Artículos

Wild Bee Diversity in Parque Nacional Volcán Isluga: Assessing Plant-Bee Interactions in a High-Altitude Desert

Explorando la diversidad de abejas silvestres en desierto de gran altitud del Parque Nacional Volcán Isluga

Bruna K. PINHEIRO-COSTA
Universidad Católica del Maule, Chile
Universidad Católica del Maule, Chile
bruna_kpc@yahoo.com.br
Benito CORTÉS-RIVAS
Universidad Católica del Maule, Chile
Universidad Católica del Maule, Chile
benitocortes.r@gmail.com
Diego G. PÁDUA
Universidad Católica del Maule, Chile
paduadg@gmail.com
Andrés MOREIRA-MUÑOZ
Pontificia Universidad Católica de Valparaíso, Chile
andres.moreira@pucv.cl
Rodrigo O. ARAUJO
Universidad Católica del Maule, Chile
araujorodrigodeoliveira@gmail.com

Revista de la Sociedad Entomológica Argentina vol. 84 núm. 4 e0408 2025

Sociedad Entomológica Argentina
Argentina

Recepción: 15 Mayo 2025
Aprobación: 25 Septiembre 2025

Abstract: Bees are highly responsive to floral resource availability and environmental variability, making them valuable biological indicators of habitat degradation, land-use change, and agricultural expansion. Despite the harsh conditions of arid and high-altitude ecosystems, these environments support remarkable bee diversity and endemism. However, bee diversity, as well as the identity of floral resources that support insect populations, remains underexplored, particularly in the high-altitude ecosystems of northern Chile, which are underrepresented in the scientific literature. This study assesses bee diversity and plant-bee interactions in a high-altitude desert ecosystem in the Volcán Isluga National Park, located in the Tarapacá region, an area of scientific interest due to mining activities. Fieldwork was conducted in two pre-Andean villages between May and June 2023. A total of 71 bees from 19 morphospecies, 13 genera, and four families were collected. The family Apidae was the most abundant, followed by Halictidae, Colletidae, and Megachilidae. Bees interacted with 18 plant species, with Fabaceae and Asteraceae being the most represented families. These findings highlight the role of local flora in supporting bee communities and underscore the need for conservation strategies to maintain ecosystem services and ensure sustained pollination services.

Keywords: Bee conservation, Chilean bees, Desertic zone, Pollination.

Resumen: Las abejas son sensibles a la disponibilidad de recursos florales y a los cambios ambientales, lo que las convierte en valiosos indicadores biológicos de la degradación del hábitat, los cambios en el uso del suelo y la expansión agrícola. Sin embargo, la diversidad de las abejas, así como la identificación de los recursos florales que sustentan las poblaciones de estos insectos, siguen sin estar suficientemente estudiadas, especialmente en los ecosistemas de gran altitud del norte de Chile, que están poco representados en la literatura científica. Este estudio evalúa la diversidad de abejas y las interacciones planta-abeja en el ecosistema desértico de gran altitud del Parque Nacional Volcán Isluga, ubicado en la región de Tarapacá, una zona de interés científico debido a las actividades mineras. El trabajo de campo se realizó en dos localidades preandinas entre mayo y junio de 2023. Se colectaron un total de 71 abejas de 19 morfoespecies, 13 géneros y cuatro familias. La familia Apidae fue la más abundante, seguida de Halictidae, Colletidae y Megachilidae. Las abejas interactuaron con 18 especies de plantas, siendo Fabaceae y Asteraceae las familias más representadas. Estos hallazgos resaltan el papel de la flora local en el apoyo a las comunidades de abejas y subrayan la necesidad de estrategias de conservación para mantener los servicios ecosistémicos y garantizar la gestión sostenible de los servicios de polinización.

Palabras clave: Abejas chilenas, Conservación de abejas, Polinización, Zona desértica.

INTRODUCTION

Bees play an important role in ecosystems as pollinators, contributing to plant reproduction, agricultural productivity, and biodiversity conservation (Klein et al., 2007; Potts et al., 2010; Ollerton et al., 2011). Due to their sensitivity to environmental change and floral resource availability, they are valuable bioindicators of habitat degradation and land-use change (Odanaka & Rehan, 2019). Despite the increasing global recognition of pollinators' importance, significant knowledge gaps persist regarding their distribution and diversity, particularly in arid and high-altitude ecosystems (Arroyo et al., 1982; Gonzalez & Engel, 2004; Henríquez-Piskulich et al., 2020).

In arid and high-altitude ecosystems, bee diversity and distribution patterns are influenced by extreme environmental conditions such as low temperatures, high solar radiation, and scarce water availability (Abrahamczyk et al., 2011; Orr et al., 2021). These ecosystems tend to support specialized bee communities adapted to harsh climatic conditions, often characterized by a dominance of ground-nesting species and seasonal activity patterns closely linked to the availability of floral resources (Minckley et al., 2000). In addition, the fragmented nature of the vegetation and the presence of endemic plant species contribute to unique plant-bee interactions (Arroyo et al., 1982; Minckley et al., 2000; Henríquez-Piskulich et al., 2018; Luna et al., 2024) that are particularly vulnerable to environmental disturbances, making their conservation a priority (Henríquez-Piskulich et al., 2018; Rodríguez et al., 2021).

In Chile, bee diversity has mainly been studied in the central and southern regions, while the northern high-altitude ecosystems remain underrepresented in the scientific literature (Montalva & Ruz, 2010;Henríquez-Piskulich et al., 2020; López-Aliste et al., 2021; Marshall et al., 2023). The northern region of Chile is characterized by an arid and semi-arid climate, with extreme variations in temperature and solar radiation (Arroyo & Cavieres, 2013; Anthelme et al., 2014; Cavieres et al., 2025). As a result, these areas support an ecosystem that is favorable to diversity and evolution of endemic forms (Orr et al., 2021; Marshall et al., 2023).

The Volcán Isluga National Park, located in the Tarapacá Region, is a protected area characterized by high-altitude desert ecosystems that harbor a rich diversity of native flora and Andean vegetation (CONAF, 1988). This Park has been declared of scientific interest, which restricts mining activities (CHILE, 1983), and natural resource extraction and land use are strictly regulated under a conservation framework that aims to sustain biodiversity and maintain key ecosystem services provided by the local species (Ormazabal, 1993). However, studies on the diversity and ecological interactions of insects in this region remain limited. Bees are the main pollinators of flowering plants (Ollerton et al., 2011), supporting essential ecological processes such as plant reproduction, fruit production, and ecological succession (Klein et al., 2007; Potts et al., 2010). In this sense, this study aims to evaluate the diversity and composition of wild bees and provide a list of plant-bee interactions in Vólcan Isluga National Park. Based on these results, we discuss the relevance of the understanding of bee diversity and their interactions with native plant species as a key component for the conservation of pollination services.

