Journal of Insect Conservation (2025) 29:93
https://doi.org/10.1007/s10841-025-00730-3

ORIGINAL PAPER

Biodiversity of leaf beetles (Coleoptera: Chrysomelidae) in Ecuador: how many species are there?

Pedro Montes-Gavilán[1,6] · J. Gómez-Zurita[2] · M. J. Macía[3,4] · J. Muñoz[5] · L. Cayuela[1,6]

Received: 2 July 2025 / Accepted: 24 October 2025

Abstract Chrysomelidae comprises a highly diverse family of phytophagous beetles that play key roles in ecosystems. Despite their ecological importance, leaf beetles remain understudied in megadiverse tropical regions such as Ecuador. The aim of this study is updating the knowledge on the diversity of Chrysomelidae in Ecuador by: (i) compiling literature and Global Biodiversity Information Facility (GBIF) records; (ii) evaluating temporal, spatial, and taxonomic biases on these data; (iii) exploring spatial patterns of species richness; and (iv) estimating the potential diversity of Chrysomelidae in Ecuador through modelling the distribution of chrysomelid species from Mexico to Paraguay, and using known ratios between plant and leaf beetle species richness from Ecuador, Brazil, El Salvador, Mexico, and Peru. We compiled a dataset of 2,348 records of 871 leaf beetle species from Ecuador, representing different degrees of temporal, spatial, and taxonomic biases. The potential richness of Chrysomelidae in Ecuador shows a clear spatial pattern, with the highest number of species predicted for the extreme NE and NW regions, while this number decreases towards the south and in the inter-Andean valleys. Species distribution models estimated the potential presence of 42 chrysomelid species not previously recorded in Ecuador. Furthermore, the comparison of leaf beetle-vascular plant richness ratios in Ecuador with those of Brazil, El Salvador, Mexico, and Peru, suggests that the actual diversity of Chrysomelidae in Ecuador may be 2–3 times higher than currently known.

Implications for insect conservation This work improves the knowledge of species diversity of Chrysomelidae in Ecuador, essential information for developing effective conservation strategies for this diverse beetle family, but much more field inventories are still needed.

Keywords Biological record biases · Checklist · Insect conservation · Observed species richness · Potential species richness.

Introduction

Phytophagous insects play a pivotal role in ecosystem services, significantly influencing the structure, functionality, and stability of terrestrial ecosystems. One of their primary functions is contributing to nutrient cycling within ecosystems (Belovsky and Slade 2000; Kitchell et al. 1979; Reynolds et al. 2000; Schowalter et al. 1991). Herbivore insects consume plant biomass, which is transformed and excreted as waste rich in nitrogen, phosphorus, and other essential nutrients facilitating the decomposition of organic matter and the release of nutrients back into the soil, making them available for uptake by plants and other organisms (Fonte and Schowalter 2005; Frost and Hunter 2004; Hollinger 1986; Huntly 1991; Kaukonen et al. 2013; Kitchell et al. 1979; Lovett et al. 2002; Metcalfe et al. 2014; Schowalter 2012). Furthermore, feeding of phytophagous insects can accelerate the breakdown of plant materials, increasing

---

✉ Pedro Montes-Gavilán
pedro.montes@urjc.es

[1] Departamento de Biología y Geología, Física y Química Inorgánica, Universidad Rey Juan Carlos, Madrid, Spain

[2] Instituto Botánico de Barcelona (CSIC-CMCNB), Barcelona, Spain

[3] Departamento de Biología, Área de Botánica, Universidad Autónoma de Madrid, Madrid, Spain

[4] Centro de Investigación en Biodiversidad y Cambio Global (CIBC-UAM), Universidad Autónoma de Madrid, Madrid, Spain

[5] Real Jardín Botánico (CSIC-RJB), Madrid, Spain

[6] Instituto de Investigación en Cambio Global, Universidad Rey Juan Carlos, Madrid, Spain

decomposition rates and nutrient turnover (Chapman et al. 2003; DeAngelis 1992; Hunter 2001; Reynolds and Hunter 2001; Seastedt and Crossley 1984; Swank et al. 1981). As an important part of nutrient cycling, phytophagous insects contribute to soil fertility, plant growth, and overall ecosystem productivity (Belovsky and Slade 2000; Lerdau 1996; Mattson and Addy 1975; Schowalter 2016; Tscharntke and Greiler 1995). Moreover, phytophagous insects directly influence plant population dynamics through herbivory, which can regulate plant growth, reproduction, and distribution (Brown and Gange 1989, 1992; Brown 1990; Crawley 1989; Lawton 1983; Lewinsohn and Price 1996; Rafes 1973; Schowalter 2000). This interaction shapes vegetation structure and composition, influencing habitat availability for other organisms and overall ecosystem biodiversity (Coley and Barone 1996; Janzen 1970; Siemann et al. 1998; Strong et al. 1984). Additionally, phytophagous insects serve as important prey for a wide range of predators, including birds, mammals, and other arthropods, thereby contributing to energy transfer and trophic dynamics within food webs (Cornell and Hawkins 1995; Van Veen et al. 2006; Hawkins et al. 1997; Janzen 1987).

Within the broad functional group of phytophagous insects, chrysomelids potentially hold particular significance owing to their ecological roles and abundance across various ecosystems (Andrew and Hughes 2004; Basset 2001; Bienkowski 2010). As a family comprising over 40,000 described species (Reid 2017), chrysomelids exhibit an astonishing array of host-plant associations and ecological interactions (Jolivet 1988; Jolivet and Hawkeswood 1995). Their phytophagous habits make them crucial components of plant-insect interactions, putatively influencing plant community dynamics, population demographics, and ecosystem processes (Bacher and Schwab 2000; Futuyma and Mitter 1996; Lewinsohn and Price 1996). Leaf beetles are known to feed on a wide range of host plants, including economically important crops, ornamental plants, and wild flora, thereby impacting agricultural productivity, plant diversity, and ecosystem stability (Annecke and Moran 1982; Hill 1979; Jolivet 1988; Jolivet and Hawkeswood 1995). Furthermore, their interactions with host plants can trigger plant defenses, leading to the induction of secondary metabolites and adaptations that shape plant-herbivore interactions and ecosystem functioning (Farrell and Mitter 1990; Nielsen 1978, 1989). Additionally, certain chrysomelid species can act as pollinators or seed and flower predators, further underlining their ecological significance beyond herbivory (Bienkowski 2010; Gottsberger 2012; Kirmse and Chaboo 2018; Momose 2005; Ribeiro-Costa and Almeida 2012; Samuelson 1994). Given their ubiquity, diversity, and ecological variability, leaf beetles may play a relevant role in shaping the structure, function, and resilience of terrestrial ecosystems worldwide.

Despite their potential ecological importance, chrysomelids remain relatively understudied, especially in tropical regions, where their diversity is particularly high (Basset 2001; Furth 2006; Sánchez-Reyes et al. 2014; Yang et al. 2024). There are significant gaps in our knowledge of chrysomelid diversity and distributions (Pärtel et al. 2011), with many tropical ecosystems still poorly sampled or entirely unexplored (Larsen et al. 2011; Thormann et al. 2016). This lack of comprehensive information hampers our ability to assess regional patterns of diversity, species composition, and community dynamics (Gómez-Zurita et al. 2016; Pärtel et al. 2011; Pärtel 2014). Moreover, numerous leaf beetle species remain undescribed or poorly documented, highlighting the need for taxonomic revisions and species inventories, especially in tropical regions where species richness is likely underestimated. The relationships between chrysomelids and their host plants further complicate our understanding, as many host associations remain poorly documented or unexplored (Jolivet and Hawkeswood 1995; Yang et al. 2024). Consequently, these knowledge gaps hinder our ability to accurately assess the ecological roles, population dynamics, and conservation status of leaf beetles in tropical ecosystems, impeding effective biodiversity management and conservation initiatives (Gómez-Zurita et al. 2016). This is a common pattern for hidden biodiversity, which includes overlooked organisms that are critical to ecosystem functioning but lack the number of dedicated researchers, or the funding available for larger and more popular species, especially birds and mammals (Delso et al. 2021).

These knowledge gaps are most evident in tropical countries such as Ecuador, despite its status as one of the most biodiverse nations globally (Dangles 2009; Sierra et al. 2002). Remarkably, little is known about the diversity of specific organismal groups, including chrysomelids. These gaps in knowledge contribute to deficiencies within Ecuador's national system of protected areas, leaving certain threatened groups of organisms vulnerable to habitat degradation and loss (Kleemann et al. 2022; Titley et al. 2017). Still today, the most comprehensive list of Chrysomelidae in Ecuador can be extracted from an 80-year-old catalogue of Neotropical Coleoptera (Blackwelder 1946). This list is obviously outdated, with numerous new species having been described, and additional records of Chrysomelidae reported in Ecuador, although research efforts have primarily focused on the subfamily Cassidinae, specifically the tortoise beetles, thoroughly explored by Borowiec (1998).

The main goal of this study is to provide an updated overview of chrysomelid diversity in Ecuador by fulfilling several specific aims: (i) compiling and organizing available information into an updated checklist of Chrysomelidae species in Ecuador; (ii) evaluating knowledge biases across temporal, spatial, and taxonomic dimensions; (iii) assessing the spatial pattern of Chrysomelidae species richness across Ecuador; and (iv) estimating the potential diversity of Chrysomelidae in this megadiverse country, including predictions of species not yet reported in Ecuador. To accomplish these objectives, we conducted an exhaustive compilation of data available in the literature and combined it with species distribution modeling of Chrysomelidae across the Neotropics. Additionally, we used known ratios between plant and chrysomelid species richness from presumably well-inventoried Neotropical countries to predict the overall number of species in Ecuador. Addressing these knowledge and diversity gaps is imperative to enhance our understanding of leaf beetles ecology and to guide evidence-based conservation strategies in tropical regions. By providing a detailed and systematic account of chrysomelid diversity, this study aims to lay the foundation for future research and conservation efforts, contributing to the rich biodiversity of leaf beetles in Ecuador.

Materials and methods

Study area

The study area was located in Ecuador, a country in the NW of South America, spanning an area of 256,370 km^2. Ecuador is geographically diverse, characterized by four major physiographic regions: the Coastal plain, the Andean highlands, the Amazon region, and Galapagos Islands (Cañadas 1983; Tropicos 2025) (Fig. 1). Recognized as a confluence of several of the world's biodiversity hotspots (Myers et al. 2000), its latitudinal position, the presence of the Andean Mountain chain, and the climatic influence of marine currents and Atlantic trade winds contribute to its high environmental heterogeneity. These factors have fostered the development of a wide range of biomes across Ecuadorian

