Universidade de Évora - Escola de Ciências e Tecnologia

Mestrado em Biologia da Conservação

Dissertação

Applying IUCN criteria for endemic species from the Cixiidae family (Hemiptera: Fulgoromorpha) in the Madeira archipelago.

Luena Soraya Kaiser Marques

Orientador(es) | Dora Aguín Pombo
Diogo André Alagador

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Applying IUCN criteria for endemic species from the Cixiidae family (Hemiptera: Fulgoromorpha) in the Madeira archipelago.

Abstract

Madeira is a key part of the biodiversity hotspot within Macaronesia, where Cixiidae planthoppers have an endemicity rate of 86%. However, only a few species of this family have been assessed under the IUCN Red List, all classified as threatened, highlighting significant conservation concerns. Six of the seven species on Madeira are endemic, yet none has been evaluated. This study addresses this gap by applying Criterion B of the IUCN Red List to assess these species. Sampling, adult monitoring, and species distribution models were used to gather occurrence data and evaluate threats. The results reveal that all six endemic species are considered rare and classified as "Endangered", except *Cixius wollastoni*, which is "Critically Endangered." The study also confirmed the presence of *Tachycixius chaoensis* on Ilhéu Chão. Threats like tourism, invasive plants, and urbanization are discussed, emphasizing the urgent need for conservation plans to protect these species and their habitats.

Key-words: Auchenorrhyncha | Biology | Conservation | Distribution models | Macaronesia

Aplicação dos critérios da UICN para as espécies endémicas da família Cixiidae (Hemiptera: Fulgoromorpha) no arquipélago da Madeira.

Resumo

A Madeira é uma parte essencial do hotspot de biodiversidade da Macaronésia, onde os Cixiidae têm uma taxa de endemismo de 86%. No entanto, poucas espécies desta família foram avaliadas na Lista Vermelha da UICN, todas classificadas como ameaçadas, destacando preocupações de conservação. Seis das sete espécies da Madeira são endémicas, mas nenhuma foi avaliada. Este estudo preenche essa lacuna aplicando o Critério B da Lista Vermelha da UICN para avaliar estas espécies. Amostragem, monitorização e modelos de distribuição de espécies foram usados para obter dados de ocorrência e avaliar ameaças. Os resultados mostram que todas as seis espécies endémicas são raras e classificadas como "Em Perigo", exceto *Cixius wollastoni*, "Criticamente Em Perigo". O estudo também confirmou a presença de *Tachycixius chaoensis* no Ilhéu Chão. Ameaças como turismo, plantas invasoras e urbanização são discutidas, sublinhando a necessidade urgente de planos de conservação para proteger estas espécies e habitats.

Palavras-chave: Auchenorrhyncha | Biologia | Conservação | Macaronésia | Modelos de Distribuição

Index

Contact Details iii
Acknowledgments iv
Abstract vi
1. Introduction 7
2. General Aspects and Overview 10
2.1 Protected Areas and Species Conservation 10
2.1.1 Protected Areas 10
2.1.2 Species Conservation: Importance of IUCN Red Lists 11
2.2 Insect Crisis and their Conservation Problems 12
2.2.1 The Family Cixiidae 13
2.2.1.1 Taxonomy and Systematics 13
2.2.1.2 Origin, Diversity and Endemicity 13
2.2.1.3 Bioecology and Life Cycle 14
2.2.1.4 Diversity in the Macaronesia Region 15
2.3 Conservation of Macaronesian Biodiversity: The Madeira Archipelago 17
2.3.1 Location and Geological Characterization 18
2.3.2 Climate 19
2.3.3 Fauna and Flora 20
2.3.4 Management and Protection 21
2.3.5 Madeira's Species on the IUCN Red List 22
3. Study Area: Vegetation 25
4. Material and Methods 27
4.1 Insights into the Experimental Design 27
4.2 Sampling for Occurrence Data 29
4.2.1 Sampling Location and Design 29
4.2.2 Selection of Food Plants for Sampling 31
4.2.3 Sampling Method 32
4.2.4. Sampling Periods 33
4.2.6 Ethical Considerations 38
4.2.7 Quality Control 38
4.2.8 Safety Measures 38

4.3 Adult Monitoring 39
4.3.1 Sampling Location and Design 39
4.3.2 Sampling Method 44
4.3.3 Sampling Data 45
4.4 Conservation, Preparation and Species Identification 46
4.5 Georeferencing of Data from Literature and Collections 46
4.6 Data Analysis 47
4.6.1 Habitat and Ecology 48
4.6.2 Adults Monitoring 49
4.6.3 Population Abundancy 50
4.6.4 Distribution 51
4.6.5 Rarity Evaluation 58
4.6.6 Conservation Status 59
5. Results 62
5.1. Habitat and Ecology: Habitat Specificity and Food Plants 62
5.2 Adult Monitoring 64
5.3 Population Abundancy 69
5.4 Distribution 73
5.4.1 Maps of Occurrence 73
5.4.2 Modelling 76
5.4.3 Geographic Range 79
5.5. Analysis of Rarity According to Rabinowitz 81
5.6 Conservation: Threats and IUCN Assessment 83
6. Discussion 88
6.1 Vulnerability and Conservation Status of Cixiidae 89
6.2 Major Threats to Cixiidae on Madeira Island 90
6.3 Challenges of Applying IUCN Criteria to Insects on Oceanic Islands 92
6.4 Conservation Measures Based on Field Sampling and IUCN Assessment 96
6.5 Final Considerations and Future Directions 101
Bibliography 103
Annexes 121

Figure Index

Figure 1 | Map of the Madeira Archipelago..18

Figure 2 | Sampling in 2 x 2 km grids system for *Cixius* spp. (A, C) and *Hyalesthes* spp. (B, D) indicating the number of sampling points in each. Preliminary (A, B) and final (C, D) sampled grids and points on Madeira Island. 29

Figure 3 | 500m x 500m grids sampled (in green) for *Tachycixius chaoensis* (China, 1938). Madeira Island: Ponta de São Lourenço (A) and islets (B). Desertas Islands: Ilhéu Chão (C) and Deserta Grande (D)...31

Figure 4 | Monitoring sites for each genus/species. (A) Location of the three study areas. (B) Handrail present on site 1 of *Cixius* spp. Monitoring of *Cixius* spp.: (C) Site 1 habitat, (D) Site 2. *Hyalesthes portonoves* monitoring area (E). *Tachycixius chaoensis* sampled area (F), in green and in red the distance to the beginning of the Vereda da Ponta de São Lourenço. 43

Figure 5 | Geographic Range Assessment of Cixiidae Using IUCN Red List Criterion B. Source: IUCN 2012. 61

Figure 6 | Habitats of the Cixiidae species on Madeira Archipelago. (A-C) Laurel forest, (D,E) *Globularia salicina* habitat, and (F) coastal xerophytic habitat of *Suaeda vera*. Species: *Cixius madeirensis* (A), *C. verticalis* (B), *C. wollastoni* (C), *Hyalesthes madeires* (D), *H. portonoves* (E), and *Tachycixius chaoensis* (F). Localities: Madeira Island: (A) Fanal, (B) Rabaçal, (C) Ribeiro Frio, (D) Santana, (E) Caniço), (F) Ilhéu Chão..62

Figure 7 | Adults recorded during one year monitoring indicating in the graph the density/number of specimens (green), temperature (orange) and humidity (blue) on the sampling moment and food plant condition.: *Cixius madeirensis* and *C. verticalis* (A), *Hyalesthes portonoves* (B) and *Tachycixius chaoensis* (C). Below the graph, sampling periods for each micro-habitat are represented: Purple = Site 1 (*Argyranthemum pinnatifidum* subsp. *pinnatifidum, Clethra arborea* and handrail*;* Grey = Site 2 (ferns and trees). Abbreviations: DC = *Diplazium caudatum*, BS = *Blechnum spicant* subsp. *spicant*, AF = *Athyrium filix-femina*, F = fern, CA = *Clethra arborea*, Cr = *Crocosmia* sp., AP = *Argyranthemum pinnatifidum* subsp. *pinnatifidum*, H = handrail, PI = *Pteris incompleta*..67

Figure 8 | Sampling area of *Tachycixius chaoensis* in Ponta de São Lourenço, delimited by a white line, indicating absence (A) and presence (B) records..69

Figure 9 | Sampling points with presences and absences of *Cixius* spp. (A) and *Hyalesthes* spp. (C). Occurrence maps: (B) *Cixius madeirensis* (CMAD), *C. verticalis* (CVERT), and *C. wollastoni* (CWOL); (C) *Hyalesthes madeirensis* (HMAD) and *H. portonoves* (HPORT). "Maybe" are captures without males. Source: 2×2 km sampling from this study and previous records from publications and the UMACI collection...74

Figure 10 | Sampling points with presences and absences of *Tachycixius chaoensis* in the Madeira Archipelago (A). Madeira Island: Ponta de São Lourenço (B), Ilhéu da Cevada (C), and Ilhéu do Farol (D). Desertas Islands: Deserta Grande (E) and Ilhéu Chão (F). Sources: 500×500 m sampling from this study and previous records from the UMACI collection.........................75

Figure 11 | Species Distribution Model obtained with MaxEnt for (A) *Cixius* spp. and (B) *Globularia salicina*, used to model the distribution of (C) *Hyalesthes* spp..............................77

Figure 12 | Species Distribution Model obtained with MaxEnt for (A, B) *Suaeda vera* and (C, D) *Tachycixius chaoensis*, with (A, C) showing Madeira Island only, and (B, D) including the Desertas Islands...78

Figure 13 | Species Extent of Occurrence (EOO) and Distribution Models. (A-C) Species Extent of Occurrence (EOO) based on occurrence data: (A) *Cixius madeirensis*, *C. verticalis*, and *C. wollastoni*; (B) *Hyalesthes madeirensis* and *H. portonoves*; (C) *Tachycixius chaoensis*. (D-F) Species distribution model obtained with MaxEnt for genera *Cixius* (D), *Hyalesthes* (E), and species *T. chaoensis* (F), considering both Madeira and Desertas Islands models (all – MAD+DES) and the Madeira-only model (MAD). Results are shown in maps with a 2×2 km grid used for measuring the area of occupancy (AOO). Abbreviations: CMAD – *C. madeirensis*, CVERT – *C. verticalis*, CWOL – *C. wollastoni*, HMAD – *H. madeirensis*, HPORT – *H. portonoves,* TC – *T. chaoensis*. Source: 2×2 km sampling for *Cixius* and *Hyalesthes* and 500×500 m sampling for *T. chaoensis* from this study and previous records from publications and the UMACI. 80

Figure 14 | Impacts on areas where *Hyalesthes* and/or *Globularia salicina* have been recorded recently and/or in the past. Urbanization from 2004 (A, C) to 2024 (B, D). Impacts include road construction (E), changes in land use for agriculture (F), production forestry (G), and wildfires (H). Localities: A-B, São Vicente; C-D, Santa Cruz (Aeroporto); E, Machico; F, Câmara de Lobos; G, Fajã da Ovelha; H, Serra d' Água (2024 wildfire). Source: Google Maps (A-D) and personal photographs (E-H). 84

Figure 15 | Impacts observed during 2023-2024 on areas where *Tachycixius chaoensis* and *Suaeda vera* are present. Types of impacts: touristic pressure (A-C) and erosion (D). (A) Tourists leaving the trail and stepping on suitable habitat; (B) Number of tourists observed in a single day (13/07/2023); (C) Cars parking on suitable habitat; (D) Soil erosion caused by coastal landslide due to marine erosion. Localities: Madeira Island, Ponta de São Lourenço (A, C) and Ilhéu Chão (D). Source: Personal photographs by the author (A, C, D) and data from Associação Insular de Geografia (AIG). 86

Figure 16 | Major threats to terrestrial insects evaluated by IUCN Red List in Madeira Island. 9090

Table Index

Table 1 | Ecological characteristics, distribution, and host plant associations of various Cixiidae species across the Madeira Archipelago. Md = Madeira Island, IC = Ilhéu Chão, S = South, N = North, Ap = April, M = May, J = June, A = August, S = September, O = October. Source: Freitas & Aguín-Pombo 2021. 16

Table 2 | IUCN Red List assessment for all evaluated Cixiidae species. Source: IUCN Red List 2025. 24

Table 3 | Characteristic vegetation of the mid-story of the Mediterranean Laurel Forest and the temperate Laurel forest. Source: Capelo *et al.* (2007). 26

Table 4 | Number of sampling days per month. J = January, F = February, Mr = March, Ap = April, M = May, Jn = June, Jl = July, A = August, S = September, O = October, N = November, D = December. Sources: publications, University of Madeira Insect Collection and sampling for this study. 34

Table 5 | Monitoring dates for adults of the target genus/species in the Cixiidae family. 40

Table 6 | Data used in model species distribution and their projection, format, and source. ...52

Table 7 | Ranked variables according to importance used for modeling habitat suitability for cixiids and host plants and with the respective output models. M = Madeira, D = Desertas. 53

Table 8 | Number of host plant occurrences (presences) from GBIF and occurrences and absences of cixiids obtained from field sampling and UMACI collection. 54

Table 9 | Coefficients of Determination (r^2) between bioclimatic variables and average altitude at 1 km^2 Scale. 55

Table 10 | Population density estimates of *Cixius* spp. and *Hyalesthes* spp. based on capture rate per 100 beats. Sampling: Presence vs. Total Area. Source: sampling data from 2022-2024. 70

Table 11 | Total Number of sites with insects and individuals captured, including mean (± SD), median, and maximum individuals per site. Source: Sampling data from this study and recorded data from UMACI Collection. 71

Table 12 | Total number of sites with insects and individuals captured, including mean (± SD), median, and maximum individuals per site. Source: Sampling data from this study and recorded data from UMACI Collection. 72

Table 13 | Extent of Occurrence (EOO) and Area of Occupancy (AOO) for Cixiidae species: Comparison of occurrence data with MaxEnt species distribution model. Source: This study, published records, and UMACI Collection..81

Table 14 | Evaluation of rarity based on Rabinowitz (1981) for Cixiidae species and endemic coexistent Auchenorrhyncha species, *Issus maderensis* and *Cyphopterum* species..................82

1. Introduction

Cixiidae planthoppers are phytophagous insects of the Auchenorrhyncha suborder predominantly distributed in tropical and subtropical regions (Gullan & Cranston 2014). They rely on specific hosts for feeding and reproduction (Attié *et al.* 2008). Some species exhibit a fully subterranean (troglobitic) life cycle, while others feed on roots at nymphal stages and on the aerial parts of plant tissues while adults (epigeans) (Hoch 2002). Despite their ecological importance, the conservation status of most species of this family is unknown, especially in vulnerable island habitats (IUCN 2025).

In the biodiversity hotspot of Macaronesia — which includes the Azores, Madeira, the Canary Islands, the Salvage Islands, and Cape Verde — evolutionary radiation has fostered remarkable levels of endemism across insect taxa (Fernández-Palacios 2010). For instance, the beetle genus *Laparocerus* Schoenherr, 1834 comprises 237 species and subspecies endemic to Macaronesia and the Macaronesia enclave in Morocco (Machado *et al.* 2017).

The family Cixiidae is no exception, with 41 species recorded in the region and an impressive endemism rate of 86% (Fennah 1967, van Stalle 1986, 1987a, 1987b, Hoch *et al.* 1999, Emeljanov 2007, Borges *et al.* 2008, Oromi *et al.* 2010, Ferreira *et al.* 2016, Freitas & Aguín-Pombo 2021, Azorean Biodiversity Portal 2024). Tenerife, La Palma, and Madeira islands host the highest numbers of island-specific Cixiidae species, with Tenerife hosting seven endemics, and La Palma and Madeira each harboring six. It is highly probable that certain species will warrant targeted conservation measures. Of the 2640 Cixiidae species described globally, only eleven have been assessed by the IUCN Red List, most are found in island ecosystems (Azores and Saint Helena). Of these, eight occur in Macaronesia, six of which are classified as Threatened and the other two as Near Threatened (IUCN 2025). These numbers emphasize the vulnerability of Cixiidae in insular environments. Madeira archipelago has seven Cixiidae species, six of them are endemic, and all remain unassessed. The endemic species belong to the genera *Cixius* Latreille, 1804, *Hyalesthes* Signoret, 1865, and *Tachycixius* Wagner, 1939, while *Pentastiridius* *leporinus* (Linnaeus, 1761) is an introduced species. The most recently described species is *Cixius wollastoni* Freitas & Aguín-Pombo, 2021.