MATERIAL AND METHODS

Study site

We conducted field sampling during May and June 2023, at two pre-Andean villages of Chiapa and Jaina located on Volcán Isluga National Park (19°15' S, 43°31' W), Provincia de Iquique, in the Tarapacá Region, Chile. This Park covers a total area of 174,744 ha and encompasses a variety of desert vegetation zones adapted to high-altitude and arid climatic conditions (Fig. 1). The park's elevation ranges from 800 to 5,550 m (CONAF, 1988). The climate in the study areas is predominantly classified as Hot Desert (BWh), with a moderate influence from the Cold Desert climate (BWk) (Sarricolea et al., 2017). In general, summers are warm, while winters are cold and dry, with temperatures ranging from -20 °C to 10 °C. Rainfall is variable throughout the year, reaching 50 to 350 mm, primarily between December and March (CONAF, 1988). Volcán Isluga National Park is a legally protected area in which mineral exploration and exploitation are restricted by the Mining Code Regulations (Chile, 1983; Law 18,248). In addition to its legal status as a biodiversity refuge, the park is recognised as a zone of development for Aymara indigenous communities, highlighting its socio-ecological importance in northern Chile (Toledo et al., 2017).

The most representative vegetation zones include the tropical Andean low shrubland (literal translation of Matorral bajo tropical andino), dominated by *Parastrephia lepidophylla* (Weed) Cabrera and *P. quadrangularis* (Meyen) Cabrera (Asteraceae), commonly known as *tolar*, which occurs above 3,000 meters above sea level. Between 2,500 and 3,000 meters, the landscape is characterized by the same vegetation type, with dominance of the endemic *Fabiana ramulosa* (Wedd.) Hunz & Barboza (Solanaceae) and *Diplostephium meyenii* Wedd (Asteraceae). The northeastern section of the National Park corresponds to high-altitude zones with tropical Andean low shrublands (Matorral bajo tropical andino) dominated by *Parastrephia lucida* (Meyen) Cabrera (Asteraceae) and *Azorella compacta* Phil. (Apiaceae), and in some areas this species is accompanied by *Pycnophyllum molle* J. Remy (Caryophyllaceae). In contrast, the southwestern section includes tropical Andean desert low shrubland (*Matorral bajo desértico tropical andino*), characterized by *Atriplex imbricata* (Moq.) D. Dietr. (Amaranthaceae) and *Aloysia deserticola* (Phil.) Lu-Irving & N.O'Leary (Verbenaceae); tropical Andean spiny forest (*Bosque espinoso tropical andino*), with species such as *Browningia candelaris* (Meyen) Britton & Rose and *Corryocactus brevistylus* (K. Schum. ex Vaupel) Britton & Rose (Cactaceae), representing the columnar cactus belt; and interior tropical Andean desert low shrubland (*Matorral bajo desértico tropical interior*), dominated by *Adesmia atacamensis* Phil. (Fabaceae) and *Silvaea salsoloides* (Barnéoud) Teillier & S.T. Ibáñez (Montiaceae), marking the transition to lower, more arid zones (Luebert & Pliscoff, 2017).

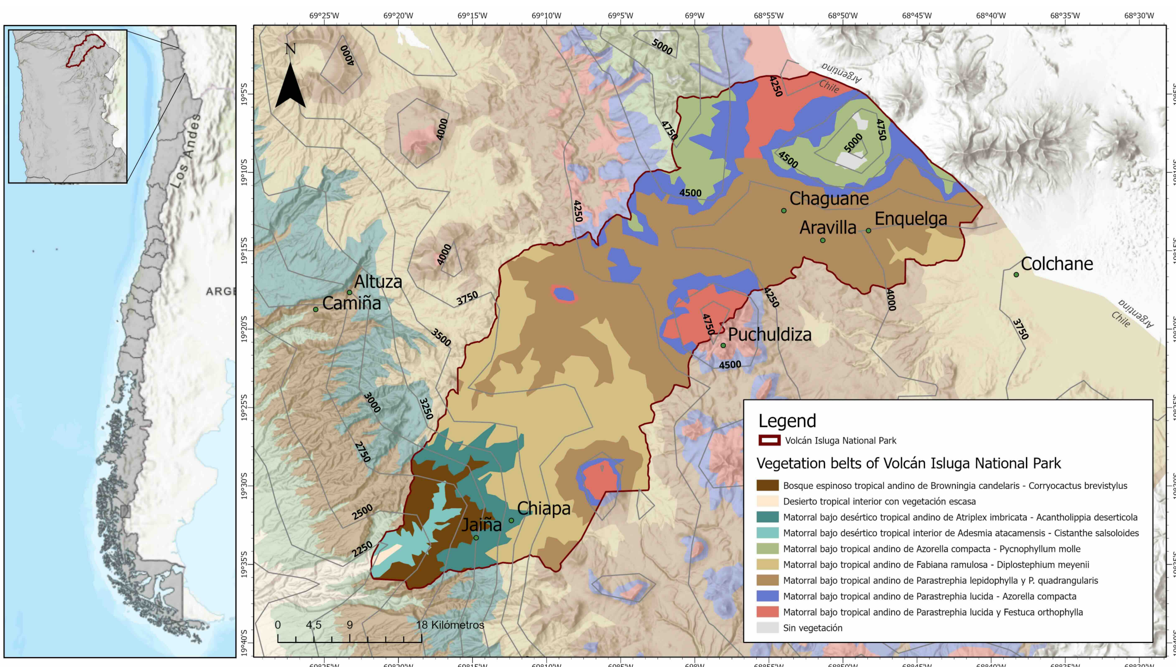

Figure 1

Study site within the Volcán Isluga National Park, Tarapacá Region, northern Chile

The map illustrates different vegetation types adapted to high-altitude and arid climatic conditions. Green dots indicate nearby settlements (villages/hamlets) used as geographic references.

The vegetation map was produced using vegetation belt data downloaded from www.geoportal.cl (accessed on May 01, 2025) (originally described by Luebert & Pliscoff, 2017) and processed in ArcGIS Pro 2.8.8 software.

Wild bee sampling

We employed two complementary sampling methods during May and June 2023 field seasons. The combination of active and passive approaches was selected to maximize the likelihood of capturing exploratory data on the richness and abundance of the regional bee community, as recommended in pollinator survey protocols (e.g., Westphal et al., 2008; Roulston et al., 2007).

For the passive collection, we used yellow pan traps (Moericke traps) consisting of 4.5 cm high, 10 cm diameter plastic bowls filled with 150 mL of water mixed with a few drops detergent to break the surface tension (Wang et al., 2017). A total of five traps were installed simultaneously along a 350 m fixed transect for five consecutive days, resulting in 25 individual trap deployments. The traps were placed at ground level in open areas near flowering vegetation, spaced approximately 50 m apart to maximize the likelihood of capturing floral visitors. Each trap was left in the field for 24 h, yielding a cumulative sampling effort of 600 trap-hours.