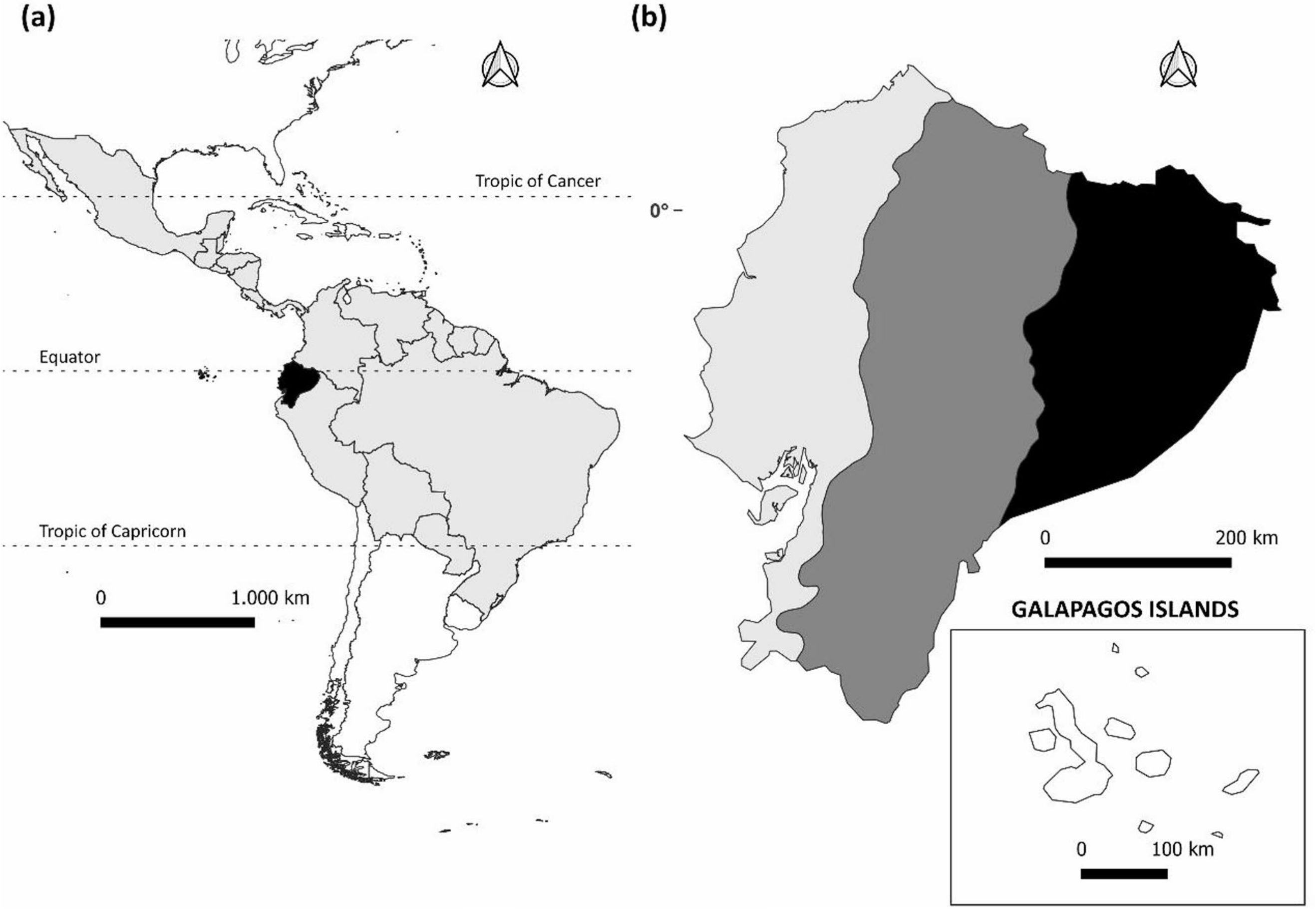

Fig. 1 **a** Map of Central American and tropical South American countries selected in this study (light grey region), and Ecuador (black region) from which leaf beetle records were collected to elaborate the species distribution models (SDM) and **b** four main physiographic regions within Ecuador: the Coastal plain (light grey region), the Andean highlands (grey region), the Amazon region (black region), and Galapagos Islands (white region)

ecosystems, leading to exceptional biological diversity (Borchsenius 1997; Dangles 2009; Sierra et al. 2002; Skov and Borchsenius 1997).

Biological data compilation and processing

We compiled all published records of Chrysomelidae of Ecuador from three bibliographic databases: Google Scholar, Web of Science, and the Biodiversity Heritage Library. The keywords used in the literature review were pairwise combinations of the keywords “Bruchinae”, “Cassidinae”, “Chrysomelidae”, “Chrysomelinae”, “Criocerinae”, “Cryptocephalinae”, “Eumolpinae”, “Galerucinae”, “Lamprosomatinae”, “leaf beetle”, with the keywords “Ecuador”, and “biological records”. The literature review was conducted between December 2023 and April 2024. In total, we reviewed information from 272 scientific publications, encompassing 2,260 records of Ecuadorian chrysomelid species dating from 1845 to 2023. These records generally included information about the taxonomy, geographic location, collection date, and in some cases, host plants of Chrysomelidae in Ecuador. This bibliographic dataset was reviewed to verify taxonomic accuracy and eliminate obvious misidentifications, such as records of European species.

To assess the spatial pattern of Chrysomelidae species richness across Ecuador and estimate the potential species richness within the country, we collected two datasets from the Global Biodiversity Information Facility (GBIF: www.gbif.org) database. First, we accessed leaf beetle distribution information spanning from Mexico to Paraguay as of March 31, 2024 (doi: https://doi.org/10.15468/dl.6xah6v). This dataset included preserved specimens existing in natural history museums, universities, accessible private collections, and research projects, comprising 62,805 records of 1,418 Neotropical chrysomelid species. Second, we downloaded GBIF vascular plant records from Mexico (doi: https://doi.org/10.15468/dl.sa54ec), Peru (doi: https://doi.org/10.15468/dl.hvrz76), El Salvador, and Ecuador (doi: https://doi.org/10.15468/dl.6d5a62), as of May 12, 2024. This dataset contained 1,493,615 records of 61,503 plant species from 550 herbaria. Brazil, El Salvador, Mexico, and Peru were selected as benchmarks due to the availability of relatively recent comprehensive species checklists of all chrysomelid subfamilies also present in Ecuador. The GBIF datasets of leaf beetles and vascular plants were supplemented with data obtained from published species checklists. Specifically, leaf beetle GBIF data were completed with species checklist data from Brazil (Linzmeier and Moura 2025), El Salvador (Van Roie et al. 2019), Mexico (Ordóñez-Reséndiz and López-Pérez 2021), and Peru (Chaboo 2015a, 2015b, Chaboo and Flowers 2015a; 2015b; Chaboo and Schmitt 2015; Chaboo and Schöller 2016; Chaboo and Staines 2015; Furth et al. 2015), and GBIF data of vascular plants were complemented with species checklist data from Brazil (Flora e Funga do Brasil 2025), Mexico (Villaseñor 2016), Ecuador, El Salvador, and Peru (Ulloa Ulloa et al. 2017).

We used the ‘CoordinateCleaner’ package (Zizka et al. 2019) in R version 4.3.0 (R Core Team 2024) to filter out GBIF records based on the following exclusion criteria: coordinates set to zero, duplicate entries, identical latitude and longitude values, coordinates outside land, discrepancies in coordinate reference systems, low-precision coordinates, and entries located within urban areas or natural history institutions. This process resulted in a Chrysomelidae dataset consisting of 22,161 records of 1,387 Neotropical species. After merging this GBIF dataset with the georeferenced records from the literature review, we obtained a dataset with 23,938 records of 1,842 species. The vascular plant dataset included 1,094,593 records of 61,503 species.

Statistical analyses of data biases

Temporal bias in Chrysomelidae records from Ecuador was assessed by analyzing sampling intensity across seven 25-year time periods spanning from 1845 to 2024. We obtained the number of records for each 25-year time period and performed Pearson’s chi-squared tests using the R packages ‘occAssess’ (Boyd et al. 2021).

The spatial bias of leaf beetle records was assessed through spatial clustering and spatial coverage analyses using 1,848 records of 555 species, each with original or assigned spatial coordinates and an estimate uncertainty in meters. Up to 501 records of 434 species lacked spatial coordinates and were therefore excluded from these analyses. In spatial clustering analysis, the nearest neighbor index was calculated over seven 25-year time periods spanning from 1845 to 2024 using the R package ‘occAssess’ (Boyd et al. 2021). Spatial coverage was analyzed independently for each of the four physiographic regions (Coastal plain, Andes highlands, Amazon, and Galapagos Islands) using the Quantum Geographical Information System (QGIS) v. 3.34.3 program (QGIS Development Team 2024).

Taxonomic bias was assessed by statistically comparing the proportions of species by subfamily in Ecuador with corresponding proportions from the entire Neotropical region, Brazil, El Salvador, Mexico, and Peru using Pearson’s chi-squared tests. The selected countries represent areas where the distribution of species among subfamilies was expected to be similar to that of Ecuador, while the overall Neotropical region was included to assess potential broader-scale differences in subfamily representation. Data was extracted from published species checklists from Brazil (Linzmeier and Moura 2025), El Salvador (Van Roie et al. 2019), Mexico (Ordóñez-Reséndiz and López-Pérez 2021), and

Peru (Chaboo 2015a, 2015b; Chaboo and Flowers 2015a, 2015b; Chaboo and Schmitt 2015; Chaboo and Schöller 2016; Chaboo and Staines 2015; Furth et al. 2015). Species proportions by subfamily in the Neotropics from Mexico to Argentina were derived from Blackwelder (1946).

Analyses of spatial patterns and potential species diversity

To assess the spatial pattern of Chrysomelidae species richness across Ecuador, we generated species distribution models (SDM) for each species, using the GBIF dataset. Initially, we mapped 23,938 literature and GBIF records, totalling 1,842 species, onto a grid of 2,861 cells with a spatial resolution of 10 × 10 km in QGIS. For species with at least 15 occurrences, SDM were created using maximum entropy (Maxent) and generalized boosted model (GBM) algorithms implemented in the R package ‘biomod2’ (Thuiller et al. 2009). Models for species with 5–14 occurrences were created as a Maxent ensemble of small bivariate models (ESM) using the R package ‘ecospat’ (Di Cola et al. 2017), as Breiner et al. (2018) demonstrated the effectiveness of ESM when dealing with small sample size datasets. Prior to modelling, we identified and removed highly correlated climatic predictor variables ($r > 0.7$) using the R package ‘corrgram’ (Wright 2018). All models were generated using a set of 10,000 random background points and 10 evaluation runs of 80% training splits for model calibration using random partitioning. A final ensemble model was obtained for each species by weighted averaging of models in each replicate, with weights calculated from True Skill Statistic (TSS > 0.7) for species with more than 15 occurrences and Somers’ D (D = 0) for species modeled using the ESM approach. Models with lower TSS or D values were discarded. This resulted in 117 SDM for species with more than 15 occurrences and 274 SDM for species with fewer records across the entire Neotropical region. The continuous habitat suitability values from each ensemble SDM were then transformed into binary raster layers with a pixel resolution of 10 × 10 km using the threshold that maximized TSS or D. Finally, the binary models were distance-constrained to account for dispersal limitations of leaf beetles. Distance constraint was performed using distance hybrid models with the R package ‘raster’. The Gaussian distance decay function with a sigma of 250 km was used to fit the hybrid models. All distance-constrained binary rasters of potentially distributed species in Ecuador were summed using QGIS ‘Raster calculator’ tool to calculate potential species richness within each 10 × 10 km grid cell.

Finally, to estimate the potential number of Chrysomelidae species in Ecuador, we used two different approaches. First, we added the number of species identified by SDM as potentially present but not yet recorded in Ecuador to the current number of species documented from the literature review and GBIF. Second, we compared the ratio of Chrysomelidae to vascular plant species richness in Ecuador to that of relatively well-sampled countries, such as Brazil, El Salvador, Mexico, and Peru. Several studies have demonstrated a relationship between plant richness and herbivorous insect richness (Dinnage et al. 2012; de Freitas et al. 2023; Haddad et al. 2001, 2009; Hertzog et al. 2016; Kemp and Ellis 2017; Knops et al. 1999; Lewinsohn and Roslin 2008; Murdoch et al. 1972; Novotny et al. 2006; Scherber et al. 2010; Siemann et al. 1998; Southwood et al. 1979; Strong et al. 1984), and this assumption allows the estimation of regional and global numbers of insect species (Erwin 1982; Gaston 1992; Hodkinson and Casson 1991; Kirby and Spence 1826; May 1990; Peck 1989; Peck and Kukalova-Peck 1990; Stork 1988; Thomas 1990).

Results

Checklist of Ecuadorian leaf beetles

We compiled a total of 2,260 Chrysomelidae records from the literature, documenting 858 species present in Ecuador, with 75 records corresponding to specimens identified at the genus level (Online Resources 1 and 2). These species belonged to eight subfamilies: Bruchinae, Cassidinae, Chrysomelinae, Criocerinae, Cryptocephalinae, Eumolpinae, Galerucinae, and Lamprosomatinae. Additionally, we obtained 88 records from the GBIF database, increasing the total to 2,348 records and representing 34 chrysomelid species from Ecuador. Of these, 13 species were not documented in the literature, bringing the total number of species recorded in Ecuador to 871.

