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Title

Assessment of Urban Bias in Iberian Butterfly Sampling through Citizen Science Data

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) utilized OpenAI's ChatGPT (GPT-4) (2024) to review and enhance the quality of the scientific writing. Following the use of this tool, the author(s) thoroughly reviewed and edited the content as necessary and take full responsibility for the final version of the published article.

Contribution of authors

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Diego Gil-Tapetado. The first draft of the manuscript was written by both authors and both authors commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

Abstract

Citizen science platforms have revolutionized biodiversity monitoring by enabling large-scale data collection. However, concerns about potential biases, such as urban sampling bias, have raised questions about the quality and representativeness of these datasets. This study assesses the spatial distribution of butterfly observations collected through the citizen science platform *Biodiversidad Virtual* in the Iberian-Balearic region over a 23-year period (2000–2023). Butterfly records were classified into three ecosystem types—urban areas, grasslands, and forests—and three population density zones—urban, peri-urban, and rural areas—using land cover and population density maps. Temporal trends in observation growth and minimum distances of records to urban and rural areas were analyzed. The results show consistent growth in butterfly observations across all ecosystem types, with rural and natural areas contributing significantly more records than urban areas. Observations in grasslands exhibited the highest growth rate, followed by forests and urban areas. The analysis of distances revealed preference for recording biodiversity in natural areas, with records consistently closer to rural areas than urban centers. These findings challenge the perceived dominance of urban bias in citizen science datasets and highlight the capability of citizen science platforms to capture data from diverse ecosystems. This study shows that, for one of the most important georeferenced datasets on butterflies of the Iberian Peninsula, urban biases are minimal, and geographic representation is robust. Further research is recommended to examine cultural and regional factors in other databases, enhancing their application in ecological research and conservation planning.

Keywords

Biodiversity monitoring, Sampling bias, Land cover classification, Lepidoptera, Habitat distribution, Spatial analysis, Conservation data quality

1. Introduction

Citizen science platforms have revolutionized biodiversity monitoring and detecting by providing tools that enable the efficient and cost-effective collection of massive amounts of data (Dickinson et al., 2012). These platforms offer numerous benefits for research, allowing investigations to be conducted at various scales and with extensive datasets, making them essential resources for ecological research and conservation (Dickinson et al., 2010). Relevant advancements have been achieved through these platforms, including the early detection of invasive alien species (González-Moreno et al., 2024), the identification of threatened species

(Rosa & Freitas, 2024), and the tracking of phenology and migratory patterns (Howard & Davies, 2006; Newson et al., 2016; Sanderson et al., 2021).

Despite their advantages, citizen science platforms are subject to various biases that can impact data quality and representativeness (Geldmnan et al., 2016). The full extent of these biases remains poorly understood, requiring further investigation to mitigate their effects (Dickinson et al., 2010). Among these biases are taxonomic biases (e.g.: misidentification or identification of species that cannot be identified by macroscopic features), which favor charismatic groups like birds while underrepresenting invertebrates and fish (Della Rocca et al., 2024). Large-scale geographic biases are also prominent, with most observations concentrated in developed countries, leaving regions with high biodiversity but low citizen participation poorly covered (Requier et al., 2020). At smaller scales, geographic biases are influenced by accessibility and visitation frequency, both of which play significant roles in the generation of observations (Mair & Ruete, 2016; Hugo & Altwegg, 2017). These limitations can reduce the potential of these platforms to address global ecological questions equitably. However, many "academic" databases also contain errors and biases, and these have to be lived with and methodologies exist to minimize them (Ponder et al., 2001; Wehi et al., 2012; Sánchez-Fernández et al., 2022).

One specific bias is urban sampling bias, where the higher density of observations in urban areas is driven by easier access and the higher concentration of participants (Ward, 2014). This bias often results in the under-sampling of natural ecosystems such as grasslands and forests, limiting the representation of species inhabiting these habitats. This issue highlights the need to assess the spatial distribution of observations to determine whether these data accurately reflect ecological patterns or are disproportionately influenced by the observer location.