In addition, active searches were conducted along transects between 09:00 and 18:00, with two researchers conducting a total of 45 hours per observer. Six sampling points were randomly selected, ensuring a minimum distance of 1,500 meters between points to minimize spatial clustering. At each point, observers were not restricted to a fixed transect line but moved slowly in search of flowering plants, taking care not to stray more than 600 meters from the designated location (adapted from Westphal et al., 2008). This transect walk approach was chosen to maximize the likelihood of encountering flowering individuals during the sampling period, given the presence of empty areas without flowering plants (Westphal et al., 2008). Direct searching along variable transects can enhance the representativeness of bee foraging activity across temporal and spatial scales, especially in fragmented or arid environments, compared to fixed transect corridors (Dafni et al., 2005). However, it should be noted that sampling effort per plant species (limited to individual plants) and the presence or abundance of plants across transects could not be standardized or controlled. Collectors remained in front of a flowering individual for approximately five minutes and captured all visiting bees using an entomological net. A plant-bee interaction matrix was constructed based on all interactions between bees and flowering plants recorded by the observers during the surveys. The sampling points and pan traps are provided in Supplementary Table S1.

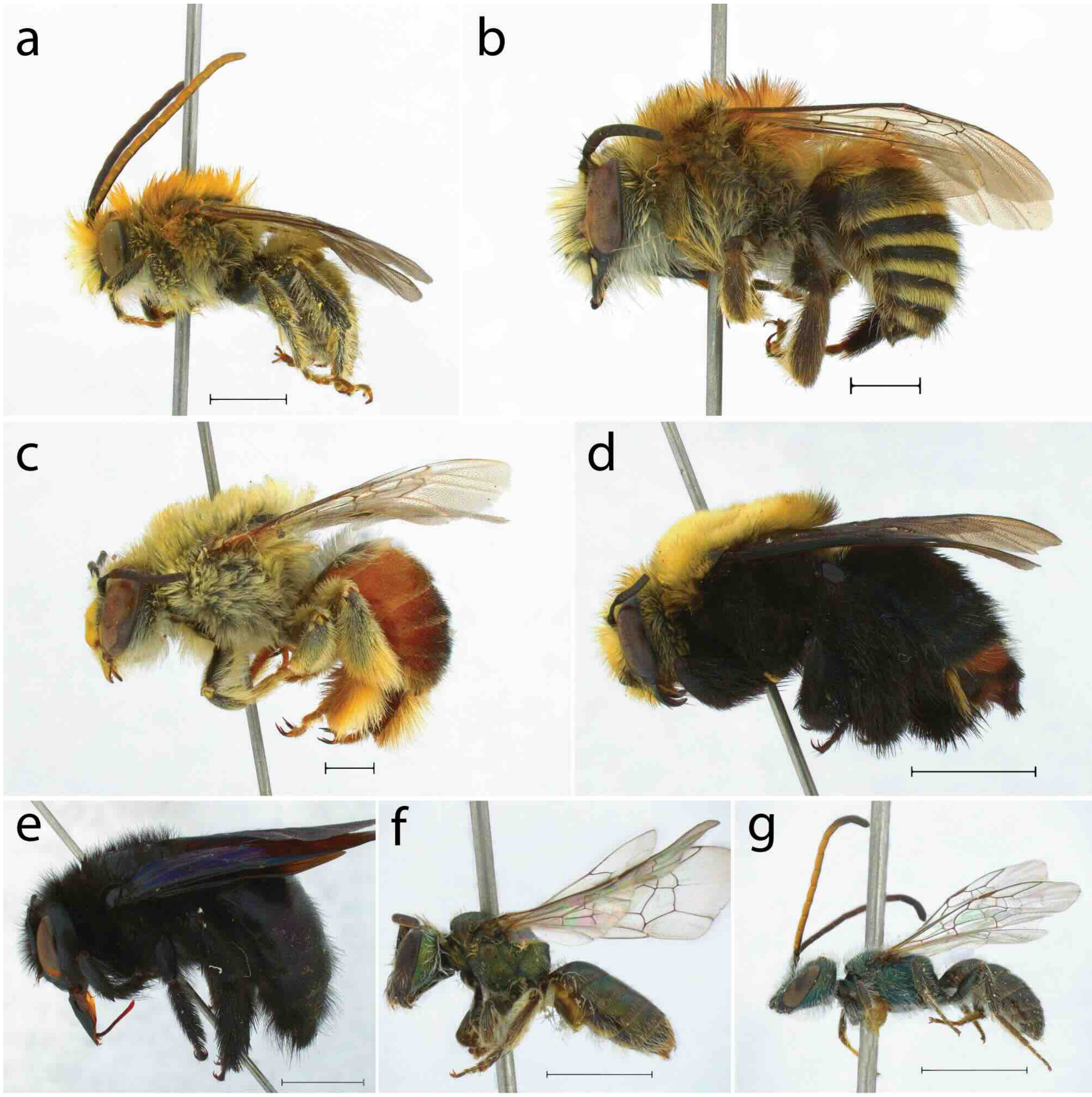

Figure 2

Representative bee specimens collected during this study

a. *Alloscirtetica weyrauchi* Michener, LaBerge & Moure, 1955. b. *Anthophora arequipensis* Bréthes, 1920. c. *Centris buchholzi* Herbst, 1918. d. *Centris sacsayhuaman* Vivallo, 2020. e. *Xylocopa viridigastra* Lepeletier, 1841. f. *Caenohalictus cuprellus* (Vachal, 1903). g. *Lasioglossum* sp. Scale bar= a, b, c, f, g: 2 mm; d, e: 5 mm

The specimens observed during this study were collected, prepared, and deposited in the Entomological Collection of the Laboratorio de Ecología de Abejas, Universidad Católica del Maule (UCM). Bees were identified to the lowest taxonomic level possible, usually species, using interactive keys and reference literature, including Michener et al. (1955); Chiappa et al. (1990); Toro (1999); Rojas & Toro (2000); Michener (2007); and Ferrari (2017). Benito Cortés-Rivas (author) conducted the identification and validation of the specimens by comparing them with reference material from the entomological collections of the Laboratorio de Ecología de Abejas at the Universidad Católica del Maule. Experienced bee taxonomist Felipe Vivallo (Museo Nacional do Rio de Janeiro, Brazil) provided confirmation for specimens from *Centris* genus. All plant species were identified at the species level by A. Moreira-Muñoz (author). Insect sociability was recorded based on the reference literature (Melander, 1902; Gerling et al., 1989; Michener, 1964; Toro et al., 1999;Chiappa et al., 2000; Silveira et al., 2002; González & Chávez, 2004; Packer, 2006; Davis et al., 2012; Montalva et al., 2012;Richards & Packer, 2021; López-Aliste et al., 2021).

A heatmap was constructed using the “ggplot2” package in R (R Core Team, 2023), based on the abundance matrix of bee visitors and host plants to visualize the interactions between bee species and their associated plant species. To contextualize our findings within the broader knowledge of bee diversity in northern Chile, we conducted a comparative analysis with published records for the Tarapacá region. Specifically, we used the checklist compiled by Toro (1986); López-Aliste et al. (2021).

Bees' images were captured with a Leica S9i stereomicroscope using an LED illumination dome (Kawada & Buffington, 2016) and the Leica Application Suite x extended-focus software. Images stacking was done using Helicon Focus 8.1.0, followed by editing in Adobe Photoshop 2020.