The endemic species inhabit diverse ecological niches, primarily in areas with native vegetation. *Tachycixius chaoensis* (China, 1938) thrives in xerophytic habitats at low altitudes, apparently feeding exclusively on *Suaeda vera* (Forssk. ex J.F.Gmel, 1776). *Hyalesthes* species are found in coastal thermophilic shrub communities, relying on *Globularia salicina* Lam., 1788 while *Cixius* species inhabit the laurel forest (Freitas & Aguín-Pombo 2021). However, knowledge gaps persist concerning their ecological and habitat preferences, distribution, and host plant relationships, leaving their conservation needs unaddressed.

Despite Madeira being a recognized biodiversity hotspot (Cruz *et al.* 2009, Boieiro *et al.* 2015), there is a significant lack of evaluations of conservation status for many species, extending far beyond the Cixiidae family. Of the 7452 terrestrial species (Borges *et al.* 2008), only 7% have been assessed by the IUCN Red List criteria, and arthropods fare even worse, with only 2% evaluated (IUCN 2025). The IUCN Red List is one of the few comprehensive and globally recognized frameworks capable of identifying insect species in urgent need of conservation measures. Unlike other checklists or legal frameworks, such as the EU Habitats Directive or Bern Convention, which include very few insect species (Cardoso *et al.* 2011a), the IUCN provides an essential platform for assessing biodiversity at a species-specific level (Samways 2018). It helps to pinpoint species at risk, offering a foundation for conservation planning that is unavailable through other mechanisms (Leandro *et al.* 2017).

Assessing insects using IUCN criteria is particularly challenging, which may explain why only 7% of all species evaluated worldwide are insects. Eighty percent of the insect species assessed as endangered by the IUCN use Criterion B, reflecting a heavy reliance on distribution data (IUCN 2025). This dependence stems from the lack of long-term population studies. Criterion B evaluates species based on geographic range, including Extent of Occurrence (EOO), Area of Occupancy (AOO), and additional threats like habitat fragmentation and population decline (IUCN 2012). However, Criterion B evaluations are often hindered by sparse or outdated data and the lack of long-term population studies

(Cardoso *et al.* 2011b). To address these challenges, IUCN assessment increasingly incorporates Species Distribution Modeling (SDM) (Fivaz & Gonseth 2014). SDM uses environmental data and known species distributions to predict potential distribution ranges, even in the absence of extensive field data (Jiménez-Valverde *et al.* 2008, Guisan *et al.* 2017, Ferreira *et al.* 2019, Sillero *et al.* 2021). By integrating environmental variables with occurrence records, SDM identifies critical habitats, provide valuable insights into ecological niches, identify at-risk populations, and help prioritize conservation actions effectively. Integrating such models with field research and updated monitoring can significantly enhance outcomes for insects' conservation (Cardoso *et al.* 2011b, Wagensommer *et al.* 2020). Although the application of SDM in insect research has grown in the last years, the focus remains biased towards the distribution of invasive or pest species (Tabor *et al.* 2021, Early *et al.* 2022, Lee *et al.* 2022, Wen *et al.* 2024).

Within Hemiptera, most SDM studies focus on Heteroptera (Zhu *et al.* 2012, Dias-Silva *et al.* 2013, Minghetti *et al.* 2024), while Auchenorrhyncha remains comparatively understudied, particularly in the context of conservation. Among Auchenorrhyncha, only two studies have applied SDM for conservation purposes: Strauss & Biedermann (2005) examined several leafhopper species (*Verdanus bensoni* (China 1933), *Rhopalopyx vitripennis* (Flor, 1861), *Macrosteles quadripunctulatus* (Kirschbaum, 1868), *Neophilaenus minor* (Kirschbaum, 1868), and *Kelisia sabulicola* (Wagner, 1952) in Germany, and Ran *et al.* (2024) studied the genus *Limassola* Dlabola, 1965 in Asia. However, no studies have focused on the potential use of SDM for endemic species within the Cixiidae family. Instead, SDM has been used to study pest outbreaks of invasive species, such as *Hyalesthes obsoletus* Signoret, 1865 (Panassiti *et al.* 2013). Additionally, insular insects are underrepresented in SDM research, which often centers on invasive pests, with native or endemic taxa, especially pollinators, addressed only sporadically (e.g., Aparício *et al.* 2018, Miličić *et al.* 2017, Picanço *et al.* 2017).

The primary aim of this study is to assess the conservation status of six endemic Cixiidae species from Madeira using IUCN Criterion B together with SDM. The use of SDMs in IUCN evaluations provides a valuable framework for conserving underrepresented groups such as these in island ecosystems where species face amplified extinction risks due to isolation, small population sizes, and vulnerability to environmental and anthropogenic pressures. By evaluating these species, the study bridges a critical gap in understanding the conservation status of the biodiversity of Madeira’s hotspot. The research will test three main hypotheses: (i) Major threats such as invasive species, tourism, and urbanization significantly contribute to the decline of Madeira's Cixiidae populations, making targeted conservation interventions essential for their survival; (ii) The vulnerability of Cixiidae species on Madeira is exacerbated by their limited geographic distribution and specialized habitat requirements, making them highly susceptible to environmental disturbances and human-induced threats; (iii) Applying IUCN criteria to insects on oceanic islands like Madeira presents unique challenges due to limited data, leading to potential underestimation of the conservation needs of endemic species.

2. General Aspects and Overview

2.1 Protected Areas and Species Conservation

2.1.1 Protected Areas

Protected areas play a vital role in biodiversity preservation by offering refuges that shield ecosystems from human interference and other pressures. These spaces are designed to conserve natural values, safeguard species, and support ecosystem resilience (Dudley 2008, Pereira 2023). Currently, 17.5% of terrestrial and 8.46% of marine areas are under protection globally, reflecting the growing recognition of their importance for biodiversity conservation (Protected Planet 2024).

The establishment and management of protected areas follow standardized guidelines developed by the IUCN, which categorize them according to different primary management goals, such as strict nature reserves, wilderness areas, national parks among others (Dudley 2008). In Portugal, these areas classified according to their ecological, cultural, and scientific value, align with IUCN principles to prevent environmental degradation (Protected Planet 2024). Protected areas are designated to conserve natural assets, protect endangered or rare species, and ensure the long-term management of local biodiversity. They serve as critical spaces for residents, surroundings, and migratory species by controlling human activities such as deforestation, overfishing, hunting, urbanization, tourism, and mining. These areas also facilitate research and monitoring, enabling species to be studied in their natural habitats under minimal human impact (Watson *et al.* 2014, Pereira 2023). Despite their critical importance, protected areas face a range of significant challenges such insufficient funding, limited political support, and slow progress in implementing conservation measures undermine their effectiveness (EEA 2024, EC 2020). Climate change further exacerbates these issues by disrupting ecosystems and shifting species distributions, often exceeding the scope for which many protected areas were initially designed (Neilson *et al.* 2005, Araújo *et al.* 2011, Alagador *et al.* 2014). Furthermore, economic pressures from agriculture and development, and competing land-use interests, undermine conservation efforts (EC 2024, Stoll-Kleemann 2010, Deus *et al.* 2018, Kati 2015). Many protected areas are in regions with lower economic value, resulting in neglect and inadequate funding. Moreover, outdated management strategies hinder the achievement of long-term conservation goals (Joppa & Pfaff 2009, Daru *et al.* 2019).

2.1.2 Species Conservation: Importance of IUCN Red Lists

The IUCN Red List is an essential global framework for assessing extinction risks of species. It uses a standardized set of criteria to evaluate species conservation status, categorizing them into threat levels ranging from "Extinct" (EX) to "Least Concern" (LC). The most critical categories - "Critically Endangered" (CR), "Endangered" (EN), and "Vulnerable" (VU) - highlight species at the greatest risk of extinction (IUCN Standards and Petitions Committee 2024).

Species assessment of extinction risk is based on five criteria (A-E) that measure factors such as population decline, restricted distribution, small populations size, and threats (IUCN 2016). Criterion A evaluates whether a species is experiencing or is projected to experience a significant decline, analyzing the underlying causes and whether they can be managed effectively. Criterion B assesses whether a species has a restricted distribution that is severely fragmented, undergoing continuous decline, or facing extreme fluctuations. It also considers "locations," which is a specific geographical or ecological area where a single threat has the potential to quickly impact the whole population of a species living there. Criterion C looks at whether a species has small populations that are currently declining or will decline soon. Criterion D identifies species with small or restricted populations that are facing imminent threats. Lastly, Criterion E uses quantitative methods, such as population viability analyses (PVAs), to estimate the likelihood of a species' extinction in the wild (IUCN 2012). Applying these criteria requires several types of data. However, data deficiencies remain a significant challenge, especially for under-researched species, particularly insects (Montgomery *et al.* 2020, Wang *et al.* 2021). The importance of the IUCN's criteria is that, even for species with limited data, assessments can be done (IUCN 2012).

By using the best available data, these assessments help focus conservation efforts, ensuring that resources are effectively used to protect biodiversity. They also provide a basis for targeted conservation strategies, helping to address the complex challenges species face today (Butchart *et al.* 2010, IUCN 2016).

2.2 Insect Crisis and their Conservation Problems

The biodiversity crisis is accelerating at a critical rate, driving an ever-growing number of species dangerously close to the brink of extinction (Black 1989, Cowie *et al.* 2022). Among the most alarming and underreported aspects of this crisis is the dramatic decline in insect populations, often called the "insect apocalypse" due to habitat destruction, climate change, and pesticide use (Hochkirch 2016, Goulson 2019, Cardoso *et al.* 2020, Hallmann *et al.* 2022, Zhou *et al.* 2023). It is particularly concerning that the full extent of this decline remains poorly understood, as millions of insect species are still undiscovered or insufficiently studied (Dunn 2005, Fonseca 2009, Cardoso *et al.* 2011a Rocha-Ortega *et al.* 2021).

This crisis is exacerbated by taxonomic biases that favor more charismatic species, leaving most insect populations unassessed and insufficiently protected (Leather 2009, Cardoso *et al.* 2011a). Of the estimated 5.5 million insect species worldwide, only 1 million have been described, and a mere 12,747 species have been evaluated by the IUCN Red List (Stork 2018, IUCN 2025). Even within this limited subset, 26% are categorized as Data Deficient. Furthermore, half of the 24 insect orders included in the IUCN Red List have fewer than ten species assessed. Assessments often focus well-studied and visually striking orders, such as Odonata, Coleoptera, Lepidoptera, and Orthoptera (Leandro *et al.* 2017). Among Hemiptera, the Cixiidae family, characterized by high endemism and exceptional rarity in the region, offers a striking example of this knowledge gap.

2.2.1 The Family Cixiidae

2.2.1.1 Taxonomy and Systematics

The Cixiidae family, belonging to the suborder Auchenorrhyncha in Hemiptera, consists of small, plant-feeding insects that feed on plant sap (Gullan & Cranston 2014). They exhibit a median ocellus, spiny hind tarsi, and a long ovipositor (Muir 1925, Müller 1942, Kramer 1983). The family has unique bristle-like antennae, distinguishing it from other planthopper families (Liang 2005, Meng & Qin 2019). Although molecular studies have advanced the understanding of their relationships within the Auchenorrhyncha suborder, the phylogenetic relationships among major Cixiidae groups remain unresolved and continue to be a subject of ongoing research (Emeljanov 2002, Liang 2005, Bucher *et al.* 2023).

2.2.1.2 Origin, Diversity and Endemicity

The Cixiidae family includes 2640 species across 254 genera. Fossil records trace their origins back to the Cretaceous period, underscoring their evolutionary success (Luo *et al.* 2021). It is likely that the long-standing established plant-insect relationships since the Early Cretaceous contributed to their diversification (Szwedo *et al.* 2006, Attié *et al.* 2008). Their remarkable adaptability allows them to inhabit a wide range of environments, from tropical regions to temperate forests and deserts (Emeljanov 2002, Holzinger *et al.* 2002).

Cixiidae species exhibit a high degree of habitat specialization and endemism, particularly in isolated environments such as islands. Geographic isolation, coupled with unique ecological niches, leads to high rates of speciation, with endemic species evolving to occupy specific roles within these ecosystems (Jaenike 1990, Luo *et al.* 2022). Island habitats function as natural laboratories for the evolution of endemic Cixiidae, where species adapt to localized environmental conditions. Such isolated settings highlight the link between isolation, ecological specialization, and increased speciation (Attié *et al.* 2008, Silva *et al.* 2016, Hoch *et al.* 2024).

2.2.1.3 Bioecology and Life Cycle

Cixiidae species are plant-feeding insects that can be generalists or have specific plant associations (see Annex 1). They feed on a range of plants, including herbs, shrubs, and trees (Nickel & Remane 2002, Mazzoni *et al.* 2006). Their life cycle unfolds in different habitats depending on the species, either living above ground (epigean) or in underground environments (cavernicolous) (Hoch 2002).

The life cycle of Cixiidae species begins as eggs laid by females on or near the soil surface or plant roots. The eggs are covered by a waxy secretion that protect them from moisture and predators (Müller 1942, Cumber 1952). Once hatched, the nymphs remain underground, feeding on plant roots while avoiding light. Then they pass through five nymphal stages (instars), moving up and down within the soil depending on soil temperature and humidity (de Polanía & Lopez 1977, Langer *et al.* 2003). In epigean species, the final instar nymphs emerge from the soil and move to the aerial part of their host plants, where they molt into adults. In hypogean species from volcanic or cave environments, the nymphs molt and often remain as adults under the ground (Cumber 1952, Silva & Tavares 1995, Pfitzer *et al.* 2022). Depending on environmental conditions, Cixiidae species may complete one or more generations per year (Halbert *et al.* 2014).

As with other phytophagous insects, Cixiidae species interact with plants throughout their life cycle in several ways (Adamson 1932, Attié *et al.* 2008, Burckhardt *et al.* 2014). According to their interactions with insects, plants can be classified as host plants, food plants, causal plants, or overwintering plants. Host plants are those on which the species complete their entire life cycle, from the immature to the adult stage. Food plants are those on which adults feed but do not reproduce or stay for long, while casual plants are places where adults land without feeding or reproducing. Overwintering or sheltering plants provide a refuge for adults during winter and may also serve as a feeding site.

Aggregation behavior is common, with both juveniles and adults often found grouped together on plants (Sforza *et al.* 2013, Bastos *et al.* 2019). However, research on the nymphal stage remains limited, leaving gaps in our understanding of the early phases of their life cycle (Emeljanov 2002).

2.2.1.4 Diversity in the Macaronesia Region

The Cixiidae family in the Macaronesia region consists of forty-one species, 86% of which are endemic to specific islands. Of these, 68% are epigean, while 32% are troglobites, some confined to a single lava tube (Hoch 1991, Hoch & Asche 1993). The taxonomy of the Macaronesian Cixiidae has been challenging due to significant intraspecific variation in body size and genital structures and adaptations to cave life, which has often led to misidentifications (Remane & Asche 1979, Hoch & Remane 1985).

In the Madeira Archipelago, there are seven Cixiidae species. Of these six are endemic and belong to three genera: *Cixius, Hyalesthes*, and *Tachycixius* being *Cixius wollastoni* the most recently described. The only species introduced is *Pentastiridius leporinus*. The endemic species exhibit a range of altitudinal and habitat preferences (Table 1).

Tachycixius chaoensis occurs in xerophytic habitats in low-altitude coastal areas of Madeira Island and Ilhéu Chão (Desertas Islands), feeding exclusively on *Suaeda vera*. The *Cixius* species are associated with humid, shaded areas in the Laurissilva Forest, found at mid-to-high altitudes of Madeira Island while *Hyalesthes* species are mostly in coastal, thermophilic shrub communities, but also in ravines or xerophytic habitats of the Island. *Hyalesthes madeires* feeds on *Globularia salicina* and occurs in areas with constant water flow, while *H. portonoves* is found in xerophytic shrub communities along the southern coast of Madeira, where it also feeds on *Globularia salicina* (Freitas & Aguín-Pombo 2021).