This study aims to evaluate the spatial distribution of observations collected through a citizen science platform, focusing on spatial biases in data collection within the Iberian-Balearic region. Butterflies were chosen as the focal taxa due to their visual appeal within citizen science, their relevance in large-scale studies as bioindicators (Parmesan, 2003; Otaki, 2020; Pallottini et al., 2023), and their central role in numerous monitoring programs worldwide—e.g., eButterfly (Prudic et al., 2017), EuropeanBMS (van Swaay et al., 2008), UKBMS (Pollard & Yates, 1994)—. The analysis spans over two decades (2000–2023), with georeferenced observations categorized under two schemes: (1) land use types—urban areas, grasslands, and forests—and (2) population density zones—urban, peri-urban, and rural areas. By analyzing temporal trends, the study seeks to determine whether citizen science data exhibit a significant bias toward urban areas or if they represent a broader range of ecosystems. These findings will provide valuable insights into the quality and representativeness of citizen science data and their applicability in addressing ecological research and conservation challenges.

2. Material and Methods

2.1. *Data Collection*

Observations of butterfly species from the superfamily Papilionoidea present in the Iberian Peninsula were gathered from the citizen science platform *Biodiversidad Virtual* (currently inside of Observation.org https://biodiversidadvirtual.observation.org/). The dataset included georeferenced records from photographs reported between 2000 and 2023 (Supplementary Material S1). These data are uploaded to GBIF until 2018 (GBIF, 2025) and subsequently included in the Observation.org data, being public data from a citizen science platform (Figure 1). Data were filtered deleting duplicates and selecting only with Spanish data (where most of records of *Biodiversidad Virtual* are held and has the highest representativeness) excluding Canary Island records.

Georeferenced and dated data were categorized using the CORINE Land Cover database (COPERNICUS, 2020) downloaded from Copernicus Global Land Service. The original land cover categories were reclassified into three main ecosystem types: Forests ("Vineyards", "Fruit trees and berry plantations", "Olive groves", "Agro-forestry áreas", "Broad-leaved forest", "Coniferous forest", "Mixed forest", and "Transitional woodland-shrub"); Grasslands ("Non-irrigated arable land", "Permanently irrigated land", "Rice fields", "Pastures", "Annual crops associated with permanent crops", "Complex cultivation patterns", "Land principally occupied by agriculture, with significant areas of natural vegetation", "Natural grasslands", "Moors and heathland", and "Sclerophyllous vegetation"); and Urban Areas ("Continuous urban fabric", "Discontinuous urban fabric", "Industrial or commercial units", "Road and rail networks and associated land", "Port areas", "Airports", "Mineral extraction sites", "Dump sites", "Construction sites", "Green urban areas", and "Sport and leisure facilities"). Other types of land cover categories unrelated to butterfly fauna (e.g.: "Glaciers and perpetual snow", "Salt marshes" or "Bare rocks") have not been considered in any of the above categories.

The data were also classified into urban, peri-urban and rural areas, by reclassifying the Gridded Population of the World version 4 (GPWv4) human population raster (CIESIN-Columbia University, 2018) using the following criteria : $\geq$1000 people km^2, periurban >250 people km^2 within a 15-km distance from urban extent edge, and rural<250 people km^2 and/or

>15 km from the urban extents edge, and is commonly used as a representative of the urbanization level in ecological studies (Cano et al. 2014; Polidori et al. 2021)

2.2. *Data Analysis*

Accumulation butterfly data by year were calculated for each ecosystem type. Temporal trends in citizen science contributions across the ecosystems were visualized using line graphs. The curve or linear adjustment for each ecosystem type were calculated by obtaining the estimated increase in data for each ecosystem type. A descriptive analysis was conducted to assess whether the data exhibits a spatial bias toward urban areas or if the observations are more evenly distributed among the three ecosystem types.

We also calculate the minimum distance of each record to the closest urban and rural area. With this information we performed an ANOVA test to show whether the means of the distances between the two areas are different or which are smaller.

Reclassification of CORINE LandCover and human population was performed in ArcGIS for Desktop v 10.8 (ESRI, 2019) using the function *Reclass*. Data analysis (ANOVA and minimum distances) and visualization were performed using the R software (version 4.3). The *ggplot2* package was used for creating graphs and *sf* and *dplyr* to the distance calculation.