RESULTS

A total of 71 bees representing 19 morphospecies in 13 genera and four families were collected during the sampling periods (Figure 2; Table I). The Apidae family was the most abundant, comprising 35.5 % of the specimens (n= 27 specimens; 7 species), followed by Halictidae (26.3 %; n= 20 individuals; 4 species), Colletidae (17.1 %; n= 13 individuals; 3 species), and Megachilidae (14.5 %; n= 11 individuals; 5 species). No individuals from the family Andrenidae were recorded.

Among the collected specimens, Apidae exhibited the highest species richness and abundance, with notable species including *Alloscirtetica weyrauchi* Michener, LaBerge & Moure, 1955, *Anthophora arequipensis* Bréthes, 1920, and multiple *Centris* species (*C. buchholzi* Herbst, 1918, *C. escomeli* Cockerell, 1926, *C. sacsayhuaman* Vivallo, 2020, and *C. miluni* Vivallo, 2020), as well as *Xylocopa viridigastra* Lepeletier, 1841 (Fig. 3). The most abundant species were *A. arequipensis* (n= 12 specimens, 16.9 %), *Caenohalictus cuprellus* (Vachal, 1903) (n= 10 specimens, 14.1 %, Table I). Bee species exhibited distinct social behaviors, including solitary, cleptoparasitic and variations of social patterns behaviour (Table I).

Table I

List of bee morphospecies collected in Volcán Isluga National Park, including their ecology and records of floral interactions

Species	Method	Body size	Sociality	Flora	Previous records
Familia Apidae					
Alloscirtetica weyrauchi Michener, LaBerge & Moure, 1955	sweep net	M	Solitary*	*Balbisia peduncularis* *Grindelia tarapacana*	López-Aliste et al., 2021;
Anthophora arequipensis Bréthes, 1920	sweep net	M	Solitary*	*Dalea cylindrica var. nova* *Lupinus oreophilus* *Grindelia tarapacana* *Polyachyrus sphaerocephalus* *Salvia rosmarinus* *Senna birostris* *Solanum montanum* *Spergularia fasciculata* *Tarasa operculata*	López-Aliste et al., 2021;
Centris buchholzi Herbst, 1918	sweep net	M	Solitary*	*Solanum montanum*	Toro (1986); López-Aliste et al., (2021).
			Solitary*	*Tarasa operculata*	Toro (1986); López-Aliste et al., (2021).
Centris escomeli Cockerell, 1926	sweep net	M	Solitary*	*Tarasa operculata*	Toro (1986); López-Aliste et al., (2021).
Centris sacsayhuaman Vivallo, 2020	sweep net	M	Solitary* Solitary*	*Caiophora cirsiifolia* *Calceolaria inamoena*	
Centris miluni Vivallo, 2020	sweep net	M	Solitary*	*Grindelia tarapacana*	
Mesonychium garleppi (Schrottky, 1910)*	sweep net	M	Cleptoparasite*	-	Toro (1986); López-

Notes *Classification of bee species by body size: S= small (5-8 mm), M= medium (9-16 mm), G= large (> 17 mm), based on body width*

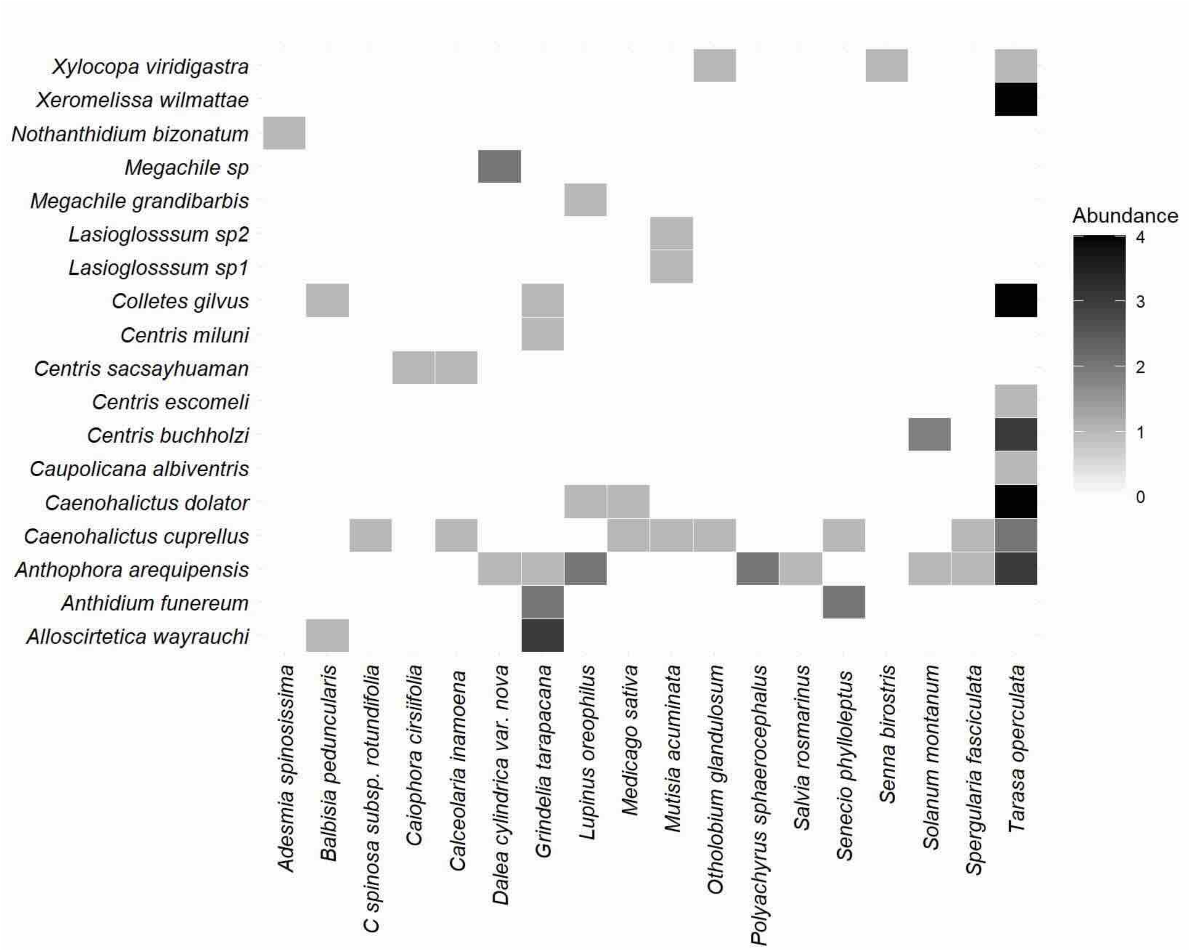

Figure 3.