The number of species by subfamily is shown in Fig. 2. The subfamily Bruchinae accounted for 261 literature records and 11 GBIF records, representing 59 species. Notably, one species, *Amblycerus nigromarginatus* (Motschulsky, 1874), preserved at Texas A&M University Insect Collection was solely recorded in the GBIF dataset and was not found in the literature. Cassidinae exhibited the highest number of records and species, with 1,417 literature and 42 GBIF records, representing 407 species. Borowiec (1998) and Borowiec and Swietojanska (2024) contributed to the literature with 457 records of 200 Cassidinae species. The GBIF records introduced seven new species not documented in the literature. Chrysomelinae comprised 147 literature and four GBIF records, encompassing 99 species in Ecuador. Criocerinae and Cryptocephalinae were only represented by literature records, with 13 records of 12 species of Criocerinae and 20 records of seven species

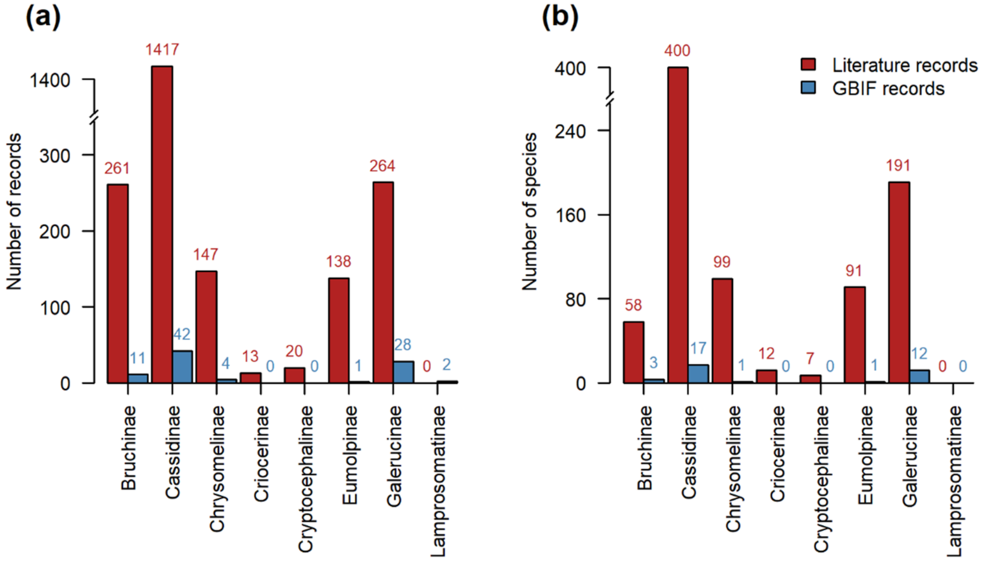

Fig. 2 **a** Number of Chrysomelidae records, and **b** species number broken down by subfamily from Ecuador. This figure includes data compiled from both the literature and the Global Biodiversity Information Facility (GBIF) database, representing eight subfamilies: Bruchinae, Cassidinae, Chrysomelinae, Criocerinae, Cryptocephalinae, Eumolpinae, Galerucinae, and Lamprosomatinae. The total number of records for each subfamily is displayed, highlighting the contributions from different sources

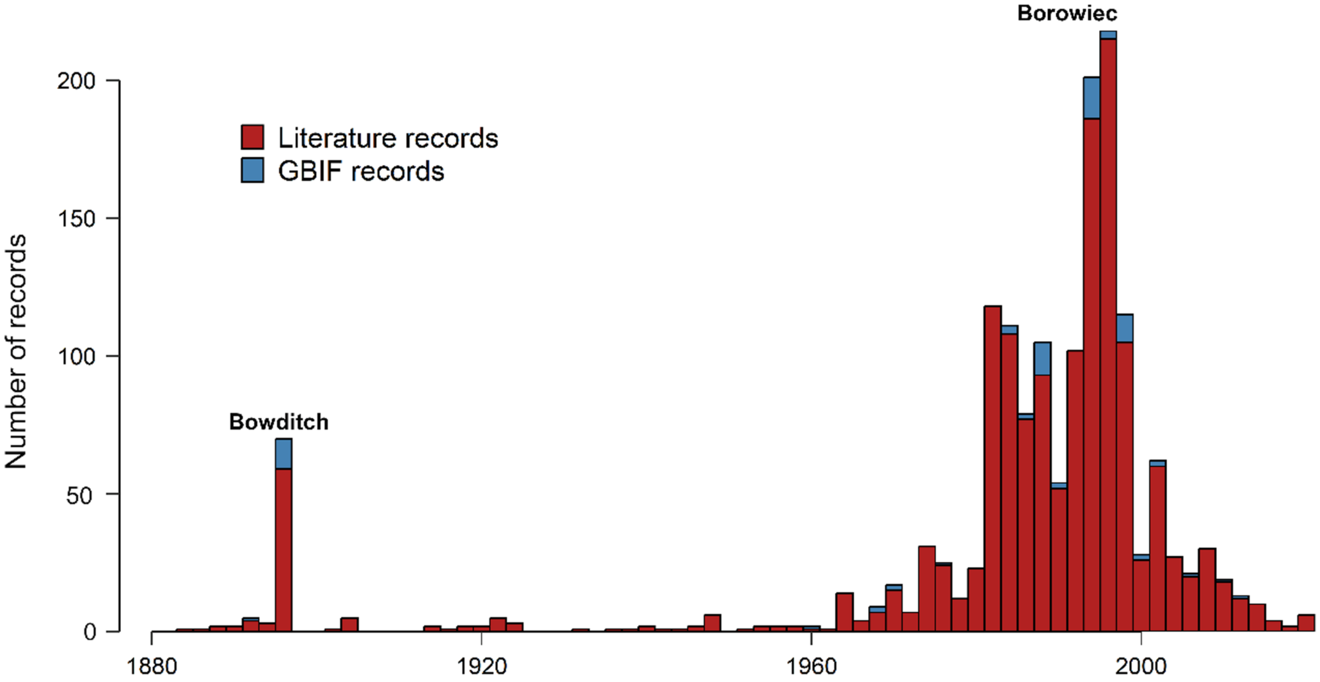

Fig. 3 Temporal bias of Chrysomelidae records obtained from the literature review and the Global Biodiversity Information Facility (GBIF) database between 1884 and 2024, highlighting the contributions from different authors

of Cryptocephalinae. Eumolpinae in Ecuador were documented through 138 literature records and one GBIF record, indicating the presence of 91 species. Galerucinae exhibited the second highest species richness in Ecuador, with 191 species compiled from 264 literature records and five additional species from 28 GBIF records. Finally, Lamprosomatinae had the fewest records, with only two records in GBIF, representing two individuals preserved at Texas A&M University Insect Collection and identified as *Oomorphus* sp.

Record biases

Out of 1,601 chrysomelid records with information on collection date, the highest number of records (1,184) corresponded to the period between 1975 and 1999, while the period between 1845 and 1870 had the fewest records (2). The 25-year time period between 1975 and 1999 had significantly greater number of chrysomelid records than expected by chance (Chi-square test; $p < 0.05$). From the year 2000 onwards, the number of leaf beetle records in Ecuador progressively decreased (Fig. 3).

Across all 25-year time periods, the nearest neighbor index was close to zero, indicating that occurrences were spatially clustered. This clustering occurred along roads, rivers, and around scientific stations and urban areas, instead of being randomly distributed throughout the study area. The highest numbers of both records and species were found in the Andean highlands region with 992 records of 371 species, while the Coastal plain region had the lowest number of records and species in mainland Ecuador, with 337 records of 152 species. The Amazon region housed 446 records of 175 leaf beetle species. Galapagos Islands was the Ecuadorian region with the fewest number of records and species, with 73 records of 10 species.

Taxonomic bias was evaluated by assessing significant differences in the proportion of species by subfamily between Ecuador and those of the entire Neotropical region, Brazil, El Salvador, Mexico, and Peru. Chi-square tests revealed that the proportions of Ecuadorian leaf beetle species differed significantly from those observed in these regions ($p < 0.05$) (Fig. 4). Additionally, pairwise comparisons of species proportions among the Neotropical region, Brazil, El Salvador, Mexico, and Peru also showed consistent significant differences ($p < 0.05$).

Observed and potential leaf beetle richness patterns in Ecuador

Observed Chrysomelidae richness pattern analysis revealed a total of 321 10 × 10 km grid cells (11.22%) containing at least one species and 2,540 empty 10 × 10 km grid cells (88.78%) in Ecuador (Fig. 5a). The highest species richness was obtained in the Esmeraldas province near San Javier de Cachabí, with 44 chrysomelid species. Other locations with high species richness, each reporting over 30 species, included: Jatun Sacha Biological Reserve in Napo province, with 43 leaf beetle species; Macas in Morona-Santiago province, with 36 species; Tena in Napo province, with 35 species; El Reventador in the Cayambe-Coca National Park in Sucumbíos province, with 33 species; and Mera in Pastaza province, with 31 species (Fig. 5a). There was an overrepresentation of 10 × 10 km grid cells with the lowest species richness values, including 148 cells containing one leaf beetle and 61 cells with two species only (Fig. 5a). The

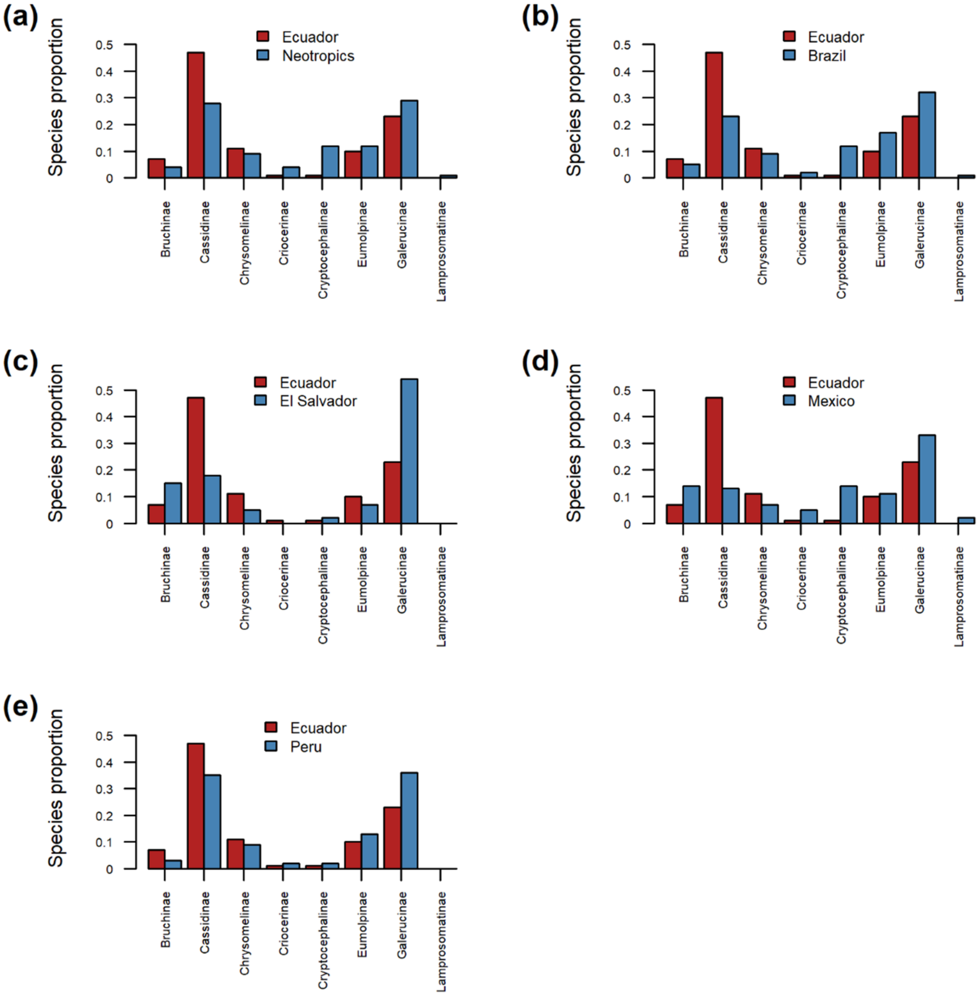

Fig. 4 Chrysomelidae species proportion by subfamily comparison between Ecuador and **a** Neotropics, **b** Brazil, **c** El Salvador, **d** Mexico, **e** Peru. Leaf beetle species proportions data was obtained from the literature review, the Global Biodiversity Information Facility (GBIF), and the leaf beetle checklists from the Neotropical region (Blackwelder 1946), Brazil (Linzmeier and Moura 2025), El Salvador (Van Roie et al. 2019), Mexico (Ordóñez-Reséndiz and López-Pérez 2021), and Peru (Chaboo 2015a, 2015b; Chaboo and Flowers 2015a, 2015b; Chaboo and Schmitt 2015; Chaboo and Schöller 2016; Chaboo and Staines 2015; Furth et al. 2015)