3. Results

The analysis showed temporal trends in the annual frequency of butterfly observations across the three ecosystem types: forests, grasslands, and urban areas. The total number of observations increased steadily for all ecosystem categories from 2000 to 2023 (Figure 2A). Observations in forest areas showed a consistent increase throughout the study period, contributing significantly to the overall dataset (linear adjustment $y= 1561.7x - 7654.8$, $R^2= 0.9431$). Observations in grassland ecosystems exhibited the highest growth rate over the study period, surpassing urban areas and approaching the number of observations recorded in forests toward the end of the analyzed period (linear adjustment $y= 1379.2x - 6764.4$, $R^2= 0.9453$). Finally, observations in urban areas also increased over time but at a slower pace compared to forests and grasslands (linear adjustment $y= 362.17x - 1884.4$, $R^2= 0.9266$). Following this, the increase of urban records is the smallest among all the studied ecosystem categories (Δurban = 362.17 < Δforest = 1561.7 and Δgrasslands =1379.2).

The same pattern is observed with the area types and the butterfly records by year (Figure 2B). In this case, the number of peri-urban and urban registers is much lower than the number of rural registers, which shows that the annual increases are also smaller (linear adjustment$_{rural}$: y= 2874.2x - 14205, R^2= 0.9429; linear adjustment$_{periurban}$: y= 292.02x - 1463.3, R^2= 0.9266; linear adjustment$_{urban}$: y = 286.8x - 1367.7; R^2= 0.9266).

The mean of the distances of each record to rural and urban areas are different (ANOVA: F= 3019.8; p< 2e-16) being higher to the urban areas and smaller to rural areas (Figure 3). This and previous analyses demonstrate that citizen science records pertain to photographs of volunteers and appear to be unbiased by proximity to cities.

4. Discussion

The study reveals the consistent growth in butterfly records across all ecosystem types over a 23-year period (an average of ~3500 butterfly photographs and records per year). Rural and natural areas contributed considerably more observations than urban regions. These findings challenge the commonly perceived urban bias in citizen science data, demonstrating instead a more balanced spatial distribution of observations.

There was greater growth in records and a higher number of observations in non-urban in our results, contrasting with those of Hugo and Hazell (2017). These authors found a greater sampling effort near urban areas and main roads in South Africa, a pattern that could be influenced by the own region or country characteristics and associated accessibility challenges. Also, in contrast with our results, Geldmann et al. (2016) observed that in Denmark, higher population density correlated with increased sampling intensity across species datasets, suggesting that cultural and demographic factors, play a significant role in shaping sampling patterns. These differences highlight the importance of regional characteristics and participant motivations in influencing data collection efforts. The Iberian Peninsula has a much higher proportion of rural and natural areas compared to other European countries (EUROSTAT, 2024) and has few dangerous organisms to humans (i.e.: poisonous and toxic fauna, parasites and vectors of diseases and endemic diseases) compared to other countries in the world (Li et al., 2024). This, together with relatively favorable climatic conditions, could explain the differences observed in the contributions of other authors. Moreover, the cultural factor may also play an important role in the non-existence of this bias in this territory. For example, in certain areas of the Iberian Peninsula (Catalonia) a usual and recurrent hobby of people is to go into the natural areas to contribute to photographs and data of wildlife.

The distances of records to natural areas were consistently shorter than those to urban areas, suggesting a deliberate cultural preference for documenting biodiversity in natural environments. It is plausible that the recreational and aesthetic appeal of these areas motivates participants to engage in citizen science projects, although further research is needed to confirm how these factors influence participation. Cultural perceptions of natural areas as biodiversity-rich spaces may also play a significant role, with participants prioritizing these areas based on their intrinsic ecological and educational value (Hugo & Altwegg, 2017). While accessibility influences spatial biases to some extent (Millar et al., 2019), the intentional focus on natural habitats reflects broader sociocultural and motivational drivers. These findings emphasize the need to account for both logistical and cultural factors when interpreting spatial patterns in citizen science data, underscoring the importance of proper study design and statistical adjustments to maximize the utility and representativeness of these datasets (Brown et al., 2019; Robinson et al., 2018).

The Iberian-Balearic region demonstrates a relatively well-represented sampling effort for butterflies (García-Barros et al., 2023), however some rural areas still need to be more sampled (e.g,: grasslands areas of the central Iberian Peninsula used for agricultural activities). As a geographically critical biodiversity hotspot, the Iberian Peninsula faces challenges such as rural abandonment and urban concentration, which could introduce geographic biases in data collection (Pascual et al., 2011; Quintas-Soriano et al., 2023). However, the results of this study align with those from well-sampled regions such as Great Britain, where most of the territory is well-represented, and spatial biases have not negatively impacted distribution models for birds (Johnston et al., 2020).