Abundance visitation matrix. Heatmap showing the abundance and interaction between bee and plant species recorded in Volcán IslugaNational Park

The vertical columns represent bee species, while each horizontal row corresponds to a plant species. The color intensity of the heatmap reflects the number of observed floral visits, with darker shades indicating higher interaction frequencies

Regarding the sampling method, only one specimen of *Lasioglossum* sp. 1 (Halictidae) was collected using yellow pan traps, while the remaining individuals were recorded using the active sweep net method (Table I). Bees were recorded interacting with 18 plant species belonging to 9 botanical families. Fabaceae (n= 7 species; 18 specimens) and Asteraceae (n= 5 species; 18 specimens) showed the highest number of plants species, while Malvaceae, represented by one single species, was the most abundant family (27 specimens). The remaining families, Calceolariaceae, Caryophyllaceae, Francoaceae, Lamiaceae, Loasaceae, Solanaceae, and Vivianiaceae, were each represented by a single species (Fig. 3).

Among the 19 bees morphospecies recorded in our study, 12 had previously documented distributions for the Tarapacá region. Notably, our survey recorded *Centris miluni* and *Centris* *sacsayhuaman*, two species that were only recently described (Vivallo et al., 2020), as well as *Caupolicana albiventris*, *Xeromelissa wilmattae*, and *Nothanthidium bizonatum*, which were previously documented only by Toro (1986). Another relevant record, *Anthidium funereum*, had only been documented previously for the Arica region (Toro, 1986).

DISCUSSION

Our findings highlight the diversity and abundance of wild bees in Volcán Isluga National Park, the first assessment of plant-bee interactions in this high-altitude desert ecosystem in this region. Our exploration of plant–bee interactions revealed that 19 bee species interacted with 18 native plant species, primarily from the Fabaceae and Asteraceae families. These results suggest that the local flora may play a key role in supporting solitary bees, particularly within the Apidae and Halictidae families.

According to López-Aliste et al. (2021), the study region has a low frequency of documented bee records. In their most recent survey of the Tarapacá region, 26 bee species were reported, ten of which were also observed in our study (See Table I). The presence of *Centris miluni, Centris sacsayhuaman, Caupolicana albiventris, Xeromelissa wilmattae*, and *Nothanthidium bizonatum* in our survey underscores the Tarapacá region's understudied bee diversity. Several of these species have been recently described or were previously documented only in distant locations (Vivallo et al., 2020; Toro, 1986), which suggests that their geographic ranges are likely broader than currently recognized. It is also important to highlight that the identification of some morphospecies was limited to the genus level due to outdated or incomplete taxonomic references for certain groups (e.g., *Lasioglossum*). This limitation reflects the taxonomic challenges documented in recent literature, particularly for morphologically difficult and cryptic taxa such as *Lasioglossum* (Halictidae) (Landaverde-González et al., 2017).

Studies in arid desert ecosystems have revealed high bee diversity of interest (Argueta-Guzmán et al., 2022; Thapa-Magar et al., 2022). The species share adaptations that allow them to survive in arid, high-altitude conditions where climatic extremes (Sakagami & Munakata, 1972; Eickwort et al., 1996; Purcell et al., 2015). These adaptations include specific body traits such as increased hair density for thermoregulation (Turnley et al., 2025) and predominantly solitary behaviour (Moss & While, 2021; Ostwald et al., 2024). In addition to arid conditions, the availability of floral resources, both spatially and temporally (Snyder et al., 2006; Pueyo et al., 2008), appear to play an important role in determining bee richness and occurrence in these ecosystems (Rodríguez et al., 2021).

In Volcán Isluga, most of the recorded species were solitary and visited especially native plants, such as *Tarasa operculata* (Malvaceae), *Grindelia tarapacana* (Asteraceae) and *Lupinus oreophilus* (Fabaceae). These species are typically found in the herbaceous and shrubby vegetation of the desert Matorral system, which occurs on the dry western slopes of the Andes. Some species, such as *Tarasa operculata*, are adapted to higher altitudes (ranging from 1,600 to 2,300 m) and to conditions with limited water availability (Chicalla-Rios, 2021). Native bees were observed collecting pollen and other floral resources, indicating that the presence of these plant species in the desert landscape may serves as key resources for sustaining bee communities and maintaining ecosystem stability.

Furthermore, our study presents limitations that may affect the generalizability of its findings. Although it provides an initial insight into plant-bees interaction, we did not quantify the influence of plant abundance and diversity across spatial heterogeneity gradients on plant-bee interactions. The availability and distribution of floral resources can directly impact bee foraging behavior (Escobedo-Kenefic et al., 2020), resource partitioning, and the overall structure of pollination networks (generalist or specialist) (Bendel et al., 2019). Although we combined different collection methods, our study was conducted in a limited time period, which restricts our ability to capture seasonal variations in bee activity and floral resource availability. Since the composition and level of specialization of plant-bee interactions are strongly influenced by phenological cycles (Oertli et al., 2005), future studies should incorporate multiseasonal sampling to adequately characterize community dynamics and assess the effect of temporal variability on pollination networks in high-altitude desert ecosystems (Bendel et al., 2019).

Combining active and passive sampling methods provides a more comprehensive assessment of bee diversity and plant-bee interactions (Wilson et al., 2016). However, the success of each type of method can vary depending on climatic conditions, seasonality, suitable habitat, trap color and insect body size (Prendergast et al., 2020). In our study, the effectiveness of passive collection methods, such as pan traps, was notably lower, recording only a single bee species. This result probably reflects the limitations of trap color selection, and the small number of samples taken, which may have reduced the ability to capture the full diversity of bee species present in the study area. To overcome these limitations, some studies have employed multi-colored pan traps combined with standardized active surveys, which improves the representativeness of bee community overviews in terms of both diversity and abundance (Vereecken et al., 2021; Hutchinson et al., 2022; Xie et al., 2024). However, these combined approaches also increase the logistical effort and financial cost of sampling and monitoring, which can limit their feasibility in remote or resource-constrained environments (Bell et al., 2023).

Despite these limitations, our study provides an important baseline characterization of plant-bee interactions in a high-altitude desert ecosystem in northern Chile. Many of the recorded interactions occur within legally protected areas, such as national parks, which help safeguard these ecological relationships. However, on a regional scale, the park is located in a zone of potential conflict due to the proximity of mining activities to protected areas (Toledo et al., 2017). Our findings underscore the importance of ongoing monitoring and conservation efforts in the region and highlight the value of Isluga Volcano as a refuge for pollinator communities and other forms of biodiversity.

CONCLUSION

Overall, our finding suggests that bee diversity in the region is underestimated and likely higher than previously reported. The presence of previously unrecorded species further underscores the importance of documenting plant-bee interactions. These interactions can provide valuable insights into local ecological processes such as pollination and ecosystem resilience. Future research should focus on analyzing plant-bee networks, including their temporal and spatial dynamics, as well as assessing the effectiveness of bees as pollinators. Incorporating measures of pollination effectiveness, beyond simple floral visitation, will allow a better understanding of the distinct roles that different floral visitors play within the community and inform conservation strategies in these high-altitude desert ecosystems (Santiago-Hernández et al., 2019).

Acknowledgments

MOREIRA-MUÑOZ (as principal investigator) and ARAUJO (as coinvestigator) thank Agencia Nacional de Investigación y Desarrollo (ANID), Chile, for funding this study through the FONDECYT Regular nº 1221879 project. PINHEIRO-COSTA thanks UCM for the doctoral fellowship provided.