Table 1 | Ecological characteristics, distribution, and host plant associations of various Cixiidae species across the Madeira Archipelago. Md = Madeira Island, IC = Ilhéu Chão, S = South, N = North, Ap = April, M = May, J = June, A = August, S = September, O = October. Source: Freitas & Aguín-Pombo 2021

Species	Distribution			Habitat	Host plants	Adult Period
	Island	Altitude (m)	Shore			
Tachycixius chaoensis (China, 1938)	Md IC		S	Xerophytic	*Suaeda vera*	M
Cixius madeirensis China, 1938	Md	500-1200	N – S	Humid areas of Laurel Forest	*Clethra arborea* *Diplazium caudatum* *Pteridium aquilinum*	Ap - S
Cixius verticalis Noualhier, 1897	Md	Mid to high	N	Humid and shaded areas of Laurel Forest	*Clethra arborea* *Euphorbia mellifera* *Diplazium caudatum* *Persea indica*	Ap - O
Cixius wollastoni Freitas & Aguín-Pombo, 2021	Md	300-1000	N – S	Laurel forests	*Clethra arborea* *Laurus novocanariensis* *Pteridium aquilinum* *Digitalis purpurea*	M - J
Hyalesthes madeires Hoch, 1985	Md	Up to 700	N – S	Thermophilic coastal areas, ravines with constant water, slopes	*Globularia salicina*	M- A
Hyalesthes portonoves Remane & Hoch, 1985	Md	Low to mid	S	Xerophytic shrub communities (coastal cliffs and gorges)	*Globularia salicina*	Ap - A

2.3 Conservation of Macaronesian Biodiversity: The Madeira Archipelago

The Madeira Archipelago belongs to the Macaronesia and the Mediterranean biodiversity hotspot (Myers *et al.* 2000). The biogeographical region of Macaronesia is renowned for its rich biodiversity and high rates of endemism. Its geological isolation, volcanic origins, and diverse climates have fostered the development of unique ecosystems. In recognition of its ecological significance, exceptional biodiversity, high endemism, and distinct habitats, Macaronesia was designated as a Key Biodiversity Area (KBA) in 2016 (Triantis *et al.* 2010, Madruga *et al.* 2016).

Unique ecosystems, such as the Macaronesian Laurel forests, contribute to the region's remarkable levels of endemism. For instance, the Canary Islands boast 50% of endemic vascular plant species. The endemism rate in land mollusks is overwhelming with 94% endemism in the Canary Islands and 84% in Madeira. Arthropods also exhibit significant endemism. In the Canary Islands 66% of spider species being unique to the region, many of which are single-island endemics, further highlighting the region's ecological uniqueness (Florencio *et al.* 2021). Some genera also display remarkable species radiation, exemplified by the exclusive plant genus *Argyranthemum* (Webb ex Sch.Bip.) or the weevil genus *Laparocerus* (Machado *et al.* 2017, White *et al.* 2020). These exceptional endemism rates, coupled with their status as a biodiversity hotspot, underscores the urgent need for targeted conservation efforts (Florencio *et al.* 2021).

Regarding protected area coverage, Madeira and the Salvage Archipelago lead the region, with over 60% of their land designated as protected areas, followed by the Canary Islands archipelago, where 40% of the territory is under conservation measures (Caujapé-Castells *et al.* 2010, Casimiro 2017). However, despite its KBA designation, Macaronesia faces persistent threats, including invasive species, habitat destruction, and human development. These pressures, combined with the stochastic risks inherent to island ecosystems, heighten the vulnerability of endemic species to extinction.

Continuous and adaptive management and focused conservation strategies are essential to address these challenges and ensure the preservation of Macaronesia's unique biodiversity. Its ecological fragility and global importance make the region a critical priority for conservation (Ricketts *et al.* 2005, Costa *et al.* 2013).

2.3.1 Location and Geological Characterization

The Madeira Archipelago is in the subtropical Atlantic within the Macaronesia region, lies approximately 700 km off the African coast (Agadir) and 850 km from mainland Portugal (Peniche) (Aguín-Pombo & Pinheiro de Carvalho 2009). It comprises the inhabited islands of Madeira (737 km²) and Porto Santo (42 km²), along with the uninhabited Desertas—Deserta Grande (10.3 km²), Bugio (3 km²), and Ilhéu Chão (0.4 km²) (Figure 1).

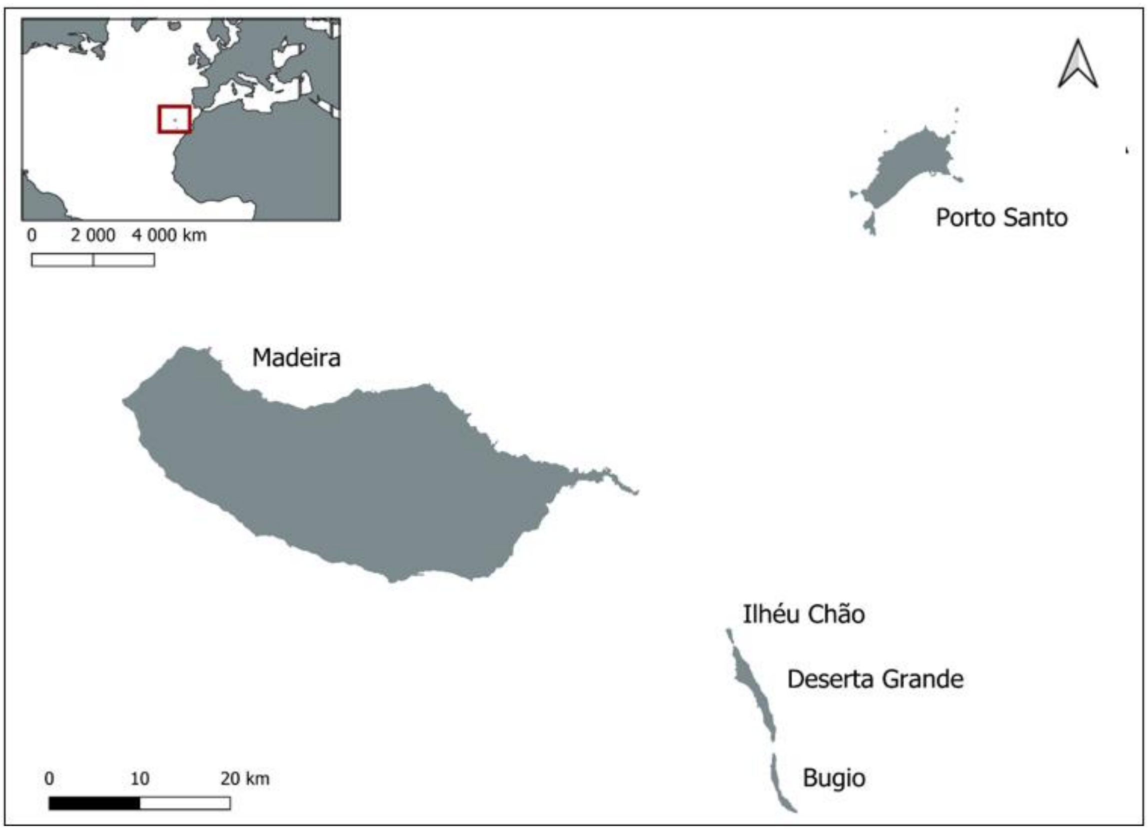


Figure 1 | Map of the Madeira Archipelago.

Geologically, the Madeira Archipelago is divided into two main units: Porto Santo and Madeira-Desertas. Porto Santo, the oldest island, emerged about 14 million years ago and displays diverse lithology, largely due to its volcanic submarine origins (Zbyszewski *et al.* 1975, Prada & Serralheiro 2000). The Madeira Island subaerial formations date to approximately 5.6 million years ago (Upper Miocene). The Desertas, an extension of Madeira Island, share similar rock compositions and are visually akin to Ponta de São Lourenço, on Madeira's eastern end (Fernández-Palacios 2010). Madeira Island has a rugged topography with about 85% of its surface above 500 m (Prada & Serralheiro 2000, Fernández-Palacios 2010).

2.3.2 Climate

Madeira's archipelago has a mild climate, moderated by the surrounding Atlantic Ocean and the Canary Current, a cool, southward-flowing current along the African coast (Cropper 2013), which helps to prevent extreme heat in summer and keeps winters mild, while also contributing to high humidity, especially in coastal areas (Navarro-Pérez & Barton 2001, Couto *et al.* 2012). These climatic factors, combined with the region's rugged terrain, create diverse microclimates. However, there are notable differences between the islands, due to variations in altitudes. The lower-altitude islands of the Deserts (388 m) and Porto Santo (517 m) are dry, while Madeira Island (1861 m), with its higher elevations, tends to be wetter and supports forest vegetation (Aguín-Pombo & Pinheiro de Carvalho 2009). The Madeira Archipelago hosts diverse habitats, with Madeira Island being the most varied due to its size, rugged geology, and terrain.

Madeira Island coastal areas are typically warm and sunny, while mountainous regions experience cloud cover and rain due to changes in elevation (Manteghi *et al.* 2015, Pullen *et al.* 2017, Gao *et al.* 2023). The northeast trade winds bring moist air, which condenses over the island's mountains, resulting in frequent rainfall in the northern and central highlands (Couto *et al.* 2012, 2016, 2017). This precipitation supports ecosystems like the Laurel Forest, which is essential for biodiversity and water regulation (de Lima & de Lima 2009, Prada *et al.* 2009). In contrast, the southern areas are drier and warmer, promoting the growth of drought-resistant vegetation (Lopes *et al.* 2011, Sim-Sim *et al.* 2014). The island's volcanic terrain, shaped by erosion and rainfall, features dramatic valleys and cliffs, but its steep landscape makes it prone to landslides and floods (Couto *et al.* 2012, Nguyen *et al.* 2013, Sotiriou & Nunes 2024, Heleno *et al.* 2016). Additionally, Madeira Island faces an increased risk of wildfire, exacerbated by climate change, strong winds, steep terrain, and human activities (Navarro *et al.* 2017, Couto *et al.* 2021, Lousada *et al.* 2022).

2.3.3 Fauna and Flora

The Madeira Archipelago stands out for its unique and diverse flora and fauna. It is home to approximately 1286 terrestrial endemic species of flora, fauna and fungi (Borges *et al.* 2008). Notably, its arthropod fauna is exceptionally rich, with approximately 1000 endemic species, particularly among insects, which include numerous lesser-known and understudied families.

Madeira Archipelago also preserves the largest concentration of Tertiary flora associated with temperate-humid forests (Capelo *et al.* 2005). The Madeira Laurel Forest, a UNESCO World Heritage Site since 1999, represents a unique vegetation type that combines characteristics of tropical rainforest and Mediterranean sclerophyllous foliage. Sensitive to both cold and drought, it plays a vital role in climate regulation, rainfall patterns, groundwater replenishment, and hydrological balance (UNESCO 1999, Capelo *et al.* 2007, Prada *et al.* 2009).

Madeira features both Mediterranean and subtropical temperate climates and soils primarily composed of cambisols, with vertisols, leptosols, and andosols also present. Key habitats include *zambujal* (wild olive forests), marmulano micro-forests, Laurissilva forests (barbusano and til types), high-altitude heathlands, and riparian woodlands (Mata *et al.* 2013).

Porto Santo, characterized by infra- and thermo-Mediterranean climates, has a xeric oceanic thermo-Mediterranean semi-arid bioclimate. Once dominated by wild olive forests, today only remnants remain in the island's north. Current habitats include figueira-do-inferno (*Euphorbia* Linnaeus 1753) shrublands and sandy substrates like dunes and fossilized dunes (Capelo *et al.* 2007).

The Desertas Islands, impacted by introduced rabbits and goats, would have supported small wild olive forests but now primarily consist of shrub-herbaceous communities (Aguiar *et al.* 2004, Capelo *et al.* 2007).

2.3.4 Management and Protection

The Madeira Archipelago currently encompasses 49 protected areas, including one natural park, three natural reserves, five Special Protection Areas, eight Sites of Community Importance, eleven Special Areas of Conservation, and fifteen natural monuments (see Annex II). However, the conservation of these native ecosystems faces increasing pressures from tourism, urbanization, and environmental changes, necessitating structured conservation and management efforts (Martins & Cró 2021, Lousada *et al.* 2022, Majdak *et al.* 2022). As a result of the increasing pressures, conservation efforts have significantly increased over the past few decades (Cruz *et al.* 2009, Ribeiro & Neves 2020, Sempere-Valverde *et al.* 2023).

The protection of these areas is governed by various regional entities, in alignment with national and international regulations and key territorial planning documents. The implementation and oversight of conservation legislation is primarily the responsibility of the Regional Government of Madeira through the Instituto das Florestas e Conservação da Natureza (IFCN). Founded in 2012, the IFCN leads efforts in habitat restoration, biodiversity monitoring, and protected area management, while ensuring compliance with European and International biodiversity legislation (IFCN 2024a). The IFCN focuses on conservation actions aimed at preserving the Laurel Forest, including invasive species removal, reforestation with native species, and fire prevention (INIAV 2019, Decreto Legislativo Regional n.º 9/2023/M).

Other key entities involved in conservation include the Madeira Natural Park Authority, which has been managing two-thirds of Madeira Island since 1982, and the Marine Authorities, responsible for overseeing marine reserves such as the Selvagens

Islands Nature Reserve (established in 1971) and the Desertas Islands Nature Reserve (established in 1990), together with IFCN (Decreto-Lei n.º 458/71, Decreto-Lei n.º 142/90, Decreto-Lei n.º 13/95). Additionally, the Funchal Municipality manages the Ecological Park of Funchal, established in 1994 (Decreto Regional nº 14/82/M, Decreto Legislativo Regional n.º 11/85/M, Decreto Legislativo Regional nº 14/90/M, AMN 2024).

Conservation planning is guided by territorial documents, such as the Madeira Regional Land Use Plan (PROT-RAM), which regulates urban growth and ecosystem protection, and the Madeira Regional Forest Plan (PROF-RAM), which addresses sustainable forestry management (Decreto Legislativo Regional nº 9/2023/M). The Natura 2000 Management Plans and Protected Areas Management Plans (POAP/POG) provide detailed zoning and conservation objectives for protected habitats (IFCN 2024b).

2.3.5 Madeira's Species on the IUCN Red List

2.3.5.1. Challenges in Conservation and Data Scarcity

The biodiversity of the Madeira archipelago, particularly its terrestrial species, is underrepresented on the IUCN Red List. Since 1996, Madeira's biodiversity has been assessed using the IUCN Red List criteria, completing 1222 evaluations by 2024. Of these, 18.4% are classified as Critically Endangered, Endangered, or Vulnerable. Notably, nearly 50% of the assessments focus on marine species, highlighting a greater investment in marine research compared to terrestrial biodiversity (IUCN 2025).

Based on data from Borges *et al.* (2008), and species assessed by the IUCN Red List, only 7% of the estimated 7452 terrestrial species in the region have been evaluated. This underscores critical knowledge gaps that hinder effective conservation efforts. While some taxa, such as Mollusca (69%) and Chordata (33%), are relatively well-studied, others remain severely underrepresented. For instance, only 1% of Ascomycota and 2% of Arthropoda have been assessed, and entire phyla, including Annelida, Nematoda, Platyhelminthes, and various fungi, lack representation altogether (Borges *et al.* 2008, IUCN 2025).

Additionally, out of the 1222 assessments conducted in Madeira, 544 require updates, emphasizing the critical need for continuous monitoring to account for shifts in population dynamics and threat levels (IUCN 2025). These outdated assessments and data gaps underscore the urgent need for targeted research on underrepresented groups, such as insects and fungi, which play essential roles in Madeira's ecosystems to enhance the effectiveness of biodiversity conservation efforts in the region.

2.3.5.2 Species of Cixiidae Evaluated According to the IUCN Red List Criteria

Out of an estimated 2640 species in the Cixiidae family, only 11 have been assessed by the IUCN Red List. Eight of these species are from the Azores, while none have been evaluated for the Madeira or Canary Islands. Among the eight Azorean species, six are classified as threatened (Vulnerable, Endangered, or Critically Endangered), and the remaining two are listed as Near Threatened, underscoring the need for urgent conservation action (Emeljanov 2002, Holzinger *et al.* 2002, IUCN 2025) (Table 2). All but one species, *Cixius caledonicus* China, 1942 — which is potentially extinct (Macadam 2022) — have been evaluated under Criterion B, which assesses species based on their range and distribution.

Table 2 | IUCN Red List assessment for all evaluated Cixiidae species. Source: IUCN 2025.

Species	Habitat	Distribution	Population Trend	Category + Criteria	Year of Assessment
Helenolius dividens (Walker, 1858)	*Epigean*	Saint Helena	Decreasing	**EN** B1ab(iii)+2ab(iii)	2018
Cixius azomariae Remane & Asche, 1979	*Epigean*	Azores	Stable	**EN** B1ab(iii,iv)+2ab(iii,iv)	2017
Cixius azoterceirae Remane & Asche, 1979	*Epigean*	Azores	Stable	**VU** B1ab(iii,iv)+2ab(iii,iv)	2018
Cixius azofloresi Remane & Asche, 1979	*Epigean*	Azores	Decreasing	**EN** B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)	2018
Cixius azopicavus Hoch, 1991	*Troglobite*	Azores	Decreasing	**EN** B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)	2018
Cixius azopifajo Remane & Asche, 1979	*Epigean*	Azores	Stable	**VU** B1ab(iii,iv)+2ab(iii,iv)	2018
Cixius azoricus Lindberg, 1954	*Epigean*	Azores	Stable	**NT** B2ab(iii)	2018
Cixius caledonicus China, 1942	*Epigean*	Scotland	Unknown	**CR** D	2022
Cixius cavazoricus Hoch, 1991	*Troglobite*	Azores	Decreasing	**CR** B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)	2018
Cixius insularis Lindberg, 1954	*Epigean*	Azores	Stable	**NT** B2ab(iii)	2018
Helenolius insulicola Van Stalle, 1986	*Epigean*	Saint Helena	Decreasing	**EN** B1ab(iii)+2ab(iii)	2018

3. Study Area: Vegetation

Understanding the distribution of target species requires examining the primary variables influencing their host plants. Therefore, analyzing the different types of preferential vegetation is critical. The Cixiidae species of Madeira occur in three main types of vegetation: Laurel Forest, coastal xerophilic vegetation where *Globularia salicina* grows, and coastal halophytic vegetation where *Suaeda vera* is found.

