribution of species of the genus *Polylepis* in the Andes (Boza Espinoza et al. 2019; Boza Espinoza and Kessler 2022). The presence of other species of the *P. sericea* complex between PCP and PNP along the eastern cordillera of the Peruvian Andes is evident in those maps. Based on these distribution patterns, hypotheses about the phylogeny and diversification process of the genus could be proposed.

Are there morphological differences between PCP and PNP? The morphological evaluation showed no evidence of significant distinguishing traits from a botanical-taxonomic perspective between the samples collected from PCP and PNP. The statistical differences found in some characters (Fig. 4A–C) can be attributed to the great phenotypic plasticity characteristic of the genus. Therefore, studies at the molecular level could provide more information on the genetic characteristics of PCP and PNP, as has been done for *P. microphylla* (Bastidas-León et al. 2021), *P. besseri* (Gareca et al. 2013), *P. australis* (Hensen et al. 2011, 2012), and *P. multijuga* (Quinteros-Casaverde et al. 2012).

What plant and animal species are associated with PCP? There is evidence for the close relationships between fragmented *Polylepis* forests and the species of flora and fauna associated with them (Fjeldså and Kessler 1996). For example, ecological and biogeographical studies confirm that many bird species are highly dependent on these forests and are considered specialists (e.g., *Conirostrum binghami*, *Anairetes alpinus*, *Zaratorinis stresemanni*) (Fjeldså 1992; Lloyd 2008). Therefore, the evolutionary process that led to the current fragmented distribution of *Polylepis* forests in the Andes is the same that which has isolated other species. Thus, it is possible that many plant and animal species with restricted distribution are also present in Huancavelica. We suggest that detailed studies of the diversity present in PCP should be conducted, since recent records indicate the presence of species outside their known distribution range as well as new taxa (Quispe-Melgar et al. 2018, 2022); this suggests that central Peru is an important biodiversity hotspot in the Andes.

What implications does this new record have for conservation actions in these forests? Currently the species is not officially categorized by the IUCN; however, its Vulnerable status has been suggested (Boza Espinoza et al. 2019; Boza Espinoza and Kessler 2022). We do not consider that PCP affects its suggested categorization. Nevertheless, an evaluation from a population perspective is necessary (Ames-Martínez et al. 2021), since it the PCP forest is isolated from the main population. We observed burned grasslands (Fig. 2H), logging and the presence of a path that crosses the forest, which threaten the integrity of this relict forest. People living in nearby settlements use large amounts of wood from this forest; however, there is no evidence of reforestation activities. The PNP of *P. albicans* is accompanied by other species such as *P. weberbaueri* and *P. microphylla* (Boza Espinoza and Kessler 2022), whereas the PCP is associated with species of the genera *Gynoxys* and *Lupinus*, and there are *P. argentea* forests within a ~10 km radius. Therefore, inventories of the diversity in this area are necessary to know the associated species that could be of conservation interest and to look for new taxa (e.g. Quispe-Melgar et al. 2022).

In sum, phylogenetic (Darwinian shortfall), biogeographic (Wallacean shortfall), and taxonomic (Linnean shortfall) studies in the Andes are important to explain speciation processes, geographic distribution patterns, and species diversity (Hortal et al. 2015). This is especially important in the Tropical Andes, one of the most diverse hotspots in the world (Myers et al. 2000) and one of the regions most vulnerable to the effects of climate change.

Finally, we highlight the need to take conservation actions in PCP, since we consider it unique with respect to its counterpart PNP. The presence of the Amaru-Huachocolpa-Chihuana Cloud Forest could play a fundamental role in PCP conservation, since that forest is close to this newly recorded population and an expansion of that protected natural area could be possible. Alternatively, a new protected natural area could be established to encompass the PCP.

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Authors' Contributions

Conceptualization: HRQM. Data curation: HRQM, TEBE. Formal analysis: HRQM. Investigation: HRQM, YSLT, RDCR, LDHH, KLLP. Methodology: HRQM, KLLP, FNAM. Visualization: HRQM, YSLT. Writing – original draft: HRQM. Writing – review and editing: HRQM, YSLT, RDCR, LDHH, KLLP, FNAM, TEBE.

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