The Iberian Peninsula, as a well-sampled region, provides an excellent case for employing citizen science data, particularly using platforms like *Biodiversidad Virtual*. This study demonstrates that, at least for this platform, urban biases are minimal, and geographic representation is robust. This may allow us to affirm with more confidence, for example, that the observation of a species in an urban area rather than a rural area is not due to a bias in the information from a citizen science source, but rather to a real pattern. Citizen science data represent a valuable resource, significantly reducing economic costs and accelerating knowledge generation by eliminating traditional data collection processes. However, it is crucial to analyze each database and region individually, as cultural factors may influence data collection patterns. Identifying and minimizing biases and errors within these datasets will enhance their transformation into robust scientific data, maximizing their utility and ensuring their effective application in ecological research and conservation planning.

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Figures

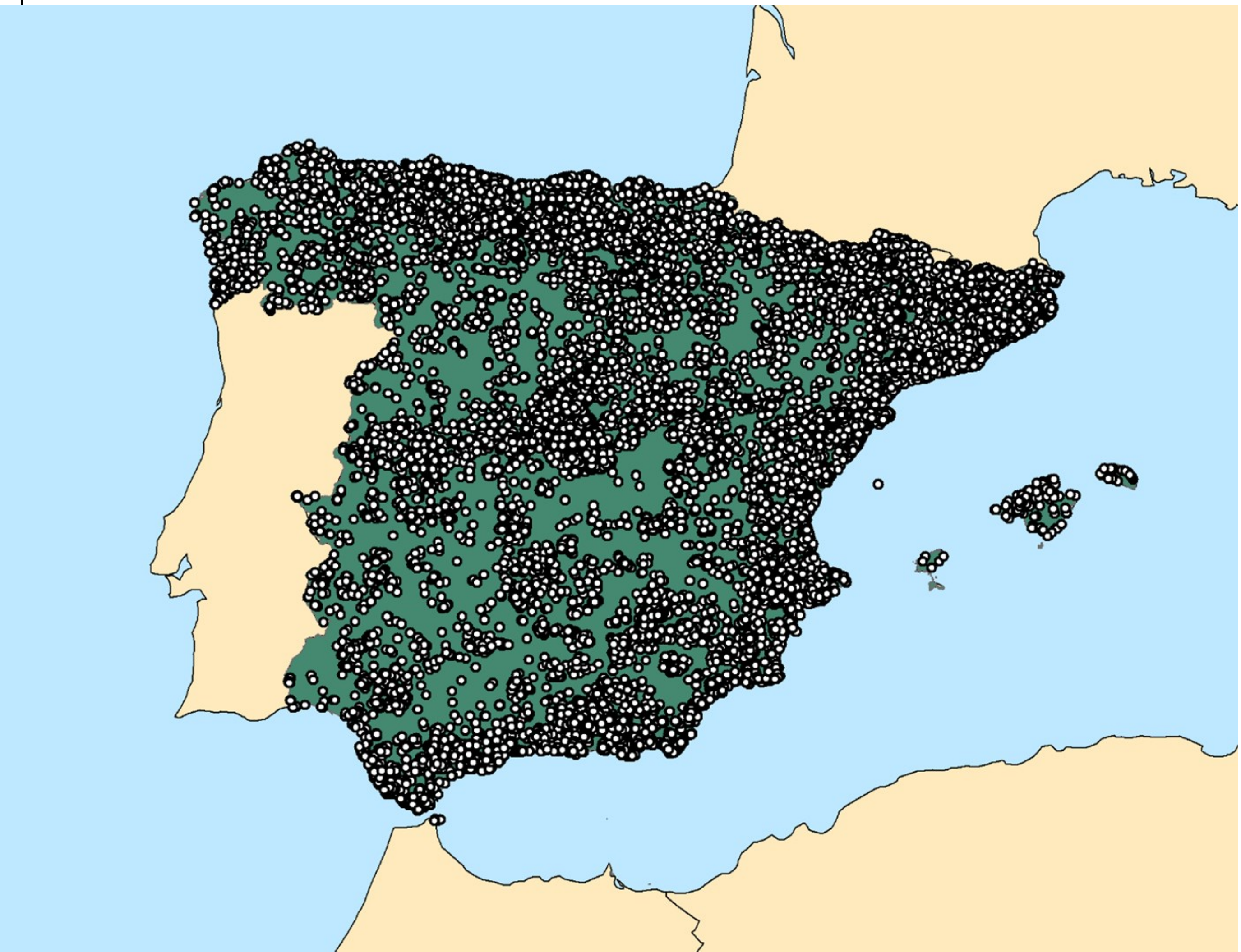

Figure 1. Geographic distribution of butterfly observations in the Iberian-Balearic region

Map showing butterfly records from the *Biodiversidad Virtual* database. Only records from the Iberian-Balearic region are represented and included in the analysis due to the high representativeness of this territory.