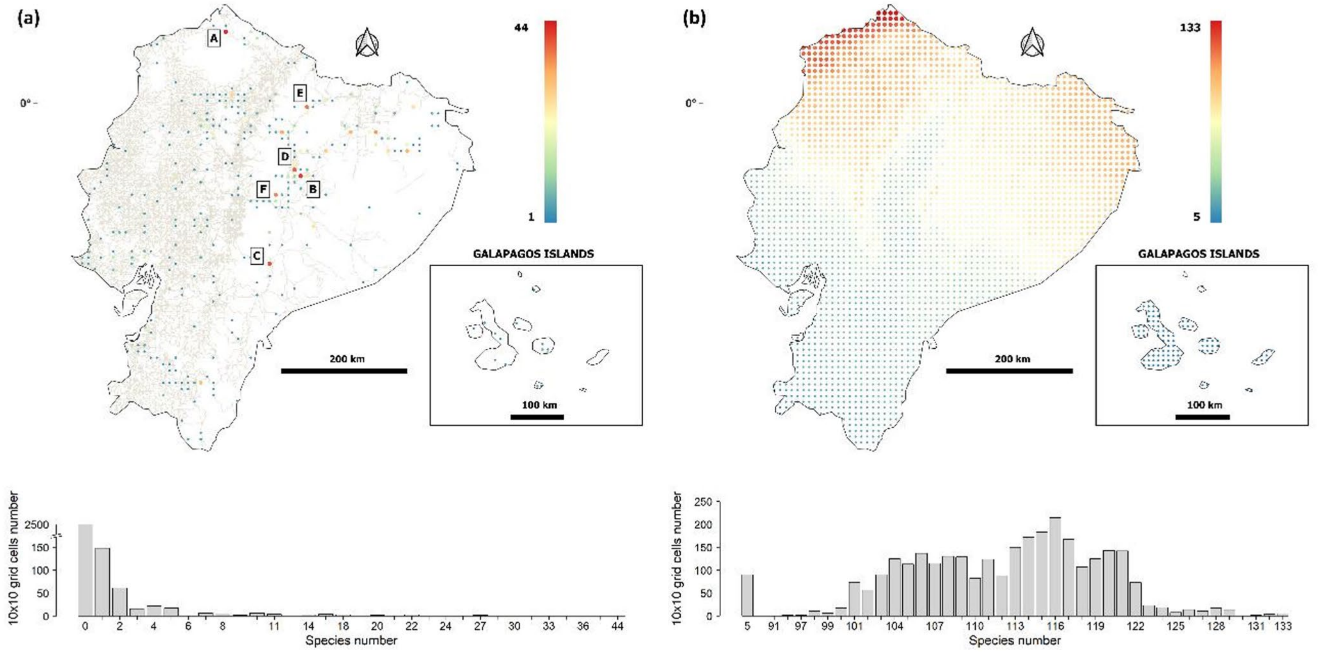

Fig. 5 **a** Observed Chrysomelidae species richness map from Ecuador. Location A: San Javier de Cachabí in Esmeraldas province, location B: Jatun Sacha Biological Reserve in Napo province, location C: Macas in Morona-Santiago province, location D: Tena in Napo province, location E: El Reventador into the Cayambe-Coca National Park in Sucumbíos province and location F: Mera in Pastaza province. The light grey lines on the map represent the Ecuadorian road network. **b** Potential Chrysomelidae species richness map from Ecuador. The figure includes the equator coordinates, the Ecuadorian physiographic regions, and two histograms indicating the number of chrysomelid species in each 10 × 10 km grid cells

highest number of Chrysomelidae species was found in the Andes highlands physiographic region (371 species), while the Galapagos Islands region had the lowest number of species (10 species). Amazon and Coastal plain regions housed 175 and 152 species, respectively.

Potential species richness based on distance-constrained SDM revealed a heterogeneous richness pattern across the Ecuadorian latitudinal gradient (Fig. 5b). The northernmost area in the Coastal plain physiographic region had the highest potential leaf-beetle richness values, ranging between 125 and 133 species, located in 77 10 × 10 km grid cells across Esmeraldas province. The lowest potential leaf-beetle richness values, ranging between 5 and 104 species, was observed in 475 10 × 10 km grid cells across the Galapagos Islands and in the southernmost areas of the Coastal plain and Andean highlands physiographic regions. At intermediate Ecuadorian latitudes, the Andean highlands was the physiographic region with the lowest potential leaf beetle species richness, between 105 and 114 species. SDM predicted the highest potential richness in the Coastal plain region with 138 species. Andean highlands and Amazon regions had similar potential richness values, with 128 and 124 species, respectively. The Galapagos Islands region showed the lowest predicted richness, with only five leaf beetle species.

Estimating total number of Chrysomelidae in Ecuador

Potential leaf beetle richness estimates based on SDM revealed that 144 species of chrysomelids present in other regions of the Neotropical realm had bioclimatic conditions compatible with their presence in Ecuador, including 42 species not previously recorded in the country (Fig. 6, Online Resource 3). This suggested that regional species richness might be 4.71% higher than estimates based solely on number of recorded species.

Furthermore, the analysis of proportions of leaf beetles to vascular plant species richness indicated that well-sampled tropical countries such as Brazil, El Salvador, Mexico, and Peru had one species of leaf beetle per 6 to 11 species of vascular plants. In contrast, the ratio in Ecuador was one species of leaf beetle per 23 species of vascular plants (Table 1). Based on the 19,903 species of vascular plants recorded in the country and the ratios of leaf beetle to vascular plant species richness observed in well-samples tropical countries, we estimated that there might be between 1,821 and 3,315 chrysomelid species in Ecuador.

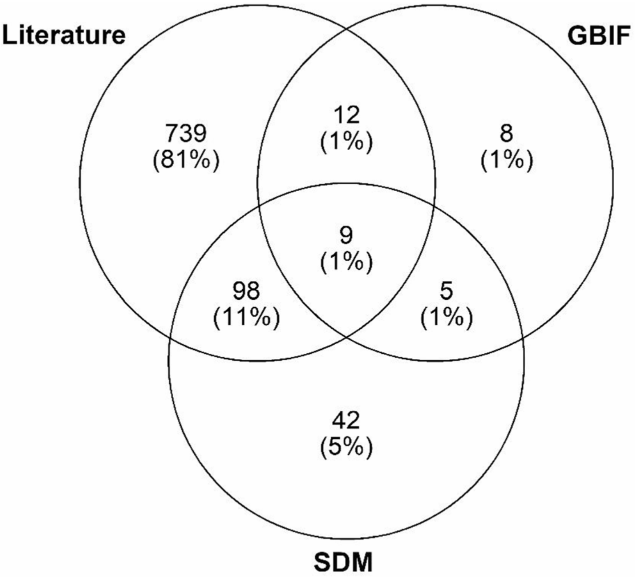

Fig. 6 Venn diagram displaying the Chrysomelidae species numbers and percentages from Ecuador sorted by source: literature review, Global Biodiversity Information Facility (GBIF) dataset, and species distribution models (SDM) across the Neotropical region

Table 1 Chrysomelidae and vascular plants species number from Ecuador, Brazil, El Salvador, Mexico, and Peru and leaf beetle-vascular plants species ratios for each tropical country. Leaf beetle species number in Brazil, El Salvador, Mexico, and Peru was compiled from Chaboo (2015a, 2015b); Chaboo and Flowers (2015a, 2015b; Chaboo and Schmitt (2015); Chaboo and Schöller (2016); Chaboo and Staines (2015); Furth et al. (2015), Linzmeier and Moura (2025), Ordóñez-Reséndiz and López-Pérez (2021), and Van Roie et al. (2019). Vascular plants species number was obtained from Flora e Funga do Brasil (2025), Ulloa Ulloa et al. (2017), Villaseñor (2016) and the Global Biodiversity Information Facility (GBIF) dataset published by the Missouri Botanical Garden

Country	Chrysomelidae species number	Vascular plants species number	Chrysomelidae-vascular plants richness ratio
Ecuador	871	19,903	1:23
Brazil	6,462	38,542	1:6
El Salvador	420	3,863	1:9
Mexico	2,505	23,314	1:9
Peru	1,767	19,147	1:11

Discussion

The Chrysomelidae species checklist generated in this study significantly increased the knowledge of leaf beetle diversity in Ecuador, expanding from 352 species in Blackwelder's catalogue (1946) to 871 species. The highest numbers of Chrysomelidae were found in the subfamilies Cassidinae and Galerucinae, representing 46.7% and 22.5% of the total species reported from Ecuador, respectively. Conversely, the subfamilies Criocerinae (1.4%), Cryptocephalinae (0.8%) and Lamprosomatinae (0%) had the lowest documented species richness in Ecuador, with only eleven and nine published references containing Criocerinae and Cryptocephalinae species records, respectively. Lamprosomatinae records were not identified to the species level. The low representation of these subfamilies aligns with patterns observed in other tropical countries like Costa Rica, El Salvador, and Panama (Van Roie et al. 2019; Vencl et al. 2004). The limited number of informative leaf beetle records from Ecuador in the GBIF database is mainly due to two factors: most Ecuadorian records published in the literature lack georeference, and they have a high degree of taxonomic uncertainty, with many records of Chrysomelidae stored in museums and universities pending identification to species or even genus level. The underrepresentation of tropical insect groups is a pervasive issue, as less than one-third of the described insect species have occurrence data stored in electronic databases (Anderson et al. 2016; García-Roselló et al. 2015, 2023; Troudet et al. 2017). Electronic databases have not been around for too long nor has their potential been universally accepted or financially supported.

The temporal bias in Ecuadorian records of Chrysomelidae aligns with patterns observed in other tropical insect groups, showing large temporal gaps (Daru and Rodriguez 2023). Data accumulation for insect inventories requires extended periods (Fattorini 2013; Lobo and Borges 2010). Notably, there has been a progressive decrease in published chrysomelid records since 2000 which contrasts with trends observed in other insect groups over recent decades (Girardello et al. 2019; López-Bedoya et al. 2024; Rocha-Ortega et al. 2021). This decline may reflect the dwindling number of specialists focusing on this family in Neotropical areas, and perhaps a progressive lack of interest in taxonomy (Engel et al. 2021).

The collection localities and observed richness in chrysomelids (Fig. 5a) reflect a clear pattern in sampling effort, but this does not negatively affect the models (Fig. 5b), which are indeed unbiased. The main cause of the observed richness pattern is the presence of accessible areas with infrastructure that facilitates fieldwork, such as roads or facilities in national parks or biological stations (Amano and Sutherland 2013; Cayuela et al. 2009; Dennis and Thomas 2000; Girardello et al. 2019; Kadmon et al. 2004; Romo et al. 2006). Second, the majority of researchers in Ecuador (and elsewhere) are employed by institutions located in the largest cities, and thus the majority of their collections, as well as those of visiting researchers who rely on local assistance, come from nearby localities. This phenomenon seems to explain the high number of records observed in central Ecuador. Third, the sampling process often targets areas that are perceived to have high overall biodiversity. The complex topography of the Andean highlands region, combined with elevational and latitudinal environmental gradients, results in a high habitat heterogeneity that supports remarkable biodiversity (Godoy-Bürki et al. 2017; Hole et al. 2011; Kreft and Jetz 2007; Zador et al. 2015). However, the number of collections is primarily influenced by accessibility, and the lack of infrastructure in the Amazon lowlands may explain the paucity of records from this region, despite being one of the most biodiverse places on Earth (Bass et al. 2010). Notwithstanding the importance of these three factors, the observed richness pattern suggests the influence of other underlying factors. The northeastern area of the coastal plains region, which are part of the Choco biogeographic region, are another recognized biodiversity hotspot (Myers et al. 2000; Sierra et al. 2002), and they have a well-developed road network and infrastructure, making them easily accessible for sampling. However, they have the lowest number of chrysomelid records, except for a single sampling event around San Juan de Cachabí. This pattern could be attributed to the loss of biodiversity due to high rates of deforestation and agricultural production, but the threats posed by drug trafficking, illegal logging, and mining may have led to the avoidance of biodiversity surveys in this region.