REFERENCES

Abrahamczyk, S., Kluge, J., Gareca, Y., Reichle, S., & Kessler, M. (2011). The influence of climatic seasonality on the diversity of different tropical pollinator groups. *PLoS One*, *6*(11), e27115. https://doi.org/10.1371/journal.pone.0027115

Anthelme, F., Jacobsen, D., Macek, P., Meneses, R. I., Moret, P., Beck, S., & Dangles, O. (2014). Biodiversity patterns and continental insularity in the tropical High Andes. *Arctic, Antarctic, and Alpine Research*, *46*(4), 811-828.

Argueta-Guzmán, M., Golubov, J., Cano-Santana, Z., & Ayala, R. (2022). The role of seasonality and disturbance in bee–plant interactions in semi-arid communities of the southern Chihuahuan desert. *Insect Conservation and Diversity*, *15*(5), 543-554. https://doi.org/10.1111/icad.12572

Arroyo, M. T. K., Primack, R., & Armesto, J. (1982). Community studies in pollination ecology in the high temperate Andes of central Chile. I. Pollination mechanisms and altitudinal variation. *American journal of botany*, *69*(1), 82-97. https://doi.org/10.1007/BF00983305

Arroyo, M. T. K., & Cavieres, L. A. (2013). High-elevation Andean ecosystems. In S. A. Levin (Ed.), *Encyclopedia of biodiversity* (2nd ed., Vol. 4, pp. 96-110). Academic Press. https://doi.org/10.1016/B978-0-12-384719-5.00428-7

Bendel, C. R., Kral-O'Brien, K. C., Hovick, T. J., Limb, R. F., & Harmon, J. P. (2019). Plant–pollinator networks in grassland working landscapes reveal seasonal shifts in network structure and composition. *Ecosphere*, *10*(1), e02569. https://doi.org/10.1002/ecs2.2569

Bell, C., Tronstad, L., & Hotaling, S. (2023). Tailoring your bee sampling protocol: Comparing three methods reveals the best approaches to capturing bees. *Agricultural and Forest Entomology*, *25*(3), 477-488. https://doi.org/10.1111/afe.12569

Cavieres, L. A., Llambí, L. D., Anthelme, F., Hofstede, R., & Arroyo, M. T. (2025). High-Andean Vegetation Under Environmental Change: A Continental Synthesis. *Annual Review of Environment and Resources*, *50,* 219-245. https://doi.org/10.1146/annurev-environ-111523-101920

Chiappa, E., Bascuñán, R., & Rodríguez, S. (2000). Nidificación, conducta de machos de *Centris* (*Wagenknechtia*) *rodophthalma* Pérez (Hymenoptera: Anthophoridae) y comparación con otras especies chilenas del género. *Acta Entomológica Chilena*, *24*, 19-28.

Chiappa, E., Rojas, M., & Toro, H. (1990). Clave para los géneros de abejas de Chile (Hymenoptera: Apoidea). *Revista Chilena de Entomología*, *18*, 67-81.

Chicalla-Rios, K. J. (2021). Comunidades vegetales del matorral desértico en las cuencas de los ríos Tambo y Moquegua en el sur de Perú. *Revista peruana de biología*, *28*(1), e17497. http://dx.doi.org/10.15381/rpb.v28i1.17497

CHILE (1983). Código de Minería promulgado mediante la Ley N° 18.248 de 26 de septiembre

CONAF (1988). Plan de manejo Parque Nacional Volcán Isluga. https://bibliotecadigital.ciren.cl/bitstreams/35e83 9bc-2135-4fd4-ac0e-799aa3ac18a3/download

Dafni, A., Kevan, P. G., & Husband, B. C. (Eds.). (2005). Practical pollination ecology. Enviroquest.

Davis, E. S., Reid, N., & Paxton, R. J. (2012). Quantifying forage specialisation in polyphagic insects: the polylectic and rare solitary bee, *Colletes floralis* (Hymenoptera: Colletidae). *Insect Conservation and Diversity*, *5*(4), 289-297. https://doi.org/10.1111/j.1752-4598.2011.00166.x

Eickwort, G. C., Eickwort, J. M., Gordon, J., Eickwort, M. A., & Wcislo, W. T. (1996). Solitary behavior in a high-altitude population of the social sweat bee *Halictus rubicundus* (Hymenoptera: Halictidae). *Behavioral Ecology and Sociobiology*, *38*, 227-233. https://doi.org/10.1007/s002650050236

Escobedo-Kenefic, N., Landaverde-González, P., Theodorou, P., Cardona, E., Dardón, M. J., Martínez, O., & Domínguez, C. A. (2020). Disentangling the effects of local resources, landscape heterogeneity and climatic seasonality on bee diversity and plant-pollinator networks in tropical highlands. *Oecologia*, *194*(3), 333-344. https://doi.org/10.1007/s00442-020-04715-8

Ferrari, R. R. (2017). Taxonomic revision of the species of *Colletes* Latreille, 1802 (Hymenoptera: Colletidae: Colletinae) found in Chile. *Zootaxa*, *4364*(1), 1-137. https://doi.org/10.11646/zootaxa.4364.1.1

Gerling, D. H. H. W. V., Velthuis, H. H. W., & Hefetz, A. (1989). Bionomics of the large carpenter bees of the genus *Xylocopa*. *Annual*

Review of Entomology, *34*, 163-190. https://doi.org/10.1146/annurev.en.34.010189.001115

Gonzalez, V. H., & Chavez, F. (2004). Nesting biology of a new high Andean bee, *Anthophora walteri* Gonzalez (Hymenoptera: Apidae: Anthophorini). *Journal of the Kansas Entomological Society*, *77*(4), 584-592. https://doi.org/10.2317/e-8.1

Gonzalez, V. H., & Engel, M. S. (2004). The tropical Andean bee fauna (Insecta: Hymenoptera: Apoidea), with examples from Colombia. *Entomologische Abhandlungen*, *62*(1), 65-75.