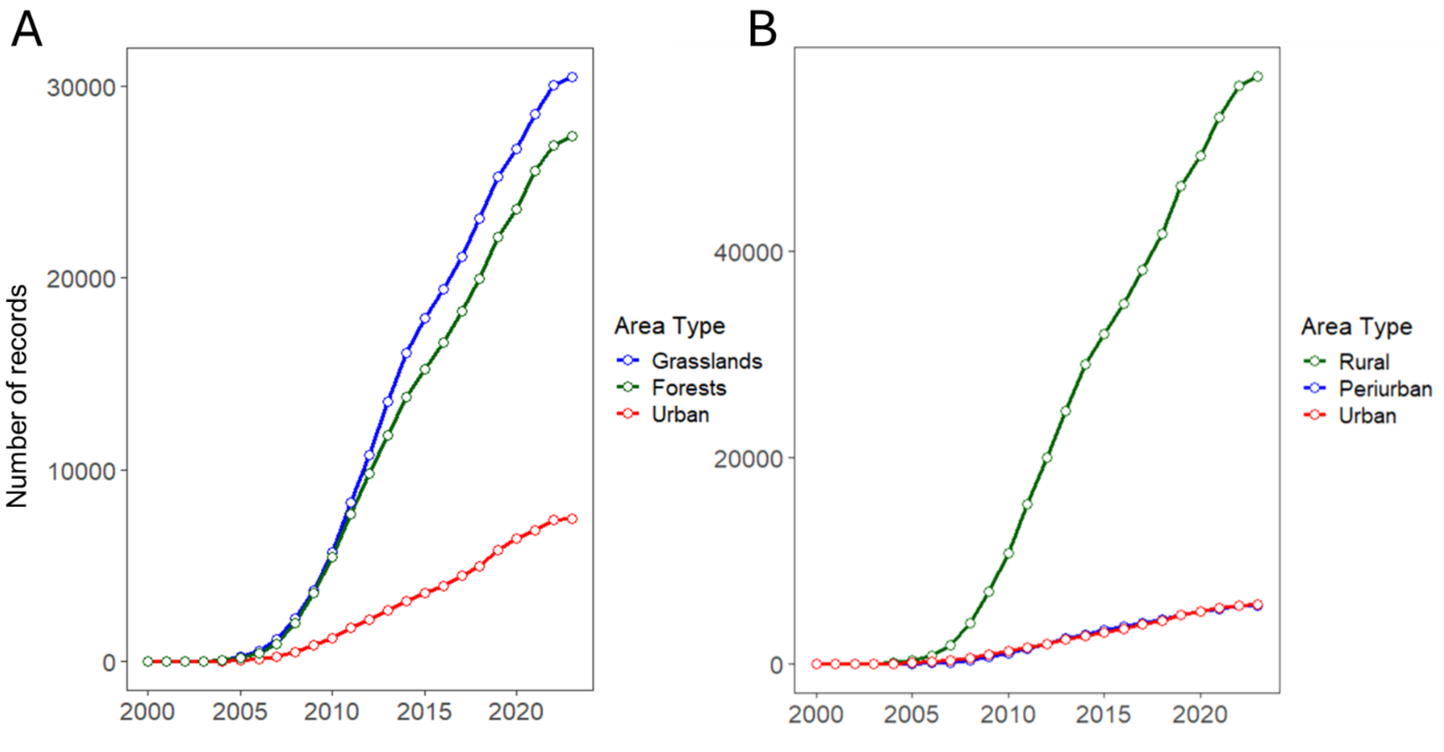

Figure 2. Temporal trends in butterfly observations by ecosystem type A) Temporal trends in cumulative butterfly observations across three ecosystem types: forests, grasslands, and urban areas, based on data collected through the citizen science platform *Biodiversidad Virtual* between 2000 and 2023. B) Temporal trends in cumulative butterfly observations across three area types: rural, periurban, and urban areas.