As expected, we found that the proportion of chrysomelid species in Ecuador differed from that of the entire Neotropical region. This aligns with the findings of Reid (2017), who reported that species proportions by subfamily are not consistent across regions, such as Australopapua (Australia and New Guinea). However, contrary to our expectations, the proportions of chrysomelid species by subfamily in Ecuador also differed from those in other countries where the distribution of species among subfamilies was expected to be similar, such as Brazil, El Salvador, Mexico, or Peru. These differences may be attributed to both environmental and historical factors, as the high environmental variability over short distances in Neotropical countries likely influences species distribution and promotes speciation (Hodkinson 2005; Hooghiemstra et al. 2006; Larsen et al. 2011; Price 2009). Additionally, this observed taxonomic bias may also reflect regional differences in research focus and taxonomic effort across subfamilies. Historical taxonomic research efforts on the Chrysomelidae in the Neotropics have been limited, given the enormous diversity of this beetle group in the region. Research has largely been the domain of a few taxonomists specializing in particular groups, contributing to taxonomic bias among Chrysomelidae subfamilies. Significant contributions to the characterization of the Neotropical Chrysomelidae fauna have been made by several entomologists: J. S. Baly, J. Bechyné, R. E. Blackwelder, C. H. Boheman, L. Borowiec, C. S. Chaboo, R. W. Flowers, J. Gómez-Zurita, M. Jacoby, C. D. Johnson, A. Konstantinov, M. Pic, V. Sabini, L. Sekerka, F. Spaeth, C. L. Staines, E. Uhmann, and M. J. Viana. Their research focused on subfamilies such as Bruchinae, Cassidinae, Chrysomelinae, Eumolpinae, and Galerucinae, which are distributed throughout Central and South America. However, Criocerinae, Cryptocephalinae, and Lamprosomatinae still remain poorly studied in the Neotropics (Chaboo and Schöller 2016; Van Roie et al. 2019), with some exceptions in Brasil (Linzmeier and Moura 2025), Mexico (Jacoby 1880–1892; Moldenke 1970, 1981; Ordóñez-Reséndiz and López-Pérez 2021), and Argentina (Agrain et al. 2017).

Observed and predicted species richness patterns of Chrysomelidae from Ecuador show similarities and discrepancies. Both patterns agree that the highest richness values occur in the Chocó biogeographic region in northwestern Ecuador. The greatest discrepancy between the two patterns occurs in the Andean highlands physiographic region. The observed richness pattern indicates that the Andean highlands region has higher species richness than the coastal plain and Amazon regions, whereas the predicted richness pattern shows the opposite trend. In addition to the differences in sampling effort discussed above, these discrepancies in leaf beetle richness may be explained by the fact that SDM predict higher species richness in Ecuadorian regions with greater annual mean temperature and precipitation. These abiotic factors positively influence beetle species richness, as they affect the seasonal activity of beetle species (Fremlin and Fremlin 2010; Lachat et al. 2012), and drive ecosystem productivity, thereby increasing food availability for phytophagous beetles (Linzmeier and Ribeiro-Costa 2008, 2013). Overall, these differences likely reflect undersampling in ecologically rich but poorly surveyed regions of Ecuador.

Species distribution models based on GBIF records predicted the potential presence in Ecuador of 42 leaf beetle species currently known from Mexico to Paraguay and not yet recorded in the country. Adding these data to the observed species richness in Ecuador would increase the potential richness to 913 species. Based on richness ratios for Chrysomelidae and vascular plants found in well-sampled tropical countries, we estimated that the total number of chrysomelids in Ecuador would potentially be between 1,821 and 3,315, which is between 109 and 280% greater than the number of recorded species and between 99 and 263% greater than the number of recorded species plus the number of species predicted by SDM. These estimates of potential chrysomelid richness are consistent with the findings of Kuschel (1963) and Peck and Kukalová-Peck (1990) for the Galápagos Islands, who used vascular plant richness to suggest that between 184 and 634 species of phytophagous beetles had not yet been reported from the islands. However, the proportion of unrecorded species in Ecuador may be even higher for two main reasons. First, estimates of the "Linnean shortfall" (i.e. knowledge gaps for species taxonomy; Brown and Lomolino 1998) suggest that the number of insect species worldwide is three to six times greater than the number currently described (Lin et al. 2022; Stork 2018). Second, in some tropical regions, the ratio of beetle species—particularly within certain groups—to plant species may surpass the ratios observed in our study. This suggests that the actual number of Chrysomelidae species in Ecuador could be up to an order of magnitude higher than currently recorded.

Conservation prospects

Comprehensive species checklists and detailed species distribution information are crucial for advancing ecological, evolutionary and conservation research (Lagomarsino and Frost 2020; Mace 2004; Yañez-Arenas et al. 2014). The limited scope of basic biological research, often due to a lack of expertise and resources, as well as various shortfalls identified by the scientific community, hinder the development and implementation of effective conservation strategies for tropical insect species (Cardoso et al. 2011; New 1997). Addressing these shortfalls is essential for the effective conservation of these species.

Enhancing taxonomic and distributional knowledge of tropical insect communities is critical for several reasons. First, it helps to reduce the Linnean (Brown and Lomolino 1998), Wallacean (knowledge gaps for species distribution) (Lomolino 2004), Prestonian (knowledge gaps for species abundance) and Hutchinsonian (knowledge gaps for abiotic tolerances of species) shortfalls (Cardoso et al. 2011). Second, it provides a better understanding of biodiversity patterns, which is fundamental to identifying areas of high conservation priority (Funk and Richardson 2002; Jones et al. 2009; McNeely 2002). Finally, it helps to elucidate the evolutionary processes that generate and maintain biodiversity (Lagomarsino and Frost 2020), providing insights into how species adapt to their environments and the potential impacts of environmental change.

In the context of Ecuador, improving our understanding of the taxonomy and distribution of chrysomelids will have significant conservation implications. Comprehensive data will allow the identification of key habitats and the formulation of targeted conservation strategies (McNeely 2002; Nagy et al. 2023). This is particularly important in a country known for its rich biodiversity and high levels of endemism (Castro and Espinosa 2015; Espinoza and Noriega 2018; Thormann et al. 2018). Moreover, improved taxonomic and distributional data can increase the effectiveness of biodiversity monitoring programs. By providing baseline data, these programs can track changes in species populations over time, thereby informing adaptive management strategies that can respond to emerging threats such as habitat loss, climate change, and invasive species (Mace 2004; Sanitha and Madeswaran 2020). Improved taxonomic data on leaf beetles will also provide a stronger foundation for future research aimed at collecting detailed information on plant-insect associations, as well as interactions between insects and their predators, parasites, and symbionts. Such data are essential for advancing our understanding of ecological interactions and the natural history of Ecuadorian ecosystems, ultimately contributing to more informed conservation and management strategies.

In conclusion, the future of conservation in Ecuador depends heavily on strengthening our knowledge of the taxonomy and distribution of tropical insects, especially in those groups with high species diversity such as the Chrysomelidae. This endeavor will not only contribute to global biodiversity conservation efforts, but will also ensure the preservation of Ecuador's unique and diverse biological heritage.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10841-025-00730-3.

Acknowledgements We thank two anonymous reviewers for their helpful and insightful comments and editions on this manuscript.

Author contributions PMG, JGZ, and LC conceived the idea and designed the research; PMG collected and compiled data; PMG analyzed the data, tables and figures; PMG, JGZ, LC, JM, and MJM wrote original draft; PMG, JGZ, LC, JM, and MJM reviewed and edited the fnal version of the manuscript. All authors approved the final version.

Funding This study was funded by a grant from the Spanish Ministry of Science, Innovation, and Universities (PID2019-105064GB-100). P.M-G. received support through a PhD grant (Personal Investigador Predoctoral Programa Propio 2020) from Universidad Rey Juan Carlos (C6PREDOC20-95). L.C. was supported by a three-year faculty excellence grant (2022–2024) from the Community of Madrid Government – Line of Action No. 3. J.G-Z. and P.M-G. received support from grant no. PID2024-160236NB-I00 (Agencia Estatal de Investigación, MICIU, Spain). J.M. was supported by the grant PID2023-146996NB-I00, funded by MCIN/AEI/https://doi.org/10.13039/501100011033.

Data availability Data is provided within the manuscript or supplementary information files.

Declarations

Competing interests The authors declare no competing interests.

Ethical approval Not applicable.

Consent for publication Not applicable, as this study does not involve human participants or sensitive data.

References

Agrain FA, Chamorro ML, Cabrera N, Sassi D, Roig-Juñent S (2017) A comprehensive guide to the Argentinian case-bearer beetle fauna (Coleoptera, Chrysomelidae, Camptosomata). ZooKeys 677:11–88. https://doi.org/10.3897/zookeys.677.10778

Amano T, Sutherland WJ (2013) Four barriers to the global understanding of biodiversity conservation: wealth, language, geographical location and security. Proc Royal Soc B 280(1756):20122649. https://doi.org/10.1038/s41559-021-01538-5

Anderson RP, Araújo M, Guisan A, Lobo JM, Martínez-Meyer E, Peterson AT, Soberón JM (2016) Are species occurrence data in global online repositories fit for modeling species distributions? The case of the global biodiversity information facility (GBIF). Final report of the task group on GBIF data fitness for use in distribution modelling. GBIF, Copenhagen

Andrew NR, Hughes L (2004) Species diversity and structure of phytophagous beetle assemblages along a latitudinal gradient: predicting the potential impacts of climate change. Ecol Entomol 29(5):527–542. https://doi.org/10.1111/j.0307-6946.2004.00639.x

Annecke DP, Moran VC (1982) Insects and mites of cultivated plants in South Africa. Butterworth, Durban

Bacher S, Schwab F (2000) Effect of herbivore density, timing of attack and plant community on performance of creeping thistle *cirsium arvense* (L.) Scop. (Asteraceae). Biocontrol Sci Technol 10(3):343–352. https://doi.org/10.1080/09583150050044619

Bass MS, Finer M, Jenkins CN, Kreft H, Cisneros-Heredia DF, McCracken SF, Pitman NCA, English PH, Swing K, Villa G, Di Fiore A, Voigt CC, Kunz TH (2010) Global conservation significance of ecuador's Yasuní National park. PLoS ONE 5(1):e8767. https://doi.org/10.1371/journal.pone.0008767

Basset Y (2001) Invertebrates in the canopy of tropical rain forests how much do we really know? Plant Ecol 153:87–107. https://doi.org/10.1023/A:1017581406101

Belovsky GE, Slade JB (2000) Insect herbivory accelerates nutrient cycling and increases plant production. Proc Natl Acad Sci 97(26):14412–14417.

Bieńkowski AO (2010) Anthophagy in the leaf beetles (Coleoptera, Chrysomelidae). Entomol Rev 90:423–432. https://doi.org/10.1134/S0013873810040032

Blackwelder RE (1946) Checklist of the coleopterous insects of Mexico, central America, the West Indies, and South America, part 4. Bull Smithson Institution USNM 185:733–757. https://doi.org/10.5479/si.03629236.185.4

Borchsenius F (1997) Patterns of plant species endemism in Ecuador. Biodivers Conserv 6:379–399. https://doi.org/10.1023/A:1018312724137

Borowiec L (1998) Review of the cassidinae of Ecuador, with a description of thirteen new species (Coleoptera: Chrysomelidae). Genus 9(2):155–246

Borowiec L, Swietojanska J (2024) Cassidinae of the world - an interactive manual (Coleoptera: Chrysomelidae). Department of Biodiversity and Evolutionary Taxonomy, University of Wroclaw. https://www.cassidae.uni.wroc.pl/katalog%20internetowy/index.htm. Accessed Apr 2024

Boyd RJ, Powney GD, Carvell C, Pescott OL (2021) Occassess: an R package for assessing potential biases in species occurrence data. Ecol Evol 11(22):16177–16187. https://doi.org/10.1002/ece3.8299

Breiner FT, Nobis MP, Bergamini A, Guisan A (2018) Optimizing ensembles of small models for predicting the distribution of species with few occurrences. Methods Ecol Evol 9(4):802–808. https://doi.org/10.1111/2041-210X.12957

Brown VK (1990) Insect Herbivores, herbivory and plant succession. In: Gilbert F (ed) Insect life cycles. Springer, London, pp 183–196

Brown VK, Gange AC (1989) Herbivory by soil-dwelling insects depresses plant species richness. Funct Ecol 3:667–671. https://doi.org/10.2307/2389498

Brown VK, Gange AC (1992) Secondary plant succession: how is it modified by insect herbivory? Vegetatio 101:3–13. https://doi.org/10.1007/BF00031910

Brown JH, Lomolino MV (1998) Biogeography. Sinuer Associates Publishers, Sunderland

Cañadas L (1983) El Mapa Bioclimático y Ecológico Del Ecuador. MAG-PRONAREG, Quito

Cardoso P, Erwin TL, Borges PA, New TR (2011) The seven impediments in invertebrate conservation and how to overcome them. Biol Conserv 144(11):2647–2655. https://doi.org/10.1016/j.biocon.2011.07.024

Castro A, Espinosa CI (2015) Seasonal diversity of butterflies and its relationship with woody-plant resources availability in an Ecuadorian tropical dry forest. Trop Conserv Sci 8(2):333–351. https://doi.org/10.1177/194008291500800205