Henríquez-Piskulich, P., Vera, A., Sandoval, G. & Villagra, C. (2018) Along urbanization sprawl, exotic plants distort native bee (Hymenoptera: Apoidea) assemblages in high elevation Andes ecosystem. *PeerJ*, *6*, e5916. https://doi.org/10.7717/peerj.5916

Henríquez-Piskulich, P., Villagra, C. A., & Vera, A. (2020). Native bees of high Andes of Central Chile (Hymenoptera: Apoidea): biodiversity, phenology and the description of a new species of *Xeromelissa* Cockerell (Hymenoptera: Colletidae: Xeromelissinae). *PeerJ*, *8*, e8675. https://doi.org/10.7717/peerj.8675

Hutchinson, L. A., Oliver, T. H., Breeze, T. D., O'Connor, R. S., Potts, S. G., Roberts, S. P., & Garratt, M. P. (2022). Inventorying and monitoring crop pollinating bees: Evaluating the effectiveness of common sampling methods. *Insect Conservation and Diversity*, *15*(3), 299-311. https://doi.org/10.1111/icad.12557

Kawada, R. & Buffington, M.L. (2016) A scalable and modular dome illumination system for scientific microphotography on a budget. *PLoS One*, *11*, e0153426. https://doi.org/10.1371/journal.pone.0153426

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the royal society B: biological sciences*, *274*(1608), 303-313. https://doi.org/10.1098/rspb.2006.3721

Krahner, A., Dietzsch, A. C., Jütte, T., Pistorius, J., & Everaars, J. (2024). Standardising bee sampling: A systematic review of pan trapping and associated floral surveys. *Ecology and Evolution*, *14*(3), e11157. https://doi.org/10.1002/ece3.11157

Landaverde-González, P., Quezada-Euán, J. J. G., Theodorou, P., Murray, T. E., Husemann, M., Ayala, R., Moo-Valle, H., Vandame, R., & Paxton, R. J. (2017). Sweat bees on hot chillies: provision of pollination services by native bees in traditional slash-and-burn agriculture in the Yucatán Peninsula of tropical Mexico. *Journal of Applied Ecology*, *54*(6), 1814-1824. https://doi.org/10.1111/1365-2664.12860

López-Aliste, M., Flores-Prado, L., Ruz, L., Sepúlveda, Y., Rodríguez, S., Saraiva, A. M., & Fontúrbel, F. E. (2021). Wild bees of Chile: a database on taxonomy, sociality, and ecology. *Ecology*, *102*(8), e03377. https://doi.org/10.1002/ecy.3377

Luebert, F., & Pliscoff, P. (2017). *Sinopsis bioclimática y vegetacional de Chile*. Editorial. Universitaria.

Luna, P., Sandoval, A. G. C., Hinojosa-Díaz, I., & Dáttilo, W. (2024). Temperature and Precipitation Explain Bee Diversity on Flowers Along an Elevation Gradient in the Mexican Transition Zone. *Sociobiology*, *71*(4), e10455-e10455. https://doi.org/10.13102/sociobiology.v71i4.10455

Marshall, L., Ascher, J. S., Villagra, C., Beaugendre, A., Herrera, V., Henríquez-Piskulich, P., Vera, A., & Vereecken, N. J. (2023). Chilean bee diversity: Contrasting patterns of species and phylogenetic turnover along a large-scale ecological gradient. *Ecosphere*, *14*(5), e4535. https://doi.org/10.1002/ecs2.4535

Melander, A. L. (1902). The nesting habits of *Anthidium*. *The Biological Bulletin*, *3*(1-2), 27-32. https://doi.org/10.2307/1535525

Michener, C. D. (1964). Evolution of the nests of bees. *American Zoologist*, 4(2), 227-239. https://doi.org/10.1093/icb/4.2.227

Michener, C. D. (2007). *The bees of the world*. JHU press. https://doi.org/10.56021/9780801885730

Michener, C. D., LaBerge, W. E., & Moure, J. S. (1955). Some American Eucerini bees. *Dusenia*, *6*(6), 213-230.

Minckley, R. L., Cane, J. H., & Kervin, L. (2000). Origins and ecological consequences of pollen specialization among desert bees. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *267*(1440), 265-271. https://doi.org/10.1098/rspb.2000.0996

Montalva, J., & Ruz, L. (2010). Actualización a la lista sistemática de las abejas chilenas (Hymenoptera: Apoidae). *Revista Chilena de Entomología*, *35*, 15-52.

Montalva, J., Castro, B., & Allendes, J. L. (2012). Biología de nidificación de *Megachile semirufa* (Hymenoptera: Megachilidae: Dasymegachile) en alta montaña, chile. *Caldasia*, *34*(2), 475-481.

Moss, J. B., & While, G. M. (2021). The thermal environment as a moderator of social evolution. *Biological Reviews*, *96*(6), 2890-2910. https://doi.org/10.1111/brv.12784

Odanaka, K. A., & Rehan, S. M. (2019). Impact indicators: Effects of land use management on functional trait and phylogenetic diversity of wild bees. *Agriculture, Ecosystems & Environment*, 286, 106663. https://doi.org/10.1016/j.agee.2019.106663

Ollerton, J., Winfree, R., & Tarrant, S. (2011). How many flowering plants are pollinated by animals? *Oikos*, *120*(3), 321-326.

Ormazabal, C. E. S. A. R. S. (1993). The conservation of biodiversity in Chile. *Revista Chilena de Historia Natural*, *66*(4), 383-402.

Oertli, S., Müller, A., & Dorn, S. (2005). Ecological and seasonal patterns in the diversity of a species-rich bee assemblage (Hymenoptera: Apoidea: Apiformes). *European Journal of Entomology*, *102*(1), 53-63.

Orr, M. C., Hughes, A. C., Chesters, D., Pickering, J., Zhu, C. D., & Ascher, J. S. (2021). Global patterns and drivers of bee distribution. *Current Biology*, *31*(3), 451-458. https://doi.org/10.1016/j.cub.2020.10.053

Ostwald, M. M., da Silva, C. R., & Seltmann, K. C. (2024). How does climate change impact social bees and bee sociality? *Journal of Animal Ecology*, *93*(11), 1610-1621. https://doi.org/10.1111/1365-2656.14160

Packer, L. (2006). Use of artificial arenas to predict the social organisation of halictine bees: data for fourteen species from Chile. *Insectes Sociaux*, *53*, 307-315. https://doi.org/10.1007/s00040-006-0873-x

Potts, S. G., Roberts, S. P., Dean, R., Marris, G., Brown, M. A., Jones, R., Neumann, P., & Settele, J. (2010). Declines of managed honey bees and beekeepers in Europe. *Journal of apicultural research*, *49*(1), 15-22. https://doi.org/10.3896/ibra.1.49.1.02

Prendergast, K. S., Menz, M. H., Dixon, K. W., & Bateman, P. W. (2020). The relative performance of sampling methods for native bees: an empirical test and review of the literature. *Ecosphere*, *11*(5), e03076. https://doi.org/10.1002/ecs2.3076

Purcell, J., Pellissier, L., & Chapuisat, M. (2015). Social structure varies with elevation in an Alpine ant. *Molecular Ecology*, *24*(2), 498-507. https://doi.org/10.1111/mec.13042

Pueyo, Y., Kéfi, S., Alados, C. L., & Rietkerk, M. (2008). Dispersal strategies and spatial organization of vegetation in arid ecosystems. *Oikos*, *117*(10), 1522-1532. https://doi.org/10.1111/j.0030-1299.2008.16735.x

R Core Team. (2023). R: A language and environment for statistical computing (Version 4.4.0) [Computer software]. https://www.R-project.org/

Richards, M. H., & Packer, L. (2021). *Lasioglossum*. In C. K. Starr (Ed.), *Encyclopedia of Social Insects* (pp. 550-554). Springer.