3.1 Laurel Forest

The Laurel Forest is highly sensitive to mediterranization influences. It thrives in constant humidity and cannot tolerate cold, dryness, or water stress. Despite the relatively stable temperature and rainfall, higher precipitation is often observed in the summer. This ecosystem is dominated by relict tree species such as *Laurus novocanariensis*, *Ocotea foetens*, *Apollonias barbujana*, and others (Capelo *et al.* 2007) (Table 3).

The forest is divided into two main types:

- **Barbusano Forest:** Found at lower altitudes (300–800 m in the south, 50–450 m in the north), this forest occupies sub-humid to humid regions with cambisols. It supports thermophilic Mediterranean species, including *Globularia salicina*
- **Til Forest:** Found at higher altitudes (800–1450 m in the south, 300–1400 m in the north), this forest is in hyper-oceanic, humid to hyper-humid bioclimates. Dominated by andosols and cambisols, they support host trees up to 30 m tall, as well as diverse ferns and endemic species.

Table 3 | Characteristic vegetation of the mid-story of the Mediterranean Laurel Forest and the temperate Laurel forest. Source: Capelo *et al.* (2007).

Type of vegetation	High-altitude Laurel Forest	Low-altitude Laurel Forest	*Globularia salicina* Habitat	*Suaeda vera* Habitat
Trees and shrubs	*Clethra arborea, Ocotea foetens, Laurus novocariensis, Picconia excelsa, Heberdenia excelsa, Persea indica, Prunus lusitanica, Ilex perado, Euphorbia mellifera, Argyranthemum pinnatifidum*	*Apollonias barbujana, L. novocanariensis, Morella faya, Ilex canariensis, Sideroxylon mirmulans*	*Olea maderensis, Maytenus umbellata, Chamaemeles coriacea, Dracaena draco, Asparagus scoparius, Echium piscatoria, Echium nervosum, Globularia salicina, Sideroxylon mirmulans, Maytenus umbellata, Sinapidendron gymnocalyx, Morella faya, Teucrium betonicum*	*Helichrysum obconicum, Suaeda vera, Olea maderensis*
Vines	*Rubus bollei, R. grandifolius, Rosa mandonii, Rubia occidens, Semele androgyna, Ruscus streptophyllus*	*S.androgyna, Smilax pendulina, S. canariensis, Hedera maderensis, Convolvulus massoni, Rubus agostinhoi, Rubus serrae*	*R. ulmifolius*	-
Ferns	*Diplazium caudatum, Pteris incomplete, Woodwardia radicans, Blechnum spicant, Culcita macrocarpa, Asplenium opteris, Dryopteris maderensis, D. aitoniana, Arachnioides webbianum*	-	-	-
Others	*Viola sequeirae, Festuca donax, Carez lowei, C. peregrina, Phyllis nobla, Hypericum grandifolium, Sibthorbia peregrina, Pericalis aurita, Aeonium glandulosum, Aichryson sp.*	*A. umbellatus lowei, Visnea mocanera, Maytenus umbellata,*	*Carlina salicifolia, Phagnalon lowei, Hyparrhenia hirta, Brachypodium distachyon, Sedum nudum, A. glandulosum, A. glutinosum, H.melaleucum, Sedum brissemoretii, H. canariense*	*Lotus glaucus, Crithmum maritimum, Calendula maderensis, A.pinnatifidum subsp. succulentum, Senecio incrassatus, Mesembryanthemum nodiflorum, Scolymus maculatus, Galactites tomentosus, Mathiola maderensis*

3.2 Thermophilic Vegetation: *Globularia salicina*

Globularia salicina is an endemic shrub found in Madeira and the Canary Islands. It thrives in xeric, thermophilic habitats and can grow up to 1.5 m tall. Typically found in shallow soils on rocky slopes exposed northern winds, this species represents early stages of ecological succession (Capelo *et al.* 2005).

- **Southern Slopes:** Found at 200–300 m in vertisols and cambisols on eroded or abandoned agricultural lands. This represents the first stage of ecological succession in the shrub community *Mayteno umbellatae-Oleo maderensis sigmetum* (Capelo *et al.* 2007).
- **Northern Slopes:** Found at 0–80 m in sub-humid climates on cambisols and leptosols. It also appears in meso-xeric micro-forests of the *Helichryso melaleuci-Sideroxylo marmulanae sigmetum* alliance (Capelo *et al.* 2007).

3.3 Halophytic Vegetation: *Suaeda vera*

Suaeda vera is a small perennial shrub restricted to Ponta de São Lourenço on Madeira Island (Pedrol & Castroviejo 1988, Capelo *et al.* 2005). This halophilic species thrives in nitrogen-rich habitats influenced by seabird droppings, such as high salt marshes and coastal cliffs. It belongs to *Calendulo maderensis-Suaedetum verae* alliance (Capelo *et al.* 2005, 2007).

4. Material and Methods

4.1 Insights into the Experimental Design

The assessment of the conservation status of Cixiidae species, following IUCN criteria, required comprehensive distribution data. Thus, to assess the conservation status of endemic species of the Cixiidae family of Madeira Archipelago, in this study we:

- **Documented current** species **occurrences**, hypothesizing range shifts due to habitat changes.
- **Georeferenced historical records**, extending known species ranges and identifying range shifts.
- **Monitored adults**, focusing on life cycle timing of adult emergence to refine sampling protocols and improve conservation accuracy.
- **Developed predictive SDM** using environmental factors such as temperature and soil type to identify suitable habitats and threats.
- **Conducted IUCN assessments**, evaluating extinction risk based on current distribution and threats, to assign preliminary conservation statuses.

The primary objective of field sampling was to gather information on species' occurrences and their preferred habitats. In addition to field data, historical records were sourced from scientific publications and insect specimens deposited at the University of Madeira's Insect Collection (UMACI). The phenology of Cixiidae species in Madeira is largely unknown, posing challenges in determining whether the absence of a species in specific areas reflects a true absence, insufficient sampling efforts, or mismatched timing in detecting adult specimens. To address this uncertainty, systematic monitoring was conducted at a representative site for each genus/species every three weeks over the course of a year. This regular monitoring provided valuable phenological data, allowing for the refinement of optimal sampling periods throughout the year.

To maximize data reliability, we employed both standardized and opportunistic sampling methods. Standardized sampling ensured consistency and comparability of data for analysis, while opportunistic sampling expanded the total area surveyed, helping to confirm that absences were genuine rather than a result of limited sampling effort.

This dual approach not only enhanced data accuracy but also helped refine sampling locations, particularly to address distribution gaps for the target species. The collected data was further used to develop predictive Species Distribution Models (SDMs). Given the ecological characteristics of most cixiid species - whose nymphal stages are rarely observed due to their root-feeding behavior (Hoch 2002) - the sampling efforts focused primarily on capturing adults.

4.2 Sampling for Occurrence Data

4.2.1 Sampling Location and Design

To systematically sample *Cixius* and *Hyalesthes* species, Madeira Island was divided into a 2 km x 2 km grid system. For *Tachycixius chaoensis*, since the sample area was very small, the grids of 500x500 m were selected (see below).

For *Cixius* and *Hyalesthes* species, each grid was assigned to a unique identifier and recorded in a shapefile. This grid size was selected to account for the island's diverse climate and habitat variability. Before sampling, a preliminary assessment was conducted for each grid to determine whether there were suitable habitats and vegetation for cixiids. For this evaluation, the most recent (2023-24) Google Earth Pro satellite imagery (7.3.6.10201 (64-bit), combined with coordinate data from GBIF (GBIF 2025a, 2025b) and Flora-On Madeira (Flora-on 2025) chosen within each grid cell, ensuring a minimum

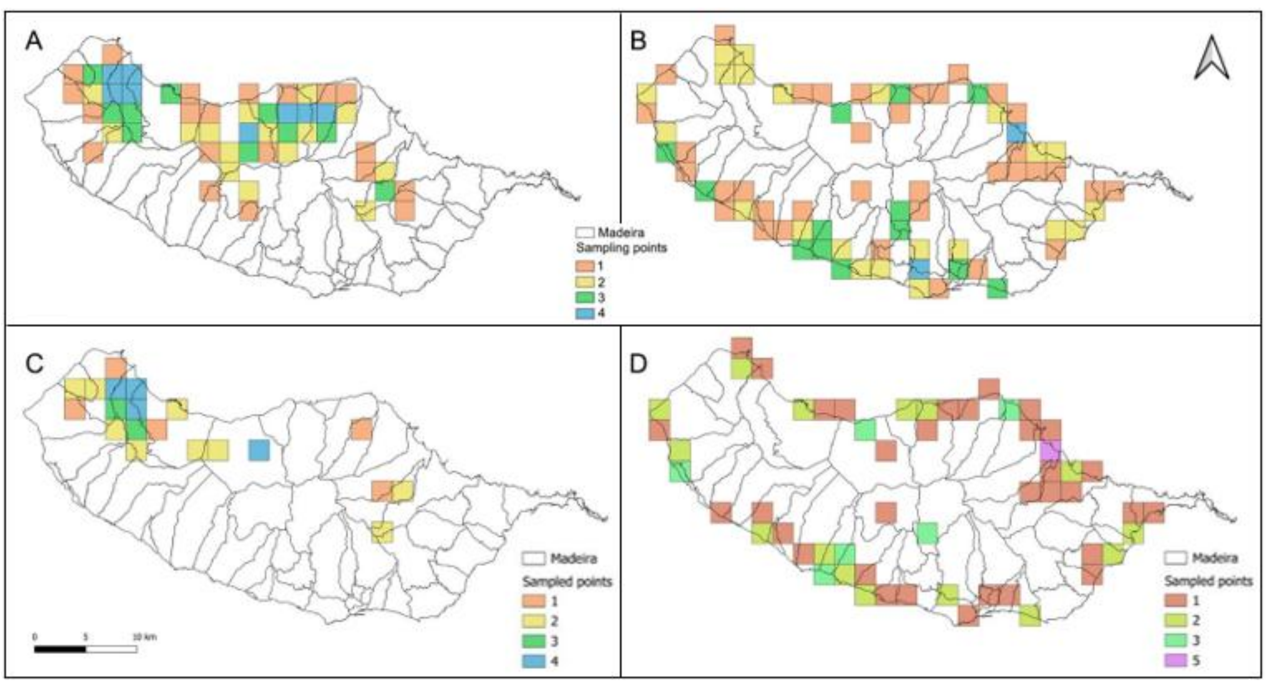


Figure 2 | Sampling in 2 x 2 km grids system for *Cixius* spp. (A, C) and *Hyalesthes* spp. (B, D) indicating the number of sampling points in each. Preliminary (A, B) and final (C, D) sampled grids and points on Madeira Island.

distance of 100 m between points. This initial selection resulted in 53 grids with 114 points for *Cixius* spp. (Fig. 2A) and 74 grids with 128 points for *Hyalesthes* spp. (Fig. 2B).

However, when prioritizing potential distribution areas, these initial selections were refined based on several factors, such as food plant presence, previous distribution data, habitat suitability, vegetation representativeness, accessibility (e.g., closed roads, landslides), and perceived habitat quality (e.g., recent replacement of native vegetation by production forests such as eucalyptus).

Following this local screening, the number of selected grids and points was adjusted, resulting in 20 grids with 47 points for *Cixius* spp. (Fig. 2C) and 57 grids with 90 points for *Hyalesthes* spp. (Fig. 2D).

The methodology for selecting sampling points varied among the three genera, reflecting differences in their feeding behavior and distributions.

- ***Cixius* (polyphagous species):** Sampling points were randomly selected using QGIS's *Random Points Along Lines* tool (QGIS 3.34.11, QGIS Development Team, 2021). Linear features such as roads, paths, *levadas*, and *veredas*, were clipped within each grid cell, ensuring a minimum distance of 100 m between points. Points located in inaccessible areas or unsuitable habitats (e.g., tunnels, areas dominated by exotic vegetation), were reassessed and adjusted during field visits.
- ***Hyalesthes* (oligophagous species):** Sampling points were chosen based on host-plant occurrence data obtained from the GBIF database (GBIF 2025b). Points were selected to maximize coverage and representativeness within the grid, prioritizing areas with abundant and well-preserved host plant populations. Whenever possible, the farthest available host plant points within the grid were selected to optimize spatial distribution.
- ***Tachycixius chaoensis* (oligophagous species):** This species has a restricted distribution in the eastern part of Madeira Island and Ilhéu Chão where the host plant, *Suaeda vera*, is present. For this species, a finer grid resolution of 500 m x 500 m was adopted. A total of 14 grids were surveyed, covering the entire known distribution range. Unlike *Cixius* spp. and *Hyalesthes* spp. the entire area within each grid was comprehensively surveyed (Fig. 3).

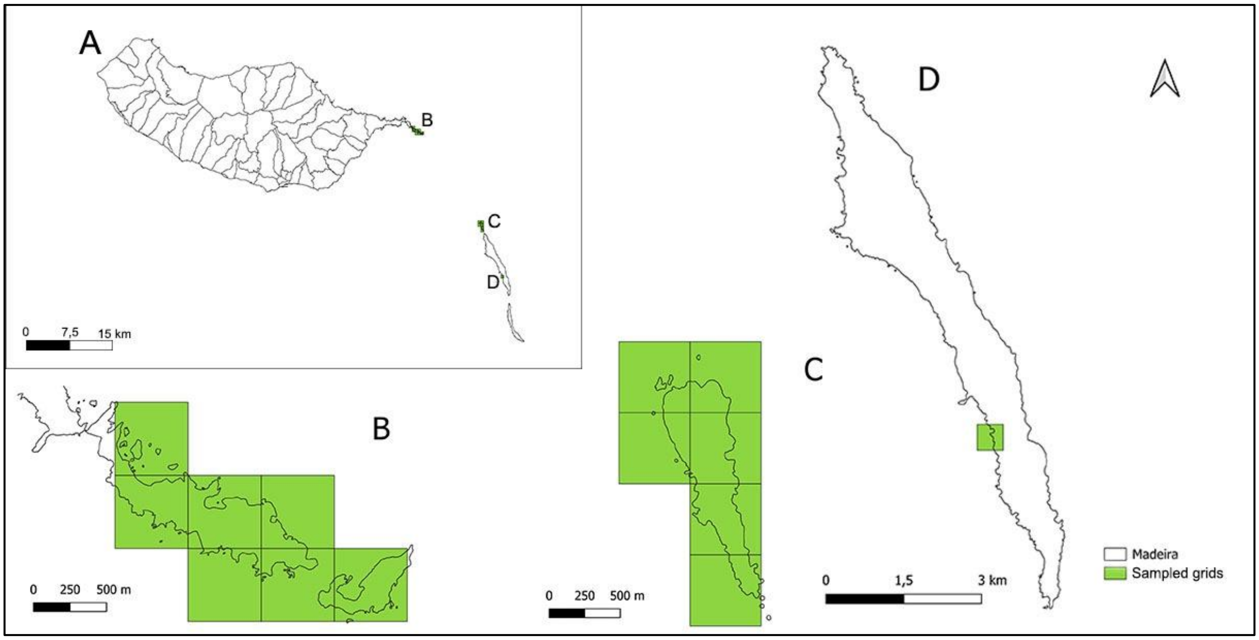


Figure 3 | 500m x 500m grids sampled (in green) for *Tachycixius chaoensis* (China, 1938). Madeira Island: Ponta de São Lourenço (A) and islets (B). Desertas Islands: Ilhéu Chão (C) and Deserta Grande (D).

4.2.2 Selection of Food Plants for Sampling

The selection of food plants aimed to optimize sampling efforts by focusing on plant species known to support populations of the target insect species. Information about food plants was drawn from scientific literature and specimen records deposited in the University of Madeira's Insect Collection (UMACI).

- ***Hyalesthes* spp.**: Sampling efforts targeted *Globularia salicina*, as nearly all documented records of the two species of this genus were associated with this specific plant species.
- ***Tachycixius chaoensis****:* Sampling focused on *Suaeda vera*, which most documented specimens are from this host plant species.
- ***Cixius* spp:** Identifying food plant for *Cixius* proved more challenging due to the genus' broad range of food plants, including trees, ferns, and herbs. To refine the sampling strategy, a preliminary survey was conducted at Queimadas, a site where

Cixius species are common. This survey helped identify the most suitable plant types for sampling.