Cayuela L, Golicher DJ, Newton A, Kolb M, De Alburquerque FS, Arets EJMM, Alkemade RM, Pérez AM (2009) Species distribution modeling in the tropics: problems, potentialities and the role of biological data for effective species conservation. Trop Conserv Sci 2(3):319–352. https://doi.org/10.1177/194008290900200304

Chaboo CS (2015a) Beetles (Coleoptera) of Peru: a survey of the families. Chrysomelidae: bruchinae Latreille, 1802. J Kans Entomol Soc 88(3):356–360. https://doi.org/10.2317/kent-88-03-356-360.1

Chaboo CS (2015b) Beetles (Coleoptera) of Peru: a survey of the families. Chrysomelidae: Galerucinae (not including Alticini). J Kans Entomol Soc 88(3):361–367. https://doi.org/10.2317/0022-8567-88.3.361

Chaboo CS, Flowers RW (2015a) Beetles (Coleoptera) of peru: a survey of the families. Chrysomelidae: Chrysomelinae. J Kans Entomol Soc 88(3):380–383. https://doi.org/10.2317/kent-88-03-380-383.1

Chaboo CS, Flowers RW (2015b) Beetles (Coleoptera) of Peru: a survey of the families. Chrysomelidae: Eumolpinae Hope, 1840. J Kans Entomol Soc 88(3):375–379. https://doi.org/10.2317/kent-88-03-375-379.1

Chaboo CS, Schmitt M (2015) Beetles (Coleoptera) of Peru: a survey of the families. Chrysomelidae: Criocerinae. J Kans Entomol Soc 88(3):384–386. https://doi.org/10.2317/kent-88-03-384-386.1

Chaboo CS, Schöller M (2016) Beetles (Coleoptera) of peru: a survey of the families. Chrysomelidae: Cryptocephalinae and lamprosomatinae. J Kans Entomol Soc 89(2):191–194. https://doi.org/10.2317/140429.1

Chaboo CS, Staines CL (2015) Beetles (Coleoptera) of Peru: a survey of the families. Chrysomelidae: cassidinae Gyllenhal sensu lato. J Kans Entomol Soc 88(3):387–398. https://doi.org/10.2317/kent-88-03-387-398.1

Chapman SK, Hart SC, Cobb NS, Whitham TG, Koch GW (2003) Insect herbivory increases litter quality and decomposition: an extension of the acceleration hypothesis. Ecology 84(11):2867–2876. https://doi.org/10.1890/02-0046

Coley PD, Barone JA (1996) Herbivory and plant defenses in tropical forests. Annu Rev Ecol Syst 27(1):305–335. https://doi.org/10.1146/annurev.ecolsys.27.1.305

Cornell HV, Hawkins BA (1995) Survival patterns and mortality sources of herbivorous insects: some demographic trends. Am Nat 145(4):563–593. https://doi.org/10.1086/285756

Crawley MJ (1989) Insect herbivores and plant population dynamics. Ann Rev Entomol 34(1):531–562. https://doi.org/10.1146/annurev.en.34.010189.002531

Dangles O (2009) Entomology in Ecuador. Annales de La Société Entomologique De France 45(4):409–409. https://doi.org/10.1080/00379271.2009.10697625

Daru BH, Rodriguez J (2023) Mass production of unvouchered records fails to represent global biodiversity patterns. Nat Ecol Evol 7(6):816–831. https://doi.org/10.1038/s41559-023-02047-3

de Freitas ÉVD, Maracahipes L, de Araújo WS (2023) Plant richness and vegetation structure drive the topology of plant-herbivore networks in Neotropical savannas. Acta Oecol 121:103961. https://doi.org/10.1016/j.actao.2023.103961

DeAngelis DL (1992) Dynamics of nutrient cycling and food webs. Chapman and Hall, New York

Delso Á, Fajardo J, Muñoz J (2021) Protected area networks do not represent unseen biodiversity. Sci Rep 11(1):12275. https://doi.org/10.1038/s41598-021-91651-z

Dennis RLH, Thomas CD (2000) Bias in butterfly distribution maps: the influence of hot spots and recorder's home range. J Insect Conserv 4:73–77. https://doi.org/10.1023/A:1009690919835

Di Cola V, Broennimann O, Petitpierre B, Breiner FT, D'Amen M, Randin C, Engler R, Pottier J, Pio D, Dubuis A, Pellissier L, Mateo RG, Hordijk W, Salamin N, Guisan A (2017) Ecospat: an R package to support Spatial analyses and modeling of species niches and distributions. Ecography 40(6):774–787. https://doi.org/10.1111/ecog.02671

Dinnage R, Cadotte MW, Haddad NM, Crutsinger GM, Tilman D (2012) Diversity of plant evolutionary lineages promotes arthropod diversity. Ecol Lett 15(11):1308–1317. https://doi.org/10.1111/j.1461-0248.2012.01854.x

Engel MS, Ceríaco LMP, Danielm GM, Dellapé PM, Löbl I, Marinov M, Reis RE, Young MT, Dubois A, Agarwal I, Lehmann P, Alvarado M, Alvarez N, Andreone F, Araujo-Vieira K, Ascher JS, Baêta D, Baldo D, Bandeira SA, Barden P, Barrasso DA, Bendifallah L, Bockmann FA, Böhme W, Borkent A, Brandão CRF, Busack SD, Bybee SM, Channing A, Chatzimanolis S, Christenhusz MJM, Crisci JV, D'elía G, Da Costa LM, Davis SR, De Lucena CAS, Deuve T, Fernandes SE, Faivovich J, Farooq H, Ferguson AW, Gippoliti S, Gonçalves FMP, Gonzalez VH, Greenbaum E, Hinojosa-Díaz IA, Ineich I, Jiang J, Kahono S, Kury AB, Lucinda PHF, Lynch JD, Malécot V, Marques MP, Marris JWM, Mckellar RC, Mendes LF, Nihei SS, Nishikawa K, Ohler A, Orrico VGD, Ota H, Paiva J, Parrinha D, Pauwels OSG, Pereyra MO, Pestana LB, Pinheiro PDP, Prendini L, Prokop J, Rasmussen C, Rödel MO, Rodrigues MT, Rodríguez SM, Salatnaya H, Sampaio I, Sánchez-García A, Shebl MA, Santos BS, Solórzano-Kraemer MM, Sousa ACA, Stoev P, Teta P, Trape JF, Santos C, Vasudevan K, Vink CJ, Vogel G, Wagner P, Wappler T, Ware JL, Wedmann S, Zacharie CK (2021) The taxonomic impediment: a shortage of taxonomists, not the lack of technical approaches. Zool J Linn Soc 193(2):381387. https://doi.org/10.1093/zoolinnean/zlab072

Erwin TL (1982) Tropical forests: their richness in coleoptera and other arthropod species. Coleopt Bull 36(1):74–75

Espinoza VR, Noriega JA (2018) Diversity of the dung beetles (Coleoptera: Scarabaeinae) in an altitudinal gradient in the East slope of Los Andes, Napo province, Ecuador. Neotrop Biodivers 4(1):145–151. https://doi.org/10.1080/23766808.2018.1512199

Farrell B, Mitter C (1990) Phylogenesis of insect/plant interactions: have *Phyllobrotica* leaf beetles (Chrysomelidae) and the lamiales diversified in parallel? Evolution 44(6):1389–1403. https://doi.org/10.1111/j.1558-5646.1990.tb03834.x

Fattorini S (2013) Regional insect inventories require long time, extensive Spatial sampling and good will. PLoS ONE 8(4):e62118. https://doi.org/10.1371/journal.pone.0062118

Flora e Funga do Brasil (2025) Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br/ Accessed 17 Sep 2025

Fonte SJ, Schowalter TD (2005) The influence of a Neotropical herbivore (*Lamponius portoricensis*) on nutrient cycling and soil processes. Oecologia 146:423–431. https://doi.org/10.1007/s00442-005-0203-4

Fremlin M, Fremlin DH (2010) Weather-dependence of *Lucanus cervus* L. (Coleoptera: scarabaeoidea: Lucanidae) activity in a Colchester urban area. Essex Naturalist (New Series) 27:214–230. https://doi.org/10.1046/j.1440-6055.2003.00369.x

Frost CJ, Hunter MD (2004) Insect canopy herbivory and frass deposition affect soil nutrient dynamics and export in oak mesocosms. Ecology 85(12):3335–3347. https://doi.org/10.1890/04-0003

Funk VA, Richardson KS (2002) Systematic data in biodiversity studies: use it or lose it. Syst Biol 51(2):303–316. https://doi.org/10.1080/10635150252899789

Furth DG (2006) The current status of knowledge of the alticinae of Mexico (Coleoptera: Chrysomelidae). Bonner Zoologische Beiträge 54(4):209–237

Furth DG, Savini V, Chaboo CS (2015) Beetles (Coleoptera) of Peru: a survey of the families. Chrysomelidae: alticinae (flea beetles). J Kans Entomol Soc 88(3):368–374. https://doi.org/10.2317/kent-88-03-368-374.1

Futuyma DJ, Mitter C (1996) Insect—plant interactions: the evolution of component communities. Philosophical Trans Royal Soc Lond Ser B: Biol Sci 351(1345):1361–1366. https://doi.org/10.1098/rstb.1996.0119

García-Roselló E, Guisande C, Manjarrés-Hernández A, González-Dacosta J, Heine J, Pelayo-Villamil P, Vari RP, Vaamonde A, Granado-Lorencio C, Lobo JM (2015) Can we derive macroecological patterns from primary GBIF data? Glob Ecol Biogeogr 24(3):335–347. https://doi.org/10.1111/geb.12260

García-Roselló E, González-Dacosta J, Lobo JM (2023) The biased distribution of existing information on biodiversity hinders its use in conservation, and we need an integrative approach to act urgently. Biol Conserv 283:110118. https://doi.org/10.1016/j.biocon.2023.110118

Gaston KJ (1992) Regional numbers of insect and plant species. Funct Ecol 6:243–247. https://doi.org/10.2307/2389513

Girardello M, Chapman A, Dennis R, Kaila L, Borges PA, Santangeli A (2019) Gaps in butterfly inventory data: a global analysis. Biol Conserv 236:289–295. https://doi.org/10.1016/j.biocon.2019.05.053

Godoy-Bürki AC, Biganzoli F, Sajama JM, Ortega-Baes P, Aagesen L (2017) Tropical high Andean drylands: species diversity and its environmental determinants in the central Andes. Biodivers Conserv 26:1257–1273. https://doi.org/10.1007/s10531-017-1311-2

Gómez-Zurita J, Cardoso A, Coronado I, De la Cadena G, Jurado-Rivera JA, Maes JM, Montelongo T, Nguyen DT, Papadopoulou A (2016) High-throughput biodiversity analysis: rapid assessment of species richness and ecological interactions of chrysomelidae (Coleoptera) in the tropics. ZooKeys 597:3–26. https://doi.org/10.3897/zookeys.597.7065

Gottsberger G (2012) How diverse are Annonaceae with regard to pollination? Bot J Linn Soc 169(1):245–261. https://doi.org/10.1111/j.1095-8339.2011.01209.x

Haddad NM, Tilman D, Haarstad J, Ritchie M, Knops JM (2001) Contrasting effects of plant richness and composition on insect communities: a field experiment. Am Nat 158(1):17–35. https://doi.org/10.1086/320866

Haddad NM, Gross K, Tilman D (2009) Plant species loss decreases arthropod diversity and shifts trophic structure. Ecol Lett 12(10):1029–1039. https://doi.org/10.1111/j.1461-0248.2009.01356.x

Hawkins BA, Cornell HV, Hochberg ME (1997) Predators, parasitoids, and pathogens as mortality agents in phytophagous insect populations. Ecology 78(7):2145–2152

Hertzog LR, Meyer ST, Weisser WW, Ebeling A (2016) Experimental manipulation of grassland plant diversity induces complex shifts in aboveground arthropod diversity. PLoS ONE 11:e0148768. https://doi.org/10.1371/journal.pone.0148768

Hill DS (1979) Agricultural insect pests of the tropics and their control. Cambridge University Press, London

Hodkinson ID (2005) Terrestrial insects along elevation gradients: species and community responses to altitude. Biol Rev 80(3):489–513. https://doi.org/10.1017/S1464793105006767