Rodríguez, S., Pérez-Giraldo, L. C., Vergara, P. M., Carvajal, M. A., & Alaniz, A. J. (2021). Native bees in Mediterranean semi-arid agroecosystems: Unravelling the effects of biophysical habitat, floral resource, and honeybees. *Agriculture, Ecosystems & Environment*, *307*, 107188. https://doi.org/10.1016/j.agee.2020.107188

Rojas, F. & Toro G., H. (2000). Revisión de las especies de *Caenohalictus* (Halictidae-Apoidea) presentes en chile. *Boletín Museo Nacional de Historia Natural*, 49, 163-214. https://doi.org/10.54830/bmnhn.v49.2020.354

Roulston, T. A. H., Smith, S. A., & Brewster, A. L. (2007). A comparison of pan trap and intensive net sampling techniques for documenting a bee (Hymenoptera: Apiformes) fauna. *Journal of the Kansas Entomological Society*, *80*(2), 179-181. https://doi.org/10.2317/0022-8567(2007)80[179:acopta]2.0.co;2

Sakagami, S. F., & Munakata, M. (1972). Distribution and bionomics of a transpalaearctic eusocial halictine bee, *Lasioglossum* (*Evylaeus*) *calceatum*, in northern Japan, with reference to its solitary life cycle at high altitude. *Journal of the Faculty of Science, Hokkaido University, VI (Zoology)*, *18*(3), 411-439.

Santiago-Hernández, M. H., Martén-Rodríguez, S., Lopezaraiza-Mikel, M., Oyama, K., González-Rodríguez, A., & Quesada, M. (2019). The role of pollination effectiveness on the attributes of interaction networks: from floral visitation to plant fitness. *Ecology*, *100*(10), e02803. https://doi.org/10.1002/ecy.2803

Sarricolea, P., Herrera-Ossandon, M., and Meseguer-Ruiz, Ó. (2017). Climatic regionalisation of continental Chile. *Journal of Maps*, *13*(2), 66-73. https://doi.org/10.1080/17445647.2016.1259592

Silveira, F. A., Melo, G. A., & Almeida, E. A. (2002). *Abelhas brasileiras: sistemática e identificação*. Guilherme Carnevale Carmona.

Snyder, K. A., & Tartowski, S. L. (2006). Multi-scale temporal variation in water availability: implications for vegetation dynamics in arid and semi-arid ecosystems. *Journal of Arid Environments*, *65*(2), 219-234.

Thapa-Magar, K. B., Davis, T. S., & Fernández-Giménez, M. E. (2022). A meta-analysis of the effects of habitat aridity, evolutionary history of grazing and grazing intensity on bee and butterfly communities worldwide. *Ecological Solutions and Evidence*, *3*(2), e12141. https://doi.org/10.1002/2688-8319.12141

Toledo R, Vidal Carter H, A., & Gutierrez, F. (2017). Exploring Conflicts Between Indigenous Communities and the Mining Industry in Chile: The Socioenvironmental Transformations of the Tarapaca Region an the Case of Lagunillas. http://repositoriodigital.uct.cl/handle/10925/2625

Toro, H. (1986). Lista preliminar de los ápidos chilenos (Hymenoptera: Apoidea). *Acta Entomológica Chilena*, *13*, 121-132.

Toro, H. (1999). Las especies chilenas del género Colletes (Hymenoptera: Colletidae): clave de especies. *Acta Entomológica Chilena*, *23*, 23-32.

Turnley, B. D., Kazenel, M. R., Wright, K. W., Griswold, T. L., Rudgers, J. A., & Whitney, K. D. (2025). Traits and functional diversity of a bee assemblage are linked to aridity. *Oecologia*, *207*(6), 96. https://doi.org/10.1007/s00442-025-05732-1

Vereecken, N., Weekers, T., Leclercq, N., De Greef, S., Hainaut, H., Molenberg, J.-M., Martin, Y., Janssens, X., Noël, G., Pauly, A., Roberts, S. P. M., & Marshall, L. (2021) Insect biomass is not a consistent proxy for biodiversity metrics in wild bees. Ecological Indicators, *121*, 107132. https://doi.org/10.1016/j.ecolind.2020.107132

Vivallo, F. (2020). *The oil-collecting bees of Centris (Paracentris) (Hymenoptera: Apidae)*. Felipe Vivallo.

Wilson, J. S., Jahner, J. P., Starley, L., Calvin, C. L., Ikerd, H., & Griswold, T. (2016). Sampling bee communities using pan traps: alternative methods increase sample size. *Journal of Insect Conservation*, *20*(5), 919-922. https://doi.org/10.1007/s10841-016-9914-6

Westphal, C., Bommarco, R., Carré, G., Lamborn, E., Morison, N., Petanidou, T., Potts, S. G., Roberts, S. P. M., Szentgyörgyi, H., Tscheulin, T., Vaissière, B. E., Woyciechowski, M., Biesmeijer, J. C., Kunin, W. E., Settele, J., & Steffan-Dewenter, I. (2008). Measuring bee diversity in different European habitats and biogeographical regions. *Ecological monographs*, *78*(4), 653-671. https://doi.org/10.1890/07-1292.1

Xie, T.-T., Wang, M.-Q., Li, Y., Su, C.-Y., Zhang, D., Zhou, Q.-S., Niu, Z.-Q., Yuan, F., Liu, X.-W., Ma, K.-P., Zhu, C.-D., Hao, J.-S., & Chesters, D. (2024). Blue Vane and Pan Traps Are More Effective for Profiling Multiple Facets of Bee Diversity in Subtropical Forests. *Insects*, *15*(11), 909. https://doi.org/10.3390/insects15110909

Notes

DATA STATEMENT

Supplementary material associated with this manuscript is available at https://doi.org/10.5281/zenodo.17042033

COMPETING INTERESTS

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

AUTHORS CONTRIBUTIONS

BCR, DGP, AMM and ROA conducted the fieldwork in Parque Nacional Volcán Isluga, including bee and plant sampling and specimen collection. BCR performed the morphological identification of bee specimens and specimen curation. AMM conducted the plant identification. BKPC processed ecological data and performed statistical analyses. BCR and BKPC drafted the original version of the manuscript. DGP and ROA reviewed and edited the manuscript, refining ecological interpretations and ensuring consistency across sections. AMM and ROA conceived the study, coordinated logistics, and obtained the necessary research permits and funding. All authors reviewed and approved the final version of the manuscript.

Notas de autor

araujorodrigodeoliveira@gmail.com

Información adicional

redalyc-journal-id: 3220

Bruna K. PINHEIRO-COSTA, Benito CORTÉS-RIVAS,
Diego G. PÁDUA, Andrés MOREIRA-MUÑOZ,
Rodrigo O. ARAUJO

Wild Bee Diversity in Parque Nacional Volcán Isluga: Assessing Plant-Bee Interactions in a High-Altitude Desert

Explorando la diversidad de abejas silvestres en desierto de gran altitud del Parque Nacional Volcán Isluga

Revista de la Sociedad Entomológica Argentina
vol. 84, núm. 4, e0408, 2025
Sociedad Entomológica Argentina, Argentina
gsanblas@mendoza-conicet.gob.ar

ISSN-E: 1851-7471

DOI: https://doi.org/10.25085/rsea.840408