The locations of various host plants were compiled using open-access resources, including the Global Biodiversity Information Facility (GBIF), the Madeira Botanical Garden database, and the Flora-On portal.

4.2.3 Sampling Method

Sampling was conducted using a sweeping net with an aluminum frame (25 cm diameter, 50 cm handle) and a nylon bag (40 cm length, 335 µm mesh). Insects were removed from the net with an entomological pooter, consisting of a 16 cm plastic tube with a 0.9 cm diameter. Then specimens were euthanized with ethyl acetate and stored in eppendorf tubes. In some cases, they were temporarily kept alive in small plastic containers for further examination. Sampling focused on food plants, where the target genera/species was most likely to be found. To quantify effort, the number of beats (sweeps) per plant was recorded. This number varied depending on plant size and surrounding vegetation structure. Larger or more robust plants received more beats, while smaller or denser plants required fewer. When plants were clustered closely, they were sampled together and treated as a single unit. When plants were more widely spaced, each was sampled and recorded individually.

To maximize specimen capture across the target genera/species, a combination of standardized and opportunistic sampling methods was employed:

- **Standardized sampling**: Sampling was conducted within a 5-meter radius around each predefined sampling point. If site conditions (e.g., dense vegetation or inaccessible terrain) made this radius unfeasible, sampling was instead conducted along a straight 10-meter transect.
- **Opportunistic sampling**: To improve genera/species detection and maximize coverage, additional sampling was conducted near standardized points.

4.2.3.1 Sampling Adaptations by Genus

***Cixius* spp.** and ***Hyalesthes* spp**: the number of beats per plant was recorded for both genera. Given time constraints and species broad distribution, this method enabled precise quantification of effort and distribution patterns.

Tachycixius chaoensis: Sampling was conducted across specific zones, including Ilhéu da Cevada (12 areas), Ilhéu do Farol (seven areas), Deserta Grande (Fajã da Doca, the only site covering all accessible *Suaeda vera* on the island), and Ilhéu Chão (26 areas). In total, 46 areas were surveyed, representing the full extent of *Tachycixius chaoensis*' known distribution and primary habitat zones. To ensure comprehensive coverage, approximately 80% of the area covered by *Suaeda vera* was sampled. Within each island or islet, sampling targeted ecologically distinct areas, classified based on variations in landscape, vegetation heterogeneity, water drainage presence, soil granulometry, and proximity to cliffs. Additionally, ecological markers used in previous botanical studies were employed as reference points to delineate sampling zones.

4.2.4. Sampling Periods

The sampling was conducted between June 2023 and July 2024 (Table 4). The definition of the sampling schedule was based on sampling dates and locations obtained from publications (Nouhalier 1897, China 1938, Lindberg 1941, 1954, 1961, Hoch & Remane 1985, 1986), recent studies (Freitas & Aguín-Pombo 2021), as well as specimens deposited in the University of Madeira's Insect Collection (UMACI).

- ***Cixius* spp.:** Literature and collection records indicate observations on 72 distinct dates, spanning from April to October, with peak sampling activity occurring in June, July, and August. Based on this data and phenological observations, field sampling focused on Laurel Forest areas was conducted over 14 days from late June to early October 2023.
- ***Hyalesthes* spp.:** Historical data identified 31 sampling dates between April and August, with most observations concentrated from April and July. This study extended sampling efforts to 33 sampling days between late June 2023 and mid-

July 2024. These sampling periods were divided into two phases: 29 days from late June to early August 2023, and further sampling efforts from February to mid-July 2024.

- ***Tachycixius chaoensis***: Four records were found in publications and collection data from May to June. To improve the sampling efforts, 22 sampling days were conducted across three periods: four days between September and November 2023, two days in January 2024, and 16 days between May and June 2024.

Table 4 | Number of sampling days per month. Sources: publications, University of Madeira Insect Collection and sampling for this study. J = January, F = February, Mr = March, Ap = April, M = May, Jn = June, Jl = July, A = August, S = September, O = October, N = November, D = December. Sources: publications, University of Madeira Insect Collection and sampling for this study.

Genus	Source	J	F	Mr	Ap	M	Jn	Jl	A	S	O	N	D
Cixius	Publications UMACI				4	13	16	27	7	4	1		
	This work						2	1	6	4	1		
Hyalesthes	Publications UMACI				7	3	2	16	3				
	This work		2	4	5	1	8	7	2				
Tachycixius chaoensis	Publications UMACI					3	1						
	This work	2				15	1			2	1	1	

4.2.5. Sampling Data

The sampling data gathered during this study provides comprehensive insights into the ecological and environmental characteristics of each sampling location. The information recorded at each sampling location included: the name of the target genus/species (*Hyalesthes*, *Cixius*, or *Tachycixius chaoensis*), location details, timing of sampling, habitat type, and general environmental features.

Additionally, data on potential food plants, natural predators, and the presence of any exotic plant species were documented. Photographs and videos were taken to contextualize the findings. Field data was registered using field notes (see Annex 3) and software tools such as *ObsMap* (ObsMap 2025) and *PlantNet* (PlantNet 2025) for a preliminary plant identification.

a. Sampling Site Description and Conditions

Sampling sessions were conducted for approximately 10-20 minutes at each point to ensure sufficient data collections. To maintain consistency across locations, for each sampling point, comprehensive data was recorded:

- **Target Genus/Species**: The name of the genus/species sampled at each point.
- **Sampling Point Classification**: Points were categorized as either standard or extra/opportunistic.
- **Location Details**: Included the name of locality, parish, and county where the sampling was conducted.
- **Altitude and Geographic Coordinates:** Altitude was recorded in meters a.s.l. along with latitude and longitude using the geodetic WGS84 (World Geodetic System 1984) reference system.
- **Accessibility and Path Type**: The kind of path leading to each sampling point, with classification including:
    - Trail: Narrow, unpaved paths primarily used by hikers.
    - Vereda: Traditional footpaths, often historic and connecting rural areas.
    - Levada: Water channels used for water transport, often accompanied by adjacent paths.
    - Road: Paved or unpaved routes accessible by vehicles.
- **Sampling Conditions:** The timing and weather conditions at each sampling location, including:
    - Date and time: Date and start time of the sampling activity.
    - Weather conditions: Observations on weather conditions (e.g., sunny, cloudy, rainy).

b. Environmental Conditions

Environmental conditions were recorded at each point. When Cixiidae specimens were found, measurements were taken near the food plant; otherwise, were collected at the designated coordinates of the point. In opportunistic sampling, environmental data was recorded only when specimens were found.

- **Air Conditions**: Temperature (°C) and relative humidity (Rh%) were measured using a multipurpose anemometer (Benetech GM8910).
- **Soil Conditions**: Soil temperature (°C), relative humidity (Rh%), and pH were recorded using a soil probe (Aicevoos AS-PH3).
- **Luminosity and Wind Conditions**: Quantitative environmental conditions were assessed using a Benetech GM8910. Quantitative measurements included light intensity (in lux), wind speed (m/s) and wind direction (degrees from North) in open areas. In addition, when quantitative data were unavailable qualitative observations were recorded for light exposure (fully exposed, partially exposed, or shaded), and wind conditions (no wind, light breeze, or strong wind).
- **Specific Environmental Conditions**: those that may influence plant color and density (e.g., stagnant water or excessive shade).

c. Habitat Description

Sampling points were categorized according to the type of habitats such as:

- **Coastal Zones**: Areas below 300 meters.
- **Exotic Forests:** Dominated by non-native tree species of *Pinus sp.*, *Eucalyptus sp.*, and *Castanea sativa*.
- **Low Altitude Laurel Forests**: Found at elevations of 300-800 meters (south) and 50-450 meters (north), with few ferns.
- **High Altitude Laurel Forests**: Found at 800-1450 meters (south) and 300-1400 meters (north), with abundant pteridophytes.
- **Laurel/Heather Transition Zones**: Found at 800-1200 meters, where the vegetation shifts to Erica-dominated vegetation.

- **Grasslands**: Found in abandoned agricultural fields, dominated by *Brachiaria mutica*.
- **Water Paths**: Humid, forested areas near streams and rivers.
- **Pteridium Zones**: Open areas dominated by *Pteridium aquilinum*.
- **Xerophytic Zones**: Areas prone to dry or saline conditions.
- **Mountain Slopes**: Ranging from 250-800 meters in elevation.

Additional habitat observations included the presence of remnants of the original vegetation within exotic or degraded habitats, unsuitable areas (e.g., eucalyptus forests). Observations also encompassed soil composition and condition and vegetation coverage, density, and dryness.

d. Insect and Host Plant Data Collection

At each sampling point, plant species and associated insects were recorded. For *Hyalesthes* spp. and *Tachycixius chaoensis*, whose food plants are shrubs, data was collected for individual plants. In contrast, for *Cixius* spp., which are typically found on ferns, groups of individuals of the same species were sampled together. Herbarium specimens were collected as needed for identification. Insects were tagged using a grid-point-alphabet format (e.g., 1221-2-a).

When exotic plant species were present, they were documented to provide additional information about the habitat conditions. The number of net beats performed per sample was noted to quantify the sampling effort. Additionally, counts of Cixiidae specimens and other Auchenorrhyncha species, such as the endemic *Cyphopterum* spp. Melichar, 1905 (Flatidae) and *Issus maderensis* Lindberg, 1954 (Issidae), were also registered. These counts were used to compare abundance patterns with the target genera, assessing the rarity and abundance of targeted species within each sampling habitats.

To ensure traceability and proper identification, each sample was assigned a unique collection code.

e. Photography and Video Documentation

At each sampling point, photographs and videos were taken to document site conditions and food plants associated with Cixiidae specimens. A Canon EOS R10 camera with an RF-S 18-150mm lens and Raynox DCR-250 macro attachment were used for high-quality imaging. Each photo was assigned an ID and recorded in the field sheet, specifying whether it was taken with the camera (photo number) or logged via ObsMap. Videos were especially useful for documenting Cixiidae specimen locations, providing accurate visual references for habitat conditions and food plant associations, particularly in studies involving *Tachycixius chaoensis*.

4.2.6 Ethical Considerations

Fieldwork in protected areas of the Madeira Natural Park was authorized by the Instituto das Florestas e Conservação da Natureza (IFCN). To minimize the impact on Cixiidae populations, when multiple individuals of the same morphotype were encountered in a single area, only one or a few specimens were collected. If male specimens were present, all female individuals were released back into their habitat.

4.2.7 Quality Control

To reduce human error, sampling was consistently conducted or supervised by the author, using the same sampling protocol and equipment for precision. Coordinates of geographic data were verified using Google Earth and QGIS for accurate georeferencing.

4.2.8 Safety Measures

Given the challenging terrain and potential natural hazards of Madeira, the sampling strategy was designed to remain flexible, allowing for the relocation of sampling points to more accessible areas when necessary. Fieldwork was conducted with a partner, and GPS tracking was used when venturing off marked trails to ensure safety.

4.3 Adult Monitoring

This study aims to determine the number of generations per year for each species, as well as the timing of adult emergence and presence, to identify optimal sampling periods and minimized the risk of false absences. Observations of adult behaviour were recorded, when possible, both *in situ* and *ex situ*. Environmental conditions, including soil type and vegetation, were also documented to explore potential correlations with the species' temporal patterns and habitat relationships.

Plant selection for adult monitoring followed the same approach as occurrence data sampling. *Cixius* spp. were sampled in various plants from the forest floor, understory and lower canopy; *Hyalesthes portonoves* on *Globularia salicina*; and *Tachycixius chaoensis* on *Suaeda vera*.

4.3.1 Sampling Location and Design

Given that the target species are phytophagous and rare, sampling was conducted using a sweeping net to collect specimens from the vegetation. One site per genus/species (Fig. 4A) was selected to monitor the genus/species's life cycle over a year, with regular three or four-week visits to each site. In total, 15 monitoring moments were done for *Cixius* spp., 16 for *H. portonoves,* and 17 for *T. chaoensis* (Table 5).

Site selection was based on accessibility and prior confirmations of substantial populations presence. Additionally, all chosen locations were easily accessible for fieldwork.

Table 5 | Monitoring dates for adults of the target genus/species in the Cixiidae family.

Year	Month	*Cixius* spp.	*H. portonoves*	*T. chaoensis*
2023	July	29	-	-
	August	20	19	-
	September	10	19	1 | 26
	October	8	15	15
	November	14	11	11
	December	16	03 | 25	03 | 20
2024	January	13	20	13
	February	10	10	4 | 24
	March	9	10	17
	April	8 | 29	7 | 28	7 | 28
	May	19	22	19
	June	10	10 | 30	10
	July	1 | 27	14	1 | 21
	August	-	3	11

a. *Cixius* spp.

The sampling site for *Cixius* species was in the Forest Park of Queimadas, Santana. Based on meteorological data from the nearest Instituto Português do Mar e da Atmosfera (IPMA) station in Santana (Station No. 0965, 380 m a.s.l.), recorded from 2021 to 2023, the site experiences a humid climate, bordering on hyper-humid conditions (de Martonne 1926).

In 2023, the maximum recorded temperature (33.2ºC, 7 in October) surpassed previous years. The temperature range is notably high, with a thermal amplitude of approximately 15ºC. Rainfall is relatively evenly distributed throughout the month, with no extreme precipitation concentrated on a single day. Santana experiences a brief dry period between June and August, though with low intensity (see Annex 4).

An exploratory visit was conducted to identify the most suitable areas in Queimadas for observing these species. The site was divided into two areas:

- **Site 1**: Located at the beginning of the dirt path "Caminho para todos"/"Caminho do Pico das Pedras" (32.783530º N, 16.905983º W), at an altitude of approximately 880 meters. This area had shrubs and trees, including *Argyranthemum pinnatifidum*, *Vaccinium padifolium*, *Clethra arborea*, and *Laurus novocanariensis* (Fig. 4C). A handrail frequented by many insects facilitated observations of cixiids (Fig. 4B).
- **Site 2**: Situated 260 meters from Site 1 and 140 meters past the shelter houses (32.781937º N, 16.907877º W), at an altitude of about 930 meters. This area was rich in ferns such as *Diplazium caudatum*, *Adiantum* sp., *Blechnum spicant*, and *Athyrium filix-femina*. Nearby slopes were many trees of laurel forest, particularly *Clethra arborea*. The site provided visibility of trees roots providing good condition for observing adults and checking for eggs or juveniles (Fig 4D).

b. *Hyalesthes portonoves*

The selected site is a small remnant of native *Globularia salicina* vegetation (approximately 74 individuals) and a nearby wasteland. It is located near Rua da Pedra Mole in Caniço, Santa Cruz (32.657314º N, 16.838067º W) at an altitude of approximately 330 meters. The site spans 595 m² with a perimeter of 115 meters (Fig. 4E).

Meteorological data from the nearest IPMA station in Cancela (Station No. 0977, 266 m a.s.l.), recorded between 2021 and 2023, indicate a semi-arid climate (de Martonne, 1926). In 2023, the maximum recorded temperature (35.9ºC in June) exceeded previous years.

The temperature range is high in spring and summer but remains lower in winter. Monthly rainfall is irregular, often concentrated in just a few days, leaving the rest of the month dry. Cancela experiences an extended dry season from April to September (see Annex 4).

c. ***Tachycixius chaoensis***

The selected sampling site was based on fieldwork information recorded by Dora Aguín-Pombo and Marta Dias in 2022. It is in Ponta de São Lourenço (Caniçal, Machico), on the left side of the "Vereda da Ponta de São Lourenço" trail, approximately 400 meters from the trailhead (32.746212º N, 16.697973º W) and at an altitude of 47 m a.s.l. The total area covers around 7811 m^2 and is bordered by the Vereda da Ponta de São Lourenço to the north, two small runoff paths leading towards coastal viewpoints, and cliffs on southeastern edge (Fig 4F).

The site is predominantly covered by *Suaeda vera,* except for the central runoff area, which contains low herbaceous vegetation. This layout provides an optimal environment for observing *T. chaoensis* in its native habitat.

Meteorological data from the nearest IPMA station in Santana (Station No. 0967, 133 m a.s.l.), recorded between 2021 and 2023, indicate a semi-arid climate, tending closer to hyper-arid conditions than the Cancela station (de Martonne, 1926). In 2023, the maximum recorded temperature (31.8ºC in October) exceeded previous years.

The temperature range remained consistently low during the year, with minimal seasonal variation. Monthly rainfall was irregular, with some months experiencing their precipitation within just a few days, leaving the rest of the month predominantly dry. Caniçal undergoes a prolonged dry season from April to November (see Annex 4).