Hodkinson ID, Casson D (1991) A lesser predilection for bugs: Hemiptera (Insecta) diversity in tropical rain forest. Biol J Linn Soc 43(2):101–109. https://doi.org/10.1111/j.1095-8312.1991.tb00587.x

Hole DG, Young KR, Seimon A, Wichtendahl CG, Hoffmann D, Schutze Paez K, Sanchez S, Muchoney D, Grau HR, Ramirez E (2011) Adaptive management for biodiversity conservation under climate change - A tropical Andean perspective. In: Herzog SK, Martínez R, Jørgensen PM, Tiessen H (eds) Climate Change and Biodiversity in the Tropical Andes. San Jose dos Campos and Paris: Inter-American Institute for Global Change Research and Scientific Committee on Problems of the Environment, pp 348

Hollinger DY (1986) Herbivory and the cycling of nitrogen and phosphorus in isolated California oak trees. Oecologia 70:291–297. https://doi.org/10.1007/BF00379254

Hooghiemstra H, Wijninga VM, Cleef AM (2006) The paleobotanical record of colombia: implications for biogeography and biodiversity. Ann Missouri Bot Gard 93(2):297–324

Hunter MD (2001) Insect population dynamics meets ecosystem ecology: effects of herbivory on soil nutrient dynamics. Agric Entomol 3(2):77–84. https://doi.org/10.1046/j.1461-9563.2001.00100.x

Huntly N (1991) Herbivores and the dynamics of communities and ecosystems. Annu Rev Ecol Syst 22:477–503. https://doi.org/10.1146/annurev.es.22.110191.002401

Jacoby M (1880–1892) Biologia Centrali-Americana. Insecta. Coleoptera. Vol. VI. Part 1 (and Supplement). Phytophaga. R.H. Porter, London

Janzen DH (1970) Herbivores and the number of tree species in tropical forests. Am Nat 104(940):501–528. https://doi.org/10.1086/282687

Janzen DH (1987) Insect diversity of a Costa Rican dry forest: why keep it, and how? Biol J Linn Soc 30(4):343–356. https://doi.org/10.1111/j.1095-8312.1987.tb00307.x

Jolivet P (1988) Food habits and food selection of chrysomelidae. Bionomic and evolutionary perspectives. Biology of chrysomelidae. Springer, Dordrecht

Jolivet P, Hawkeswood T (1995) Host-plants of chrysomelidae of the world. An essay about the relationships between the leaf-beetles and their food-plants. Backhuys, Leiden

Jones OR, Purvis A, Baumgart E, Quicke DL (2009) Using taxonomic revision data to estimate the geographic and taxonomic distribution of undescribed species richness in the Braconidae (Hymenoptera: Ichneumonoidea). Insect Conserv Divers 2(3):204–212. https://doi.org/10.1111/j.1752-4598.2009.00057.x

Kadmon R, Farber O, Danin A (2004) Effect of roadside bias on the accuracy of predictive maps produced by bioclimatic models. Ecol Appl 14(2):401–413. https://doi.org/10.1890/02-5364

Kaukonen M, Ruotsalainen AL, Wäli PR, Männistö MK, Setälä H, Saravesi K, Huusko K, Markkola A (2013) Moth herbivory enhances resource turnover in subarctic mountain Birch forests? Ecology 94(2):267–272. https://doi.org/10.1890/12-0917.1

Kemp JE, Ellis AG (2017) Significant local-scale plant-insect species richness relationship independent of abiotic effects in the temperate cape floristic region biodiversity hotspot. PLoS ONE 12(1):e0168033. https://doi.org/10.1371/journal.pone.0168033

Kirby W, Spence W (1826) An introduction to entomology: or Elements of the natural history of insects, vol. IV. Longman, Rees, Orme, Brown and Green, London

Kirmse S, Chaboo CS (2018) Polyphagy and florivory prevail in a leaf-beetle community (Coleoptera: Chrysomelidae) inhabiting the canopy of a tropical lowland rainforest in Southern Venezuela. J Nat Hist 52(41–42):2677–2721. https://doi.org/10.1080/00222933.2018.1548666

Kitchell JF, O'Neill RV, Webb D, Gallepp GW, Bartell SM, Koonce JF, Ausmus BS (1979) Consumer regulation of nutrient cycling. Bioscience 29(1):28–34. https://doi.org/10.2307/1307570

Kleemann J, Koo H, Hensen I, Mendieta-Leiva G, Kahnt B, Kurze C, Inclan DJ, Cuenca F, Noh JK, Hoffmann MH, Factos A, Lehnert M, Lozano P, Fürst C (2022) Priorities of action and research for the protection of biodiversity and ecosystem services in continental Ecuador. Biol Conserv 265:109404. https://doi.org/10.1016/j.biocon.2021.109404

Knops JM, Tilman D, Haddad NM, Naeem S, Mitchell CE, Haarstad J, Ritchie ME, Howe KM, Reich PB, Siemann E, Groth J (1999) Effects of plant species richness on invasion dynamics, disease outbreaks, insect abundances and diversity. Ecol Lett 2(5):286–293. https://doi.org/10.1046/j.1461-0248.1999.00083.x

Kreft H, Jetz W (2007) Global patterns and determinants of vascular plant diversity. Proc Natl Acad Sci U S A 104(14):5925–5930. https://doi.org/10.1073/pnas.0608361104

Kuschel G (1963) Composition and relationship of the terrestrial faunas of Easter, Juan Fernandez, Desventuradas and Galapagos Islands. Occas Pap Calif Acad Sci 44:79–95

Lachat T, Wermelinger B, Gossner MM, Bussler H, Isacsson G, Müller J (2012) Saproxylic beetles as indicator species for dead-wood amount and temperature in European beech forests. Ecol Ind 23:323–331. https://doi.org/10.1016/j.ecolind.2012.04.013

Lagomarsino LP, Frost LA (2020) The central role of taxonomy in the study of Neotropical biodiversity. Ann Missouri Bot Gard 105(3):405–421. https://doi.org/10.3417/2020601

Larsen TH, Escobar F, Armbrecht I (2011) Insects of the tropical Andes: diversity patterns, processes and global change. In: Herzog SK, Martínez R, Jørgensen PM, Tiessen H (eds) Climate Change and Biodiversity in the Tropical Andes. San Jose dos Campos and Paris: Inter-American Institute for Global Change Research and Scientific Committee on Problems of the Environment, pp. 228–244

Lawton JH (1983) Plant architecture and the diversity of phytophagous insects. Annu Rev Entomol 28:23–39. https://doi.org/10.1146/annurev.en.28.010183.000323

Lerdau M (1996) Insects and ecosystem function. Trends Ecol Evol 11:151. https://doi.org/10.1016/0169-5347(96)30007-4

Lewinsohn TM, Price PW (1996) Diversity of herbivorous insects and ecosystem processes. In: Solbrig OT, Medina E, Silva JF (eds) Biodiversity and savanna ecosystem processes, vol 121. Springer, Berlin, pp 143–157

Lewinsohn TM, Roslin T (2008) Four ways towards tropical herbivore megadiversity. Ecol Lett 11(4):398–416. https://doi.org/10.1111/j.1461-0248.2008.01155.x

Lin H, Caley MJ, Sisson SA (2022) Estimating global species richness using symbolic data meta-analysis. Ecography 2022(3):e05617. https://doi.org/10.1111/ecog.05617

Linzmeier AM, Ribeiro-Costa CS (2008) Seasonality and temporal structuration of alticini community (Coleoptera, Chrysomelidae, Galerucinae) in the araucaria forest of Parana, Brazil. Rev Bras Entomol 52(2):289–295. https://doi.org/10.1590/S0085-56262008000200009

Linzmeier AM, Ribeiro-Costa CS (2013) Seasonal pattern of chrysomelidae (Coleoptera) in the state of Paraná, Southern Brazil. Biota Neotrop 13:153–162. https://doi.org/10.1590/S1676-06032013000100018

Linzmeier AM, Moura LA (2025) Chrysomelidae in Catálogo Taxonômico da Fauna do Brasil. http://fauna.jbrj.gov.br/fauna/faunadobrasil/115540. Accessed 17 Sep 2025

Lobo JM, Borges PA (2010) The provisional status of arthropod inventories in the Macaronesian islands. In: Serrano ARM, Borges PAV, Boieiro M, Oromí P (eds) Terrestrial arthropods of Macaronesia-Biodiversity, Ecology and Evolution. Sociedade Portuguesa de Entomologia, Lisboa, pp 33–47

Lomolino MV (2004) Conservation biogeography. In: Lomolino MV, Heaney LR (eds) Frontiers of Biogeography: new directions in the geography of nature. Sinauer, Sunderland, pp 293–296

López-Bedoya PA, Magura T, Méndez-Rojas DM, Noriega JA, Horgan FG, Edwards DP (2024) Knowledge of ground-dwelling beetle communities in the tropical andes: gaps and trends. Austral Ecol 49(1):e13440. https://doi.org/10.1111/aec.13413

Lovett GM, Christenson LM, Groffman PM, Jones CG, Hart JE, Mitchell MJ (2002) Insect defoliation and nitrogen cycling in forests: laboratory, plot, and watershed studies indicate that most of the nitrogen released from forest foliage as a result of defoliation by insects is redistributed within the ecosystem, whereas only a small fraction of nitrogen is lost by leaching. Bioscience 52(4):335–341

Mace GM (2004) The role of taxonomy in species conservation. Philos Trans R Soc Lond B Biol Sci 359(1444):711–719. https://doi.org/10.1098/rstb.2003.1454

Mattson WJ, Addy ND (1975) Phytophagous insects as regulators of forest primary production. Science 190(4214):515–522. https://doi.org/10.1126/science.190.4214.515

May RM (1990) How many species? Philosophical transactions of the Royal society of London. Ser B: Biol Sci 330(1257):293–304. https://doi.org/10.1098/rstb.1990.0200

McNeely JA (2002) The role of taxonomy in conserving biodiversity. J Nat Conserv 10(3):145–153. https://doi.org/10.1078/1617-1381-00015

Metcalfe DB, Asner GP, Martin RE, Silva Espejo JE, Huasco WH, Farfán Amézquita FF, Carranza-Jimenez L, Galiano Cabrera DF, Durand Baca L, Sinca F, Huaraca Quispe LP, Alzamora Taype I, Eguiluz Mora L, Rozas Dávila A, Mamani Solórzano M, Puma Vilca BL, Laupa Román JM, Guerra Bustios PC, Salinas Revilla N, Tupayachi R, Girardin CAJ, Doughty CE, Malhi Y (2014) Herbivory makes major contributions to ecosystem carbon and nutrient cycling in tropical forests. Ecol Lett 17(3):324–332. https://doi.org/10.1111/ele.12233

Moldenke AR (1970) A revision of clytrinae of North America, North of the isthmus of Panama (Coleoptera: Chrysomelidae). Stanford University, Stanford

Moldenke AR (1981) A generic reclassification of the New World Clytrinae (Coleoptera: Chrysomelidae). Entomologische Arbeiten aus dem Museum G. Frey, Muenchen 29(30):75–116

Momose K (2005) Beetle pollination in tropical rain forests. In: Roubik DW, Sakai S, Hamid Karim AA (eds) Pollination ecology and the rain forest, vol 174. Springer, New York, pp 104–110

Motschulsky V (1874) Enumération des nouvelles espèces de Coléoptères rapportés de différentes parties du monde. Bulletin de la Société Impériale des Naturalistes de Moscou 46(3):203–252

Murdoch WW, Evans FC, Peterson CH (1972) Diversity and pattern in plants and insects. Ecology 53(5):819–829. https://doi.org/10.2307/1934297

Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403(6772):853–858. https://doi.org/10.1038/35002501

Nagy A, Rácz IA, Arnóczkyné Jakab D, Szanyi S (2023) Setting priorities and evaluation of habitats for the conservation of orthopterans: case study in the Aggtelek National park (N Hungary). Biol Futura 74(4):401–412. https://doi.org/10.1007/s42977-023-00199-8

New TR (1997) Butterfly conservation. Oxford University Press, Melbourne

Nielsen JK (1978) Host plant discrimination within cruciferae: feeding responses of four leaf beetles (Coleoptera: Chrysomelidae) to glucosinolates, cucurbitacins and cardenolides. Entomol Exp Appl 24(1):41–54. https://doi.org/10.1111/j.1570-7458.1978.tb02755.x

Nielsen JK (1989) Host plant relations of *Phyllotteta nemorum* L. (Coleoptera, Chrysomelidae) part II. Various defensive mechanisms in plants and their role in defining the host plant range. J Appl Entomol 107(1–5):193–202. https://doi.org/10.1111/j.1439-0418.1989.tb00248.x