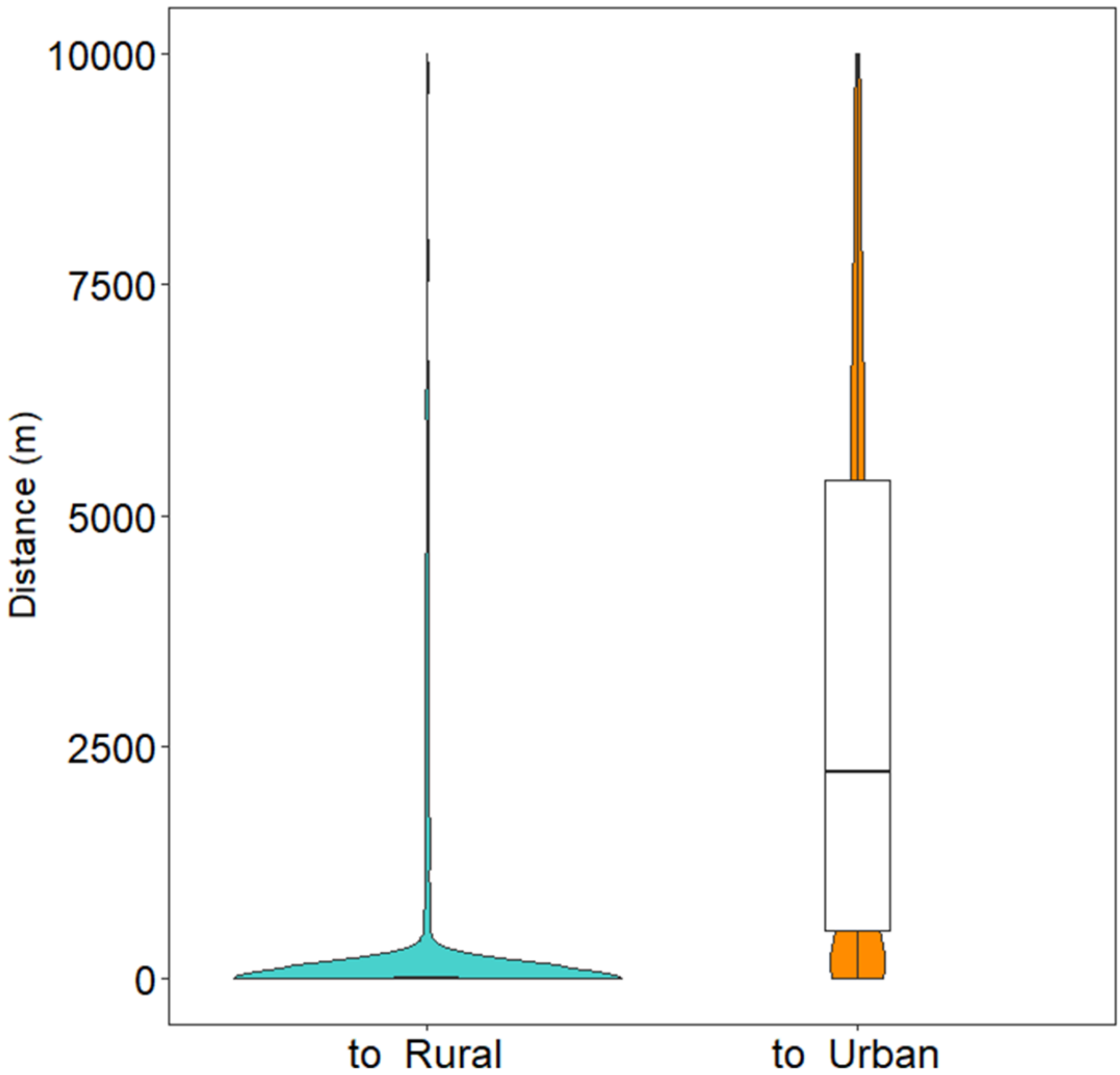

Figure 3. Distance analysis of butterfly observations to rural and urban areas Violin and boxplot plot with the minimum distances in meters of each record of butterflies from *Biodiversidad Virtual* database to the closest rural and urban area.

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