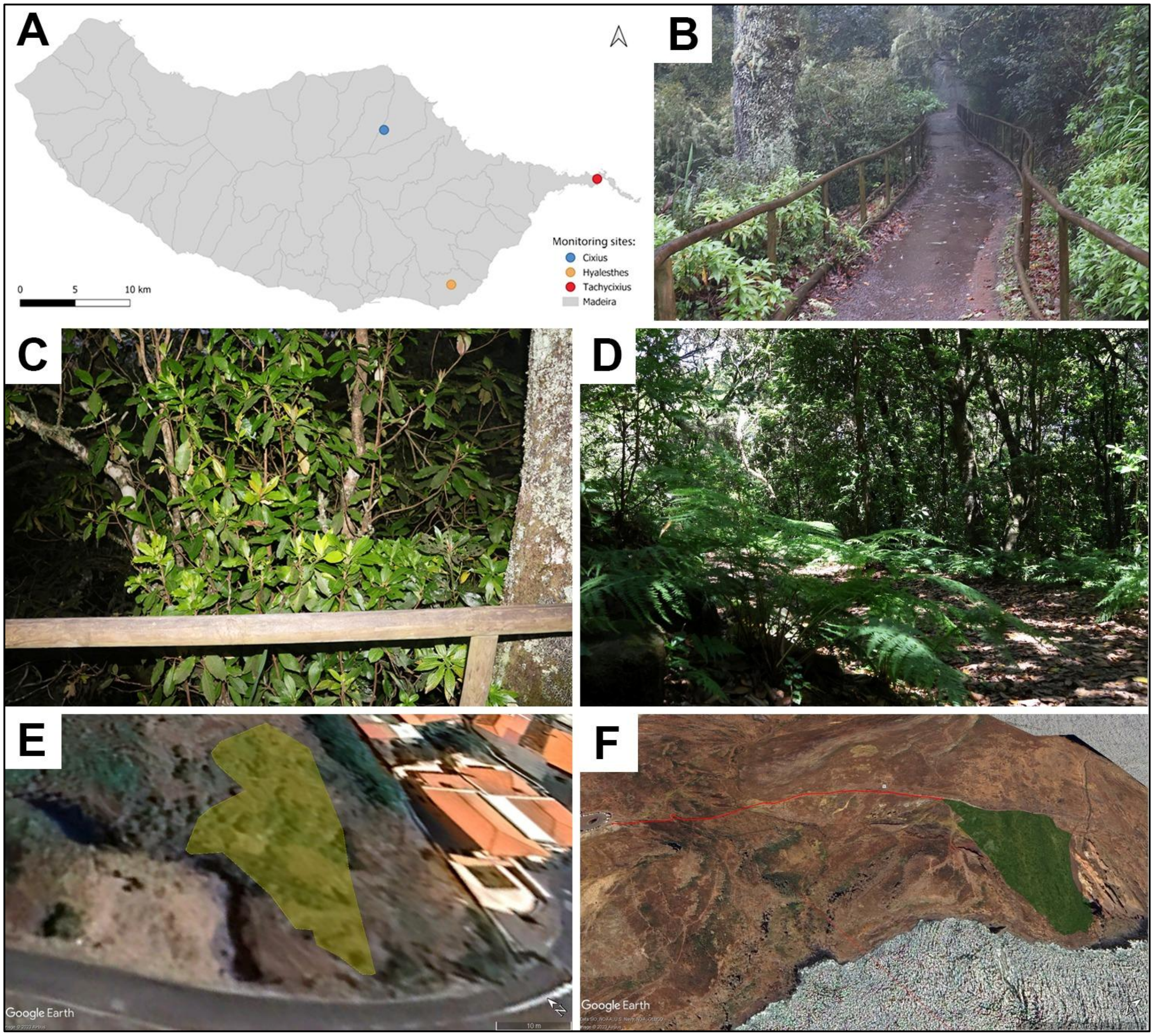


Figure 4 | Monitoring sites for each genus/species. (A) Location of the three study areas. (B) Handrail present on site 1 of *Cixius* spp. Monitoring of *Cixius* spp.: (C) Site 1 habitat, (D) Site 2. *Hyalesthes portonoves*'s monitoring area (E). *Tachycixius chaoensis*'s sampled area (F), in green and in red the distance to the beginning of the Vereda da Ponta de São Lourenço.

4.3.2 Sampling Method

a. Adult Sampling

Adult specimens were collected using the same sweeping net and equipment used for occurrence records. Sampling began by beating the vegetation to dislodge Cixiidae specimens.

For *Cixius* spp., sampling was done during sunset and nighttime in Site 1 and during nighttime in Site 2. In Site 1, observations during sunset were done on all plant parts of *Argyranthemum pinnatifidum* subsp. *pinnatifidum* and surrounding soil half an hour to one hour before nighttime, when the insects were most active. In the same site, in a nearby plant sprouts of a *Clethra arborea* tree was net-sampled to detect adults or exuviae. This procedure was repeated after nightfall but instead of netting *Clethra arborea*, a 30-meter transect along a handrail was observed for *Cixius* specimens on both sides of the path. All the arthropods encountered were counted and recorded. In Site 2, fern species were net sampled during nighttime. In the two sites, sampling and observations lasted between one hour and a half to four hours, depending on whether adults were or not present. On one occasion (20 August 2023), some cixiids were captured to study their behavior in laboratory cages.

For *Tachycixius chaoensis,* sampling was performed during daylight between 10h30 and 11h30, across 30 *Suaeda vera* plants along linear transects. The sampling lasted around one hour. Photos of each plant sampled were taken, and notes were made on plant size and phenology, coordinates and the presence of other arthropods.

Sampling for *Hyalesthes portonoves* was conducted during midday, lasting between 30 minutes and one hour. Initially, sampling covered the entire study area, but as most specimens were found on three *Globularia salicina* plants in the center of the area, subsequent sampling focused primarily on these plants, with occasional checks of other nearby plants.

b. Searching for Eggs and Immature Stages

Additionally, the presence of other life stages (nymphs, exuviae, eggs) was searched on plant by carefully inspecting leaves, branches or fronds, nearby ground, and roots if possible. The soil surface was gently moved to look for eggs and nymphs.

4.3.3 Sampling Data

Sampling data and observations were recorded on individual sheets (see Annex 5), documenting key details for target genera:

- **Site Identification**: GPS Coordinates were recorded using the geodesic WGS84 reference system.
- **Date and Environmental Conditions**: Air and soil variables (temperature, humidity, soil pH) were measured with the same anemometer and soil probe as in the sampling for occurrences.
- **Site Characteristics**: Observations included vegetation type, soil/litter characteristics, light levels, time of observation, and the presence of exotic insect species or potential predators.
- **Food Plant Conditions**: Plant conditions (branches, leaves, flowers, seeds) were documented and photographed, with notes on phenology.
- **Other Observations**: Cixiidae specimens were documented with precise details of their location (e.g., plant structure or substrates), stage/gender, number of specimens, and behavior (e.g., feeding, copulation). Adult behavior was recorded through photos and/or videos using the same equipment mentioned above. The presence of insect predators (e.g., spiders, ants, flies) and other Auchenorrhyncha species was also noted.

4.4 Conservation, Preparation and Species Identification

Once captured, Cixiidae specimens were euthanized on-site using ethyl acetate. Upon arrival at the laboratory, they were transferred to an oven set at 40ºC for drying to minimize the risk of fungal contamination and then stored in a refrigerator at 5ºC. The insects were then glued with Dimethyl Hydantoin Formaldehyde (DMHF) on entomological triangle cards and pinned together with entomological labels.

For species identification male genitalia was detached and boiled in a 10% KOH solution for three minutes, followed by cleaning with distilled water, following the protocol in Freitas & Aguín-Pombo (2021), with some modifications. Then the abdomen was placed on a slide with a drop of glycerine and examined under a microscope. Species identification was done according to Freitas & Aguín-Pombo (2021).

Food plants, particularly ferns, were collected and herborized for further identification in the laboratory. Plant identification was performed according to Press & Short (1994).

4.5 Georeferencing of Data from Literature and Collections

Older specimens of insects and food plants from collections and literature often lack precise geographic coordinates, requiring georeferencing for subsequent analyses. For *Globularia salicina* and *Suaeda vera*, georeferencing was based on data obtained from plant specimens recorded in GBIF (GBIF 2025a, 2025b) and at the Madeira Botanical Garden. For the Cixiidae specimens, historical literature served as the primary data source, referencing works by Nouhalier (1897), China (1938), Lindberg (1941, 1954, 1961), Hoch & Remane (1985) and Remane & Hoch (1986). These sources were processed using *Specify* software (version 6) with the *GEOLocate* plugin, incorporating locality name, broader geographic context (e.g., municipality, island, country), and known coordinates or altitude. Output coordinates were generated in decimal degrees using the WGS84 datum.

4.5.1 Selection Criteria for Geolocation

Georeferencing followed best practices as outlined by Chapman & Wieczorek (2020) and Zermoglio *et al.* (2020). When multiple geolocation options were provided by GEOLocate, the first suggested point was selected by default. If this point was incorrect or located over water, subsequent options were reviewed in numerical order.

In cases where no accurate points were suggested, the nearest available point was selected, and manual adjustments were made using Specify to refine the location.

4.5.2 Validation of Coordinates

Coordinates were validated using *Google Earth Pro* to cross-check accuracy. Precision errors were minimized by adjusting decimal places, particularly for sites lacking altitude data. Final validation was performed using *Quantum GIS* (version 3.34.3) to ensure all coordinates were positioned on land. If a point was found over water, georeferencing results were revisited and adjusted for greater precision.

4.6 Data Analysis

The information obtained from field research was analyzed across four main aspects. First, habitat and population dynamics were evaluated using sampled data, phenology information, and literature records to better understand the species' biology and ecology, which are essential for interpreting its distribution and rarity. Second, distribution patterns were analyzed by developing suitability habitat maps based on species occurrence and genus-level SDM, enabling predictions of potential habitats in unsampled areas and addressing limitations in field sampling. These models were critical for assessing species rarity under Criterion B of the IUCN Red List. Third, the rarity of the target insect species was evaluated by comparing it with other coexisting endemic species, such as *Issus maderensis*, *Cyphopterum* spp., and *Cyphopterum fauveli* (Noualhier, 1897), providing key data for assessing geographic range and habitat fragmentation under IUCN Criterion B. Finally, the conservation status of each species was assessed by identifying threats, evaluating habitat decline, and applying the IUCN

Red List criteria to determine extinction risks. These analyses collectively provide a robust framework for understanding the ecological status and conservation needs of the target species.

4.6.1 Habitat and Ecology

Habitat specificity reflects how tightly a species is associated with environments, its adaptability to habitat changes, and its distribution across ecological conditions. To highlight both ecological constraints and adaptability, habitat was evaluated through two complementary approaches:

- **Habitat in its strict ecological sense**, assessing environmental and altitudinal preferences, geographical distribution, and habitat types. For this was used data collected in 2023–2024.
- **Habitat interpreted as food plants**, emphasizing the association between insect species and their food plants, reflecting their ecology. The data used range from the beginning of the 21st century until 2024.

a. Habitat Diversity

Habitat diversity and resilience were analyzed. Habitat diversity was quantified by counting the number of distinct habitat types occupied by each genus/species. Habitat types were classified considering the type of flora present in each area (Table 3, Annex 3). Resilience to habitat degradation was scored on a scale of 1 to 4:

- **1 (Not Resilient):** Limited to undisturbed habitats with almost no exotic plants.
- **2 (Low Resilience):** Rarely present in degraded habitats or areas with few exotic plants.
- **3 (Medium Resilience):** Occasionally present in degraded habitats or areas with multiple exotic plants.
- **4 (Highly Resilient):** Frequently present in degraded or exotic habitats.

b. Food Plant Associations

Species were ranked based on habitat and plant specificity to highlight their ecological specialization. To explore the relationships between species and their food plants, both historical and recent data were analyzed. Key metrics included:

- **Total Plant Associations**: The number of plant species where insect observations were recorded.
- **Likely Host Plants**: Plants confirmed as ecological hosts, supporting more than two individuals.

To evaluate rarity using Rabinowitz's rarity index, *Hyalesthes*, *Cixius*, and *Tachycixius chaoensis* (the target species) were compared based on the number of associated plants. For *Hyalesthes*, and *Cixius* species, comparisons were made with *Cyphopterum* spp., and *Issus maderensis*. For *Tachycixius chaoensis*, results were compared with *Cyphopterum fauveli*.

4.6.2 Adults Monitoring

Understanding the activity periods of insect species is critical for evaluating their responses to environmental conditions. Correlating insect densities over time with meteorological data, we can assess habitat suitability and identify potential environmental constraints on species populations. Insect densities over time were calculated for *Cixius* spp. and *Hyalesthes portonoves* based on the number of individuals captured per net beat (number of insects/number of beats). For *Tachycixius chaoensis*, densities were determined relative to the number of plants sampled (number of insects/number of plants).

To track species activity, an adult activity and presence timeline was created, recording observations of individuals across different months, along with weather conditions and specific food plants where they were found. This timeline also notes disturbances in the surveyed sites. Photographs of host and food plants were included to visually document habitat associations. The timeline also included graphs displaying the temperature and humidity recorded on the sampling days alongside the species density data.

4.6.3 Population Abundancy

The assessment of population abundance across various sites provides valuable insights into the relative abundance and distribution of each genus/species. The data collected between 2022 and 2024, along with additional historical sampling from the late 20th century to the present, suggest differences across genera and species. For each genus, both local abundance and general abundance were calculated.

a. Field Sampling Data (2022–2024)

- **Local Abundance**: For *Hyalesthes* and *Cixius* spp., it was calculated from the number of individuals captured per 100 beats in areas where the species was detected. This value reflects species density and habitat suitability.
- **General Abundance**: For *Hyalesthes* and *Cixius* spp., it was estimated by the number of individuals per 100 beats across all sampling areas, including sites where the species was absent. This measure provides insights into broader patterns of rarity or abundance across the study area.

For *Tachycixius*, abundance was assessed by considering the number of individuals found relative to the size of each sampled region, specifically based on 80% of the actual area of each site (Ponta de São Lourenço, Ilhéu da Cevada, Ilhéu do Farol, Deserta Grande, and Ilhéu Chão).

To assess rarity and population dynamics, *Hyalesthes*, *Cixius*, and *Tachycixius chaoensis* (the target species) were compared with related species based on abundance data. For *Hyalesthes* and *Cixius*, comparisons were made with *Cyphopterum spp.* and *Issus maderensis* to identify genus-level trends in population dynamics. Similarly, for

Tachycixius chaoensis, comparisons were made with *Cyphopterum fauveli* to highlight differences in population size and distribution patterns.

b. Historical Data - 2024

Integrated historical and recent data allowed the calculation of maximum, minimum, mean, and median individual counts. This approach highlights species with restricted ranges or consistently low densities. Key metrics included:

- **Overall Abundance:** Total number of individuals recorded for each species.
- **Density Patterns:** Variability in individual counts across sites.

4.6.4 Distribution

Occurrence and habitat suitability maps are vital for understanding species distribution and identifying potential habitats in unsampled areas. Through SDM field data are combined with environmental variables, addressing sampling gaps and supporting conservation efforts, including IUCN Red List assessments.

a. Environmental and Spatial Data Collection and Sorting

To model species distributions (both targeted species and host plants), a comprehensive set of environmental datasets was compiled, covering species occurrences, vegetation, climate, soil characteristics, and terrain features (Table 6). Data selection prioritized long-term metrics aligned with IUCN Red List criteria, as these are less influenced by short-term fluctuations compared to meteorological and field-sampled data. The final selected datasets included:

- **Insect Species Occurrences**: Data were obtained from this study's field sampling, supplemented by historical records from literature (dating back to the 20th century) and collections (early 21st century), including recent additions from the UMACI collection (2022).

- **Host Plant Data**: Distribution records for *Suaeda vera* and *Globularia salicina* were sourced from GBIF (GBIF 2025a, 2025b).
- **Climatic Data**: Bioclimatic data were obtained from the WorldClim 2.0 database (WorldClim 2024), providing 19 long-term temperature- and precipitation-based variables.
- **Geological and Geographic Data**: Geological digital maps provided insights into soil types, sediment characteristics, and bedrock composition. Additionally, altitude, slope, and aspect were extracted from digital elevation models (DEMs).
- **Land Use and Conservation Data**: Information on land use, protected areas, and forest cover was compiled from open sources and local institutions.

Table 6 | Data used in model species distribution and their projection, format, and source.

Class	Data	Acronym	Projection	Format	Source
Occurrence	Cixiidae	-	-	csv	UMACI Field occurence data
	Suaeda vera	-	-	csv	GBIF
	Globularia salicina	-	-	csv	GBIF
Landscape	Inventário Florestal da RAM2	IFRAM2	EPSG:5016 PTRA08/UTM28N	shp	IFCN
	Land Use	-	EPSG:4326	shp	DROTE
Soil/ Geology	Association	-	EPSG:5016 PTRA08/UTM28N	shp	DROTE
	Litology	-	EPSG:5016 PTRA08/UTM28N	shp	DROTE
Terrain	Digital Elevation Model	DEM	EPSG:4326	tif	Japan Aerospace Exploration Agency
	Shading	-	EPSG:4326	tif	Japan Aerospace Exploration Agency (obtained from DEM)
	Carta Administrativa Oficial de Portugal	CAOP	EPSG:5016 PTRA08/UTM28N	shp	General Directore of Territory
Climatic	Bioclimatic variables	BIO (number)	-	tif	WorldClim

Environmental variables were ranked based on their relevance to species distribution modeling. For host plants such as *Suaeda vera* and *Globularia salicina*, bioclimatic variables were prioritized. Precipitation and minimum temperature were key factors for *Suaeda vera*, as described in Flora-On (Flora-on 2025), while similar habitat-associated variables were used for *Globularia salicina* (Table 7).

Table 7 | Ranked variables according to importance used for modeling habitat suitability for cixiids and host plants and with the respective output models. M = Madeira, D = Desertas.

		Plant			Cixiidae			
	Species	*G. salicina*	*Suaeda vera*		*Cixius* spp.	*Hyalesthes* spp.	*T. chaoensis*	
	Island	M	M	M+D	M	M	M	M+D
RANKED VARIABLES	**1**	Bio6	Bio6	Bio6	IFRAM2	Model 1	Model 2	Model 3
	2	Bio19	Bio12	Bio12	Bio11	Bio11	Bio11	Bio11
	3	Bio7	DEM	DEM	DEM	DEM	DEM	DEM
	4	Land-use	Lithology	Bio14	Land-use	Shading	Shading	Shading
	5	DEM	Association	-	Association	Land-use	Land-use	Bio3
	6	Lithology	Bio14	-	Bio3	Association	Association	Bio12
	7	Association	-	-	Bio12	Bio3	Bio3	Bio7
	8	-	-	-	Bio7	Bio12	Bio12	Bio10
	9	-	-	-	Bio 11	Bio7	Bio7	Bio14
	10	-	-	-	-	IFRAM	-	Bio19
Output		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7

For Cixiidae species, vegetation presence and food plants were the primary environmental factors considered. Comparative studies on environmental conditions affecting other cixiid species also informed the selection of variables (see Annex 6).

- *Cixius* spp.: As an inland forest insect, key factors included bioclimatic variables related to temperature, altitude, and vegetation type (IFRAM). Land use was also considered, as variations in habitat structure may impact species occurrence.

- *Hyalesthes* spp. and *T. chaoensis*: As coastal, oligophagous insects, the most critical variables were host-plant distribution, which was modeled beforehand. Bioclimatic and geological features were also considered. However, for *T. chaoensis*, land use was excluded, as this species is exclusively found in protected areas, meaning no land-use variation exists in its distribution.

b. Preparation of Data

To ensure accuracy, plant species occurrence data were validated before use. GBIF plant records underwent quality control, including GPS error correction and removal of anomalous records, such as occurrences mistakenly placed in the ocean. The final dataset sizes for both plant and insect records are summarized in Table 8.

Table 8 | Number of host plant occurrences (presences) from GBIF and occurrences and absences of cixiids obtained from field sampling and UMACI Collection.

Class	Species	Presences	Absences
Plant	*Globularia salicina*	887	-
	Suaeda vera	1334	-
Cixiidae	*Cixius* spp.	22	57
	Hyalesthes spp.	61	165
	Tachycixius chaoensis	80	569

To enhance analytical efficiency without compromising output quality, categorical layers with excessive classifications were reclassified to reduce complexity. The Land-use layer was reduced from 45 to 9 categories, soil association from 13 to 8 categories, lithology from 56 to 8 categories and the floristic inventory from 24 to 12 categories.

WorldClim bioclimatic data, originally at a 1 km^2 resolution, were statistically downscaled to 100 m × 100 m for Madeira and Desertas Islands using strong correlations with altitude (coefficients of determination r^2). Variables were matched to this resolution using custom QGIS procedures. Variables with weak correlations ($r^2<0.500$), such as mean diurnal range, isothermality, and precipitation of the warmest quarter were retained at 1 km² resolution (Table 9). All remaining variables were converted to TIFF format and standardized according to the resolution guidelines described above. Data analysis and distribution modeling were performed using RStudio 2022.07.2+576 with R.

Table 9 | Coefficients of Determination (r^2) between bioclimatic variables and average altitude at 1 km² Scale.

Bioclimatic variables		Coefficient of determination (r^2)
Name	**Abbreviation**	
Annual Mean Temperature	bio1	0.946
Mean Diurnal Range	bio2	0.000
Isothermality	bio3	0.330
Temperature Seasonality	bio4	0.688
Max Temperature of Warmest Month	bio5	0.837
Min Temperature of Coldest Month	bio6	0.938
Temperature Annual Range	bio7	0.243
Mean Temperature of Wettest Quarter	bio8	0.954
Mean Temperature of Driest Quarter	bio9	0.905
Mean Temperature of Warmest Quarter	bio10	0.926
Mean Temperature of Coldest Quarter	bio11	0.949
Annual Precipitation	bio12	0.932
Precipitation of Wettest Month	bio13	0.773
Precipitation of Driest Month	bio14	0.868
Precipitation Seasonality	bio15	0.829
Precipitation of Wettest Quarter	bio16	0.893
Precipitation of Driest Quarter	bio17	0.913
Precipitation of Warmest Quarter	bio18	0.031
Precipitation of Coldest Quarter	bio19	0.897

c. Modelling Design

Due to the absence of systematically recorded absences for host plants, MaxEnt (Maximum Entropy) was selected as the primary modeling algorithm. MaxEnt, well-suited for presence-only data, uses pseudo-absence points (background points where the species' presence is unknown) to improve habitat predictions. This approach provides insights into the environmental conditions that favor species presence (Merow *et al.* 2013). Although Generalized Linear Models (GLMs) are typically better for SDM because they use both presence and absence data to predict real presence or absence, they were not used in this study. This is because presence data was sparse across the study area compared to the absence data. As a result, MaxEnt, which predicts habitat suitability rather than actual presence or absence, was used instead.

To minimize overfitting, each MaxEnt run should include at least ten presence records per variable. For Cixiidae species, this limitation allowed the inclusion of two to three variables for *Cixius*, six for *Hyalesthes*, and eight for *Tachycixius*. Modeling *Cixius* was particularly challenging due to the limited number of presences. The most important modeling metrics included:

- **True Skill Statistic (TSS):** Used to evaluate model accuracy, it provides information of the model’s ability to correctly predict both presences and absences while accounting for chance Models with TSS values above 0.6 were included in the final analysis.
- **Pseudo-absences:** Three independent sets (~9,700 points each) reduced selection bias.
- **Ensemble Modeling:** Results from 45 MaxEnt runs per species were combined (i.e., weigthed average based on TSS), to enhance robustness and predictive reliability.
- **Splitting:** 80% of the dataset was used for training and 20% for testing, with 15 repetitions for robustness.

MaxEnt suitability scores (0 to 1) were converted to binary maps using thresholds that maximized sensitivity (true positives) and specificity (true negatives). This balanced approach ensured precise differentiation between suitable and unsuitable habitats.

d. R Packages

The following R packages were utilized in this analysis for various purposes, including species distribution modeling, data visualization, and spatial analysis:

1. biomod2: For species distribution modeling (Thuiller *et al.* 2023).
2. ggplot2: For data visualization and plotting (Wickham 2016).
3. gridExtra: For handling grid graphics (Auguie 2017).
4. raster: For raster data spatial analysis (Hijmans 2023).
5. rasterVis: For enhanced raster visualization and plotting (Lamigueiro & Hijmans 2023).
6. ggtext: For improved text rendering in ggplot2 (Wilke & Wiernik 2022).
7. tidyterra: For spatial data manipulation and analysis (Hernangómez 2023).

e. Geographic Range

Two key metrics were calculated in QGIS to evaluate geographic range for each species:

- **Extent of Occurrence (EOO):** This is spatial spread of each species. It is represented by the minimum convex polygon encompassing all occurrence points and habitat patches. Calculation used the "Minimum Bounding Geometry" tool in QGIS and the Official Administrative Map (CAOP) of Madeira. Polygons areas were derived by adding a new field to the attribute table and applying the area expression.
- **Area of Occupancy (AOO):** This is the total area of occupied patches. It is calculated using a 2 km × 2 km grid, as recommended by the IUCN Red List. Occupied grid cells were counted, and the total area was derived by multiplying the number of occupied grids by 4 km².

For the five species modeled (*C. madeirensis, C. verticalis, H. madeires, H. portonoves,* and *T. chaoensis*), EOO and AOO calculations were also performed on final binary maps from the distribution models. Results were refined by:

- Splitting modeled genus data (e.g., *Hyalesthes*) equally among species.
- Final results averaging occurrence-based and model-based areas.
- Using combined data from Madeira and Desertas for *T. chaoensis*.

Results were expressed in km², with smaller and more fragmentated ranges indicating higher rarity.

4.6.5 Rarity Evaluation

Rarity evaluation offers significant insights, particularly through the application of the Rabinowitz framework. This approach assesses geographic range, local population size, and habitat specificity, providing a robust foundation for initiating IUCN species assessments. The analysis included species from the family Cixiidae and comparative species such as *Cyphopterum fauveli*, *Cyphopterum* spp., and *Issus maderensis*. The *Cyphopterum* species that is used for comparison with *Cixius* and *Hyalesthes* species will be named *Cyphopterum* spp. since there are taxonomic questions about the *Cyphopterum* species that occurs in *Globularia salicina*.

The Rabinowitz matrix synthesized geographic range, local population size, and habitat specificity to rank species rarity. The evaluation formula used was:

$(A \vee E)+((T \vee U) \wedge M)+(H \vee R \wedge (P \vee HP))$

Where:

- **A:** Area of Occupancy (AOO)
- **E:** Extent of Occurrence (EOO)
- **T:** Number captured per 100 beats in specific areas
- **U:** Number captured per 100 beats across all areas
- **M:** Mean individuals per site
- **H:** Number of habitats
- **R:** Resilience to habitat degradation

- **P:** Number of plant species associated with
- **HP:** Likely host plants

Thresholds were established by analyzing the range of observed values for each variable. Rather than using extreme minimum or maximum values, an intermediate threshold was selected to differentiate between species classified as rare and non-rare. This ensured that the classification captured meaningful ecological distinctions without being overly restrictive or too lenient.:

1. **Geographic Range:**
   - Large: $A > 100$ km²; $E > 200$ km²
   - Small: $A \leq 100$ km²; $E \leq 200$ km²
2. **Local Population Size:**
   - Large: $T > 5$; $U > 1$; $M > 5$
   - Small: $T \leq 5$; $U \leq 1$; $M \leq 5$
3. **Habitat Specificity:**
   - Wide: $H > 3$; $R > 2$; $P > 5$; $HP > 1$
   - Narrow: $H \leq 3$; $R \leq 2$; $P \leq 5$; $HP \leq 1$

This systematic approach identified species with heightened rarity and ecological constraints, informing conservation priorities effectively.

4.6.6 Conservation Status

The conservation status of the target species was evaluated by assessing habitat decline, threats, and applying the IUCN Red List criteria. The evaluation focuses on understanding the extent of habitat loss and the potential impacts of human activities. The analysis combines field data with historical imagery, species occurrence, and distribution modeling to assess the species' vulnerability. Even though, the species have enough data to evaluate using the IUCN Criterion D, the assessment was conducted only using the Criterion B, focusing on the EOO, AOO and threats to the species' habitats. This evaluation is crucial for determining the species' risk of extinction and informing conservation strategies.

a. Threats and Habitat decline

Habitat decline for *Cixius* spp. was evaluated using data from two forest inventories in Madeira. The first inventory, based on aerial photography (2004) and field data (2008), while the second inventory used aerial photography (2008–2010) and field data (2015). Changes in the extent of Laurel Forest (*Laurisilva*) were assessed by comparing mapped forest cover and field observations. Vegetation composition and habitat conditions were documented to evaluate fragmentation and habitat quality decline.

For *Hyalesthes* species, coastal habitat decline was studied over nearly two decades using historical imagery from Google Earth. Imagery from 2004 was compared with the most recent data from 2023, focusing on urbanization and habitat loss in areas where *G. salicina* occurs. Two key sites were analysed: São Vicente in the North and Santa Cruz (airport) in the South of the island. Field surveys complemented image analysis to identify habitat changes, with particular attention to natural disturbances such as landslides and wildfires affecting coastal habitats.

The impact of tourism on *T. chaoensis* was evaluated at Vereda da Ponta de São Lourenço through visitor surveys and fieldwork. Key aspects included: visitor trends from Regional Tourism data analyzed to identify trends in visitor numbers; visitor counts (locals and tourists) conducted at Baía d'Abra on July 13th, 2023, recording individuals every 15 minutes from 9:00 to 18:00 and field observations based on direct impacts of tourism on habitats studied.

b. IUCN Assessment

The assessment under Criterion B used available data to assess the following parameters: B1, Extent of Occurrence (EOO) and B2, Area of Occupancy (AOO). The values EOO and AOO were obtained in the Geographic Range evaluation, as the assessment also incorporates sub-criteria (a) and (b).

Sub-Criteria Analysis

Sub-criterion (a). Assessed using the final distribution model map, which provided insights into habitat fragmentation by identifying isolated patches and potential suitable locations. Fieldwork data, combined with information on threats and habitat quality, was used to determine the number of distinct locations where species are present.

Sub-criterion (b). Focused on threats, particularly sub-point (iii), which addresses ongoing habitat loss and degradation. Due to sparse historical data and a lack of precise geographic specificity, comparisons related distribution changes under sub-points (i) and (ii) were limited.

Sub-criterion (c). Not applicable because of inconsistent data on species occurrences and population dynamics over time.

The classification under Criterium B relied primarily on sub-criteria (a) and (b). If a species satisfied only one sub-criterion, or both if both sub-criteria failed to meet the thresholds for B1 or B2, the species was classified as 'Near Threatened' under Criterion B.

The collection and analysis of data were supported by the supplementary tables provided by the IUCN for species assessments (REF).

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals			
(c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals			

Figure 5 | Geographic Range Assessment of Cixiidae Using IUCN Red List Criterion B. Source: IUCN 2012.

5. Results

5.1. Habitat and Ecology: Habitat Specificity and Food Plants

5.1.1 Habitat Specificity

Habitat specificity reflects the degree to which a species is associated with environments, its adaptability to habitat changes, and its distribution across various ecological conditions (Fig. 6).

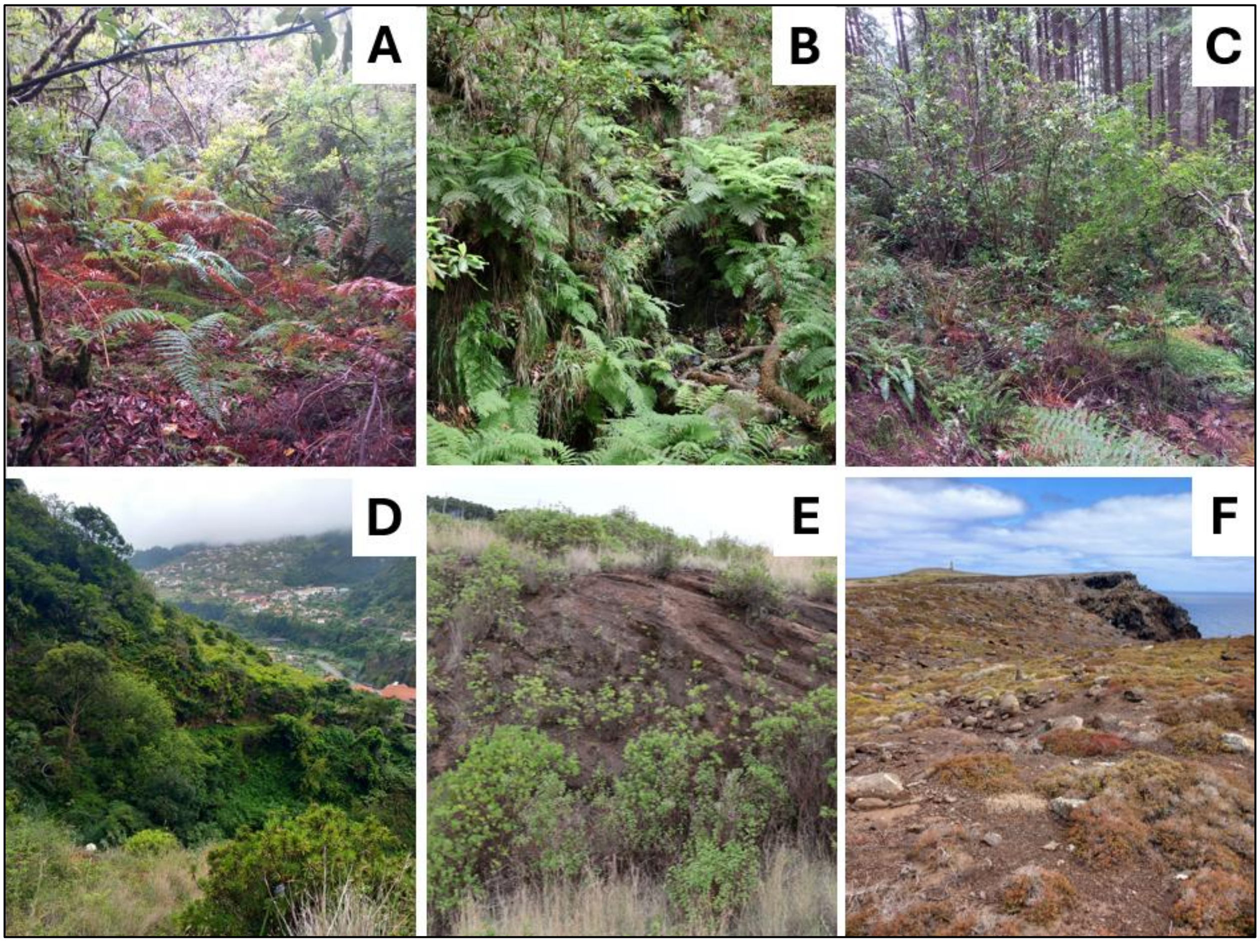


Figure 6 | Habitats of the Cixiidae species on Madeira Archipelago. (A-C) Laurel forest, (D,E) *Globularia salicina* habitat, and (F) coastal xerophytic habitat of *Suaeda vera*. Species: *Cixius madeirensis* (A), *C. verticalis* (B), *C. wollastoni* (C), *Hyalesthes madeires* (D), *H. portonoves* (E), and *Tachycixius chaoensis* (F). Localities: Madeira Island: (A) Fanal, (B) Rabaçal, (C) Ribeiro Frio, (D) Santana, (E) Caniço, (F) Ilhéu Chão.

In the case of *Cixius* species, habitat specificity is evident in their preference for native forest environments, particularly high-altitude laurel forests (Fig. 6A, B, C). Most individuals (53%) were found in intact high-altitude laurel forests, while 26% occurred in transitional zones between laurel forest and heather vegetation, all of which were *C. madeirensis*. The remaining 21% were found in degraded patches of laurel forest, often surrounded by exotic vegetation or abandoned agricultural land. Only one individual (*C. verticalis*) was recorded at altitudes below 300 m, within a low-altitude laurel forest.

Hyalesthes madeires exhibited clear ecological and geographical segregation from H. *portonoves*. For *H. madeires*, 93% of individuals were found in rocky habitats with *Globularia salicina* (Fig. 6D). These habitats included coastal cliffs (67%) and inland rocky slopes near streams or valleys. The remaining 7% were recorded at the margins of low-altitude laurel forest with *Globularia salicina*. *Hyalesthes madeires* was primarily associated with plants growing on rocky substrates and was predominantly distributed in the northern and central regions of Madeira. In contrast, *H. portonoves* was restricted to southern habitats. *Hyalesthes portonoves* exhibited higher population densities at inland locations, which accounted for 67% of the captured individuals, though the greatest number of different locations occurred on coastal cliffs (Fig. 6E). Both species were also found in areas showing various signs of degradation, such as remnants of native vegetation in urbanized areas, cultivation zones and areas with high density of exotic plants.

Tachycixius chaoensis was strictly confined to xerophytic coastal habitats (Fig. 6F). No ecological variation was observed across its range, with the species consistently associated with *Suaeda vera* shrubs in exposed, wind-swept environments.

5.1.2 Food Plants

Published data and sampling records indicate that *Cixius* species are primarily associated with native and endemic plant species, except for two specimens–one of *Cixius madeirensis* and one for *C. wollastoni* – which were found on introduced plants.

Cixius madeirensis was recorded on ten plant species, with the highest abundance on the native ferns like *Diplazium caudatum* (24 individuals) and *Pteridium aquilinum* (22 individuals). Although primarily associated with native ferns (other registers on *Adiantum* spp., *Dryopteris affinis,* and *Pteris incompleta*), it occasionally occurs on other plants such as *Cedronella canariensis* and *Argyranthemum pinnatifidum* (eight individuals each), *Rubus* spp. (four individuals) and other shrubs or trees (*Clethra arborea* with ≤ two individuals). The species was also found one single time on an introduced species (*Hydrangea macrophylla*).

In contrast, *C. verticalis*, found on nine plant species, had the highest number of individuals recorded on *Clethra arborea* (seven individuals) and *Argyranthemum pinnatifidium* (four individuals). Additionally, it was found on ferns, herbs, and other plants (*Adiantum* spp., *Diplazium caudatum, Dryopteris affinis, Polypodium* spp., *Festuca donax, Euphorbia mellifera*, and *Persea indica* with ≤ two individuals per species), suggesting that *C. verticalis* prefers trees and shrubs.

For *C. wollastoni,* data is limited due to the low number of captures. The species was recorded on only four plant species, with three individuals found on *Digitalis pupurea* and few additional records, each with just one individual per plants species (*Pteridium aquilinum* and *Clethra arborea*). This included one individual on an ornamental plant (*Crocosmia* sp.).

Both *Hyalesthes* species appear to use the shrub *Globularia salicina* as their hostplant (*H. madeires* - 126 individuals, *H. portonoves* - 254 individuals). Other individuals found on herbs and low shrubs near *G. salicina*, seem to be accidental captures, as the numbers were very low (1-2 individuals). These plants included *Suaeda vera* (two individuals) for *Hyalesthes portonoves,* and three species (*Bituminaria bituminosa, Deschampsia argentea*, and *Hyparrhenia hirta*) for *Hyalesthes madeires*.

Tachycixius chaoensis was exclusively associated with the shrub *Suaeda vera* (71 individuals), suggesting a high degree of host specialization.

5.2 Adult Monitoring

5.2.1 *Cixius* spp.

Over the one-year monitoring period (29th July 2023 – 27th July 2024) at two sites, adult *Cixius* species exhibited distinct temporal activity patterns (Fig. 7A). Both *Cixius madeirensis* and *Cixius verticalis* were found to be active at night, as they were frequently observed on handrails only after dark, while during the day, they remained on plants or in flight. Adult *Cixius* individuals were consistently recorded throughout the monitoring period, with insects detected at all sampling sites at some point. However, their presence was seasonal: adults were observed from 29th July to 10th September 2023 and again from 8th April to 27th July 2024, with no detections between October and March. The highest number of individuals was recorded on 29th July 2023, likely due to the extended sampling duration on that date, as it was the first sampling event used to refine the methodology. According to the study, *C. madeirensis* was more frequently encountered (22 individuals) than *C. verticalis* (eight individuals). *C. madeirensis* was recorded from July to August 2023 and April to July 2024, while *C. verticalis* was found from July to August 2023 and May to July 2024.

Mating behavior was observed in *C. madeirensis* during July and August 2023. Exuviae were abundant on *Diplazium caudatum* plants in August. The peak in adult activity coincided with the final nymphal stage, as exuviae were most frequently found from late July through August. Some locations could not be sampled during certain periods due to habitat disturbances that made sampling impossible, such as plant removal.

5.2.2 *Hyalesthes portonoves*

Only adults of *Hyalesthes portonoves* were observed. They were present from April to July 2024. Throughout the observation period, no eggs or nymphs were detected. Adults, two males and one female (density = 0.23 per net beat), were first recorded on 28th April 2024. The last individuals, three females (density = 0.08 individuals per beat), were collected on 14th July 2024 (Fig. 7B). Captures peaked on 22nd May 2024, with five males and three females recorded (density = 1.60 individuals per beat). As the season progressed, male abundance declined sharply, and by 30 June, females dominated the observations. On this date, the density dropped to 0.8 individuals per beat, and all specimens collected (four individuals) were females. By 14th July 2024, the three females observed were full of wax.

Adults were recorded under a range of weather conditions, including sunny, cloudy, and rainy days, with no apparent influence of temperature or humidity variations on their activity. They were typically found resting on the upper surfaces of *G. salicina* leaves or actively feeding on flower buds, particularly during their abundance peak in June. No visible relationship was observed either between the plant's condition and the insect population dynamics. While *H. portonoves* activity coincided with certain phenological stages of *G. salicina*, particularly during its flowering and leaf-spotting phases from April to June, adults continued to be present even as the leaves declined in health and structure. This suggests that their activity may not be directly influenced by the health or flowering patterns of their host.

5.2.3 *Tachycixius chaoensis*

Observations revealed two distinct activity periods, suggesting a bivoltine life cycle. A total of 35 adult specimens were recorded, but no nymphs or eggs were observed, except for a single exuvium. The first activity period began on 26th September 2023, with a single male recorded (density = 0.1 individuals per plant) (Fig. 7C), and ended on 2nd December 2023, with only one female recorded (density = 0.033 individuals per plant). The peak of the first activity period occurred on 11th November 2023 (three ♂♂ and three ♀♀) and 3rd December (two ♂♂ and four ♀♀), with a total of six individuals (density = 0.2 individuals per plant). The second activity period occurred in 2024, beginning on 7th April, with a single female (density = 0.033 individuals per plant), and peaking on 28th April, with six individuals (two ♂♂ and four ♀♀, density = 0.2 individuals per plant). The last specimens of this period (one ♂, two ♀♀) were recorded on 10th June (density = 0.1 individuals per plant).

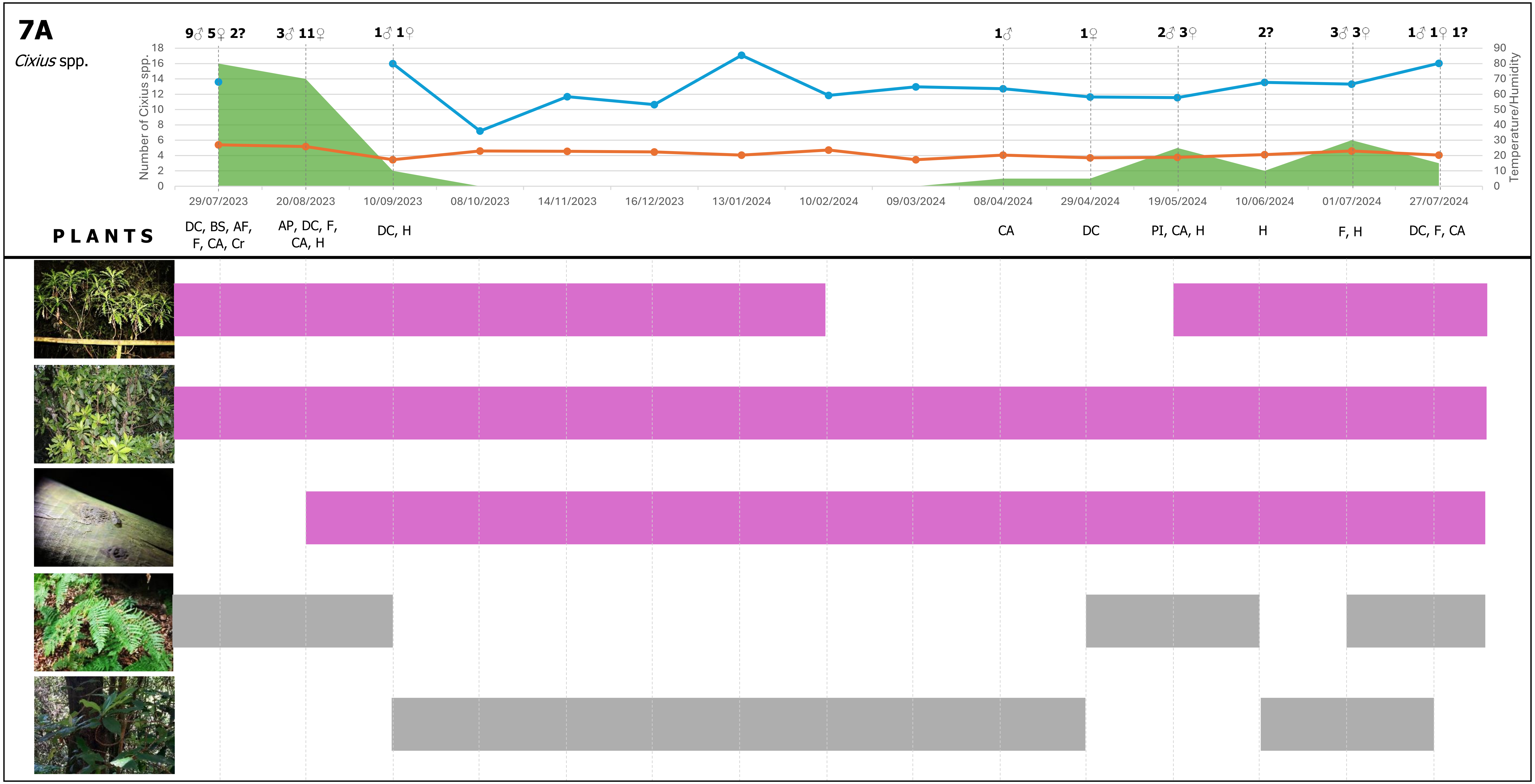
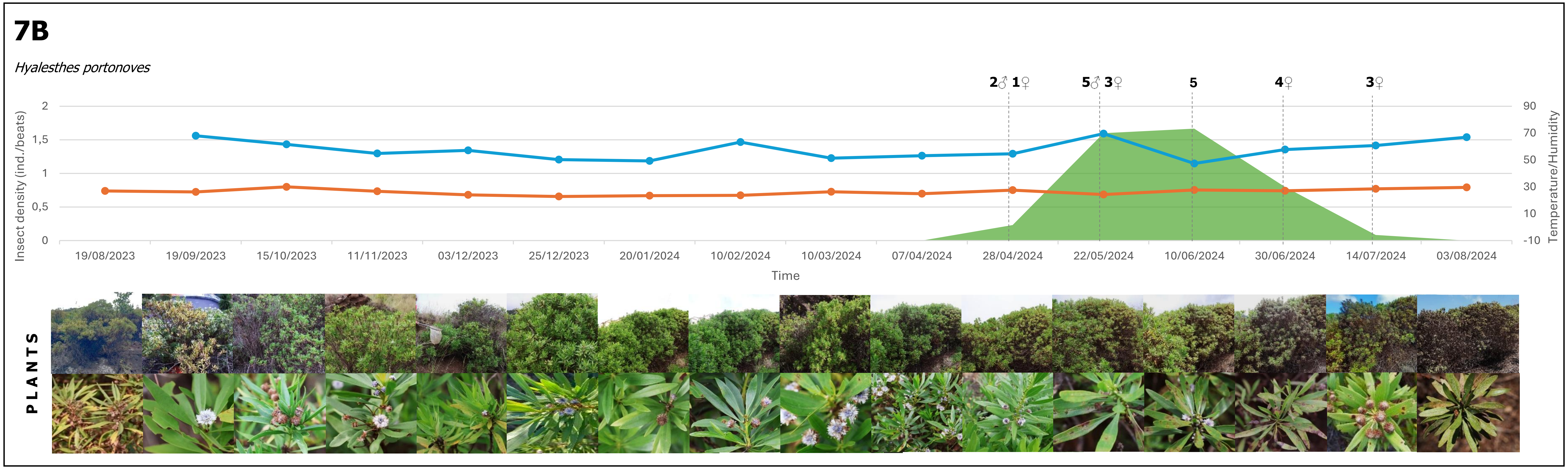


Figure 7 | Adults recorded during one year monitoring indicating in the graph the density/number of specimens (green), temperature (orange) and humidity (blue) on the sampling moment and food plant condition.: *Cixius madeirensis* and *C. verticalis* (A), *Hyalesthes portonoves* (B) and *Tachycixius chaoensis* (C). Below the graph, sampling periods for each micro-habitat are represented: Purple = Site 1 (*Argyranthemum pinnatifidum* subsp. *pinnatifidum*, *Clethra arborea* and handrail; Grey = Site 2 (ferns and trees). Abbreviations: DC = *Diplazium caudatum*, BS = *Blechnum spicant* subsp. *spicant*, AF = *Athyrium filix-femina*, F = fern, CA = *Clethra arborea*, Cr = *Crocosmia* sp., AP = *Argyranthemum pinnatifidum* subsp. *pinnatifidum*, H = handrail, PI = *Pteris incompleta*.