Novotny V, Drozd P, Miller SE, Kulfan M, Janda M, Basset Y, Weiblen GD (2006) Why are there so many species of herbivorous insects in tropical rainforests? Science 313(5790):1115–1118. https://doi.org/10.1126/science.1129237

Ordóñez-Reséndiz MM, López-Pérez S (2021) Mexican leaf beetles (Coleoptera: Megalopodidae, Orsodacnidae, and Chrysomelidae): new records and checklist. Rev Mex Biodivers. https://doi.org/10.22201/ib.20078706e.2021.92.3873

Pärtel M (2014) Community ecology of absent species: hidden and dark diversity. J Veg Sci 25(5):1154–1159. https://doi.org/10.1111/jvs.12169

Pärtel M, Szava-Kovats R, Zobel M (2011) Dark diversity: shedding light on absent species. Trends Ecol Evol 26(3):124–128. https://doi.org/10.1016/j.tree.2010.12.004

Peck SB (1989) A survey of insects of the Florida Keys: post-Pleistocene land-bridge islands: introduction. Fla Entomol 72:603–612. https://doi.org/10.2307/3495034

Peck SB, Kukalova-Peck J (1990) Origin and biogeography of the beetles (Coleoptera) of the Galápagos Archipelago, Ecuador. Can J Zool 68(8):1617–1638. https://doi.org/10.1139/z90-242

Price DL (2009) Phylogeny and biogeography of the dung beetle genus *phanaeus* (Coleoptera: Scarabaeidae). Syst Entomol 34(1):137–150. https://doi.org/10.1111/j.1365-3113.2008.00443.x

QGIS Development Team (2024) Quantum GIS Geographic Information System Desktop v. 3.34.3 user guide

R Core Team (2024) R: A Language and environment for statistical computing. R Foundation for Statistical Computing, Vienna

Rafes PM (1973) Estimation of the effects of phytophagous insects on forest production. In: Reichle D (ed) Analysis of temperate forest ecosystems. Springer Verlag, New York, pp 100–106

Reid CA (2017) Australopapuan leaf beetle diversity: the contributions of hosts plants and geography. Austral Entomol 56(2):123–137. https://doi.org/10.1111/aen.12251

Reynolds BC, Hunter MD (2001) Responses of soil respiration, soil nutrients, and litter decomposition to inputs from canopy herbivores. Soil Biol Biochem 33(12–13):1641–1652. https://doi.org/10.1016/S0038-0717(01)00085-2

Reynolds BC, Hunter MD, Crossley DA Jr (2000) Effects of canopy herbivory on nutrient cycling in a Northern hardwood forest in Western North Carolina. Selbyana 21(1–2):74–78

Ribeiro-Costa CS, Almeida LM (2012) Seed-chewing beetles (Coleoptera: Chrysomelidae: Bruchinae). In: Panizzi AR, Parra JRP (eds) Insect Bioecology and Nutrition for Integrated Pest Management. CRC Press, Florida, pp 325–352

Rocha-Ortega M, Rodriguez P, Córdoba-Aguilar A (2021) Geographical, temporal and taxonomic biases in insect GBIF data on biodiversity and extinction. Ecol Entomol 46(4):718–728. https://doi.org/10.1111/een.13027

Romo H, García-Barros E, Lobo JM (2006) Identifying recorder-induced geographic bias in an Iberian butterfly database. Ecography 29(6):873–885. https://doi.org/10.1111/j.2006.0906-7590.04680.x

Samuelson GA (1994) Pollen consumption and digestion by leaf beetles. In: Jolivet PH, Cox ML, Petitpierre E (eds) Novel aspects of the biology of chrysomelidae. Springer, Dordrecht, pp 179–183

Sánchez-Reyes UJ, Niño-Maldonado S, Jones RW (2014) Diversity and altitudinal distribution of chrysomelidae (Coleoptera) in Peregrina Canyon, Tamaulipas, Mexico. ZooKeys 417:103. https://doi.org/10.3897/zookeys.417.7551

Sanitha SK, Madeswaran P (2020) Taxonomy matters in monitoring and EIA studies: an urgent need to revive systematic and taxonomy research in India. J Coastal Res 89(SI):71–76. https://doi.org/10.2112/SI89-013.1

Scherber C, Eisenhauer N, Weisser WW, Schmid B, Voigt W, Fischer M, Schulze ED, Roscher C, Weigelt A, Allan E, Beler H, Bonkowski M, Buchmann N, Buscot F, Clement LW, Ebeling A, Engels C, Halle S, Kertscher I, Klein AM, Koller R, König S, Kowalski E, Kummer V, Kuu A, Lange M, Lauterbach D, Middelhoff C, Migunova VD, Milcu A, Müller R, Partsch S, Petermann JS, Renker C, Rottstock T, Sabais A, Scheu S, Schumacher J, Temperton VM, Tscharntke T (2010) Bottom-up effects of plant diversity on multitrophic interactions in a biodiversity experiment. Nature 468:553–556. https://doi.org/10.1038/nature09492

Schowalter TD (2000) Insects as regulators of ecosystem development. In: Coleman DC, Hendrix PF (eds) Invertebrates as webmasters in ecosystems. CABI Publishing, Oxford, pp 99–114

Schowalter TD (2012) Insect herbivore effects on forest ecosystem services. J Sustain Forest 31(6):518–536. https://doi.org/10.1080/10549811.2011.636225

Schowalter TD (2016) Insect ecology: an ecosystem approach. Academic Press, Elsevier, San Diego

Schowalter TD, Sabin TE, Stafford SG, Sexton JM (1991) Phytophage effects on primary production, nutrient turnover, and litter decomposition of young Douglas-fir in Western Oregon. For Ecol Manage 42(3–4):229–243. https://doi.org/10.1016/0378-1127(91)90027-S

Seastedt TR, Crossley DA Jr (1984) The influence of arthropods on ecosystems. Bioscience 34(3):157–161. https://doi.org/10.2307/1309750

Siemann E, Tilman D, Haarstad J, Ritchie M (1998) Experimental tests of the dependence of arthropod diversity on plant diversity. Am Nat 152(5):738–750. https://doi.org/10.1086/286204

Sierra R, Campos F, Chamberlin J (2002) Assessing biodiversity conservation priorities: ecosystem risk and representativeness in continental Ecuador. Landsc Urban Plann 59(2):95–110. https://doi.org/10.1016/S0169-2046(02)00006-3

Skov F, Borchsenius F (1997) Predicting plant species distribution patterns using simple climatic parameters: a case study of Ecuadorian palms. Ecography 20(4):347–355. https://doi.org/10.1111/j.1600-0587.1997.tb00379.x

Southwood TRE, Brown VK, Reader PM (1979) The relationships of plant and insect diversities in succession. Biol J Linn Soc 12(4):327–348. https://doi.org/10.1111/j.1095-8312.1979.tb00063.x

Stork NE (1988) Insect diversity: facts, fiction and speculation. Biol J Linn Soc 35(4):321–337. https://doi.org/10.1111/j.1095-8312.1988.tb00474.x

Stork NE (2018) How many species of insects and other terrestrial arthropods are there on earth? Annu Rev Entomol 63:31–45. https://doi.org/10.1146/annurev-ento-020117-043348

Strong DR, Lawton JH, Southwood SR (1984) Insects on plants. Community patterns and mechanisms. Blackwell Scientific, Oxford

Swank WT, Waide JB, Crossley DA, Todd RL (1981) Insect defoliation enhances nitrate export from forest ecosystems. Oecologia 51:297–299. https://doi.org/10.1007/BF00540897

Thomas CD (1990) Fewer species. Nature 347(6290):237. https://doi.org/10.1038/347237a0

Thormann B, Ahrens D, Armijos DM, Peters MK, Wagner T, Wägele JW (2016) Exploring the leaf beetle fauna (Coleoptera: Chrysomelidae) of an Ecuadorian mountain forest using DNA barcoding. PLoS ONE 11(2):e0148268. https://doi.org/10.1371/journal.pone.0148268

Thormann B, Ahrens D, Espinosa CI, Armijos DM, Wagner T, Wägele JW, Peters MK (2018) Small-scale topography modulates elevational α-, β- and γ-diversity of Andean leaf beetles. Oecologia 187:181–189. https://doi.org/10.1007/s00442-018-4108-4

Thuiller W, Lafourcade B, Engler R, Araújo MB (2009) BIOMOD–a platform for ensemble forecasting of species distributions. Ecography 32(3):369–373. https://doi.org/10.1111/j.1600-0587.2008.05742.x

Titley MA, Snaddon JL, Turner EC (2017) Scientific research on animal biodiversity is systematically biased towards vertebrates and temperate regions. PLoS ONE 12(12):e0189577. https://doi.org/10.1371/journal.pone.0189577

Tropicos (2025) Tropicos connecting the world to botanical data since 1982 (Tropicos v3.4.2). Missouri Botanical Garden. https://tropicos.org. Accessed 9 Jan 2025

Troudet J, Grandcolas P, Blin A, Vignes-Lebbe R, Legendre F (2017) Taxonomic bias in biodiversity data and societal preferences. Sci Rep 7(1):9132. https://doi.org/10.1038/s41598-017-09084-6

Tscharntke T, Greiler HJ (1995) Insect communities, grasses, and grasslands. Ann Rev Entomol 40(1):535–558. https://doi.org/10.1146/annurev.en.40.010195.002535

Ulloa Ulloa C, Acevedo-Rodríguez P, Beck S, Belgrano MJ, Bernal R, Berry PE, Brako L, Celis M, Davidse G, Forzza RC, Gradstein SR, Hokche O, Léon B, León-Yánez S, Magill RE, Neill DA, Nee M, Raven PH, Stimmel H, Strong MT, Villaseñor JL, Zarucchi JL, Zuloaga FO, Jørgensen PM (2017) An integrated assessment of the vascular plant species of the Americas. Science 358(6370):1614–1617. https://doi.org/10.1126/science.aao0398

Van Roie M, De Wint F, Güngor A, Huyghe C, Dekoninck W, Sekerka L (2019) An annotated checklist of the leaf beetles (Coleoptera, Chrysomelidae) from El Salvador, with additions from the Bechyné collection in the Royal Belgian Institute of natural sciences. ZooKeys 856:137. https://doi.org/10.3897/zookeys.856.32017

Van Veen FJ, Morris RJ, Godfray HCJ (2006) Apparent competition, quantitative food webs, and the structure of phytophagous insect communities. Ann Rev Entomol 51(1):187–208. https://doi.org/10.1146/annurev.ento.51.110104.151120

Vencl FV, Levy A, Geeta R, Keller G, Windsor DM (2004) Observations on the natural history, systematics and phylogeny of the criocerinae of Costa Rica and Panama. In: Jolivet P, Santiago-Blay JA, Schmitt M (eds) New developments in the biology of chrysomelidae. SPB Academic Publishing bv, The Hague, pp 423–454

Villaseñor JL (2016) Checklist of the native vascular plants of Mexico. Rev Mex Biodivers 87(3):559–902. https://doi.org/10.1016/j.rmb.2016.06.017

Wright K (2018) Corrgram: Plot a Correlogram. R package version 1.13

Yañez-Arenas C, Guevara R, Martínez-Meyer E, Mandujano S, Lobo JM (2014) Predicting species' abundances from occurrence data: effects of sample size and bias. Ecol Model 294:36–41. https://doi.org/10.1016/j.ecolmodel.2014.09.014

Yang C, Liao C, Xu J, Dai X (2024) Host relationships and biological notes of Cassidinae beetles (Coleoptera, Chrysomelidae) in Qiannan Prefecture, Guizhou, China. Biodiv Data J 12:e116267. https://doi.org/10.3897/BDJ.12.e116267

Zador M, Young B, Josse C, Stern M, Vasconez S, Olander J, Sanchez de Lozada A, Smyth R, Comer P, Moull K (2015) Ecosystem profile: Tropical Andes biodiversity hotspot. Critical Ecosystem Partnership Fund. NatureServe and EcoDecision, Arlington, Virginia

Zizka A, Silvestro D, Andermann T, Azevedo J, Duarte Ritter C, Edler D, Farooq H, Herdean A, Ariza M, Scharn R, Svantesson S, Wengström N, Zizka V, Antonelli A (2019) Coordinatecleaner: standardized cleaning of occurrence records from biological collection databases. Methods Ecol Evol 10(5):744–751. https://doi.org/10.1111/2041-210X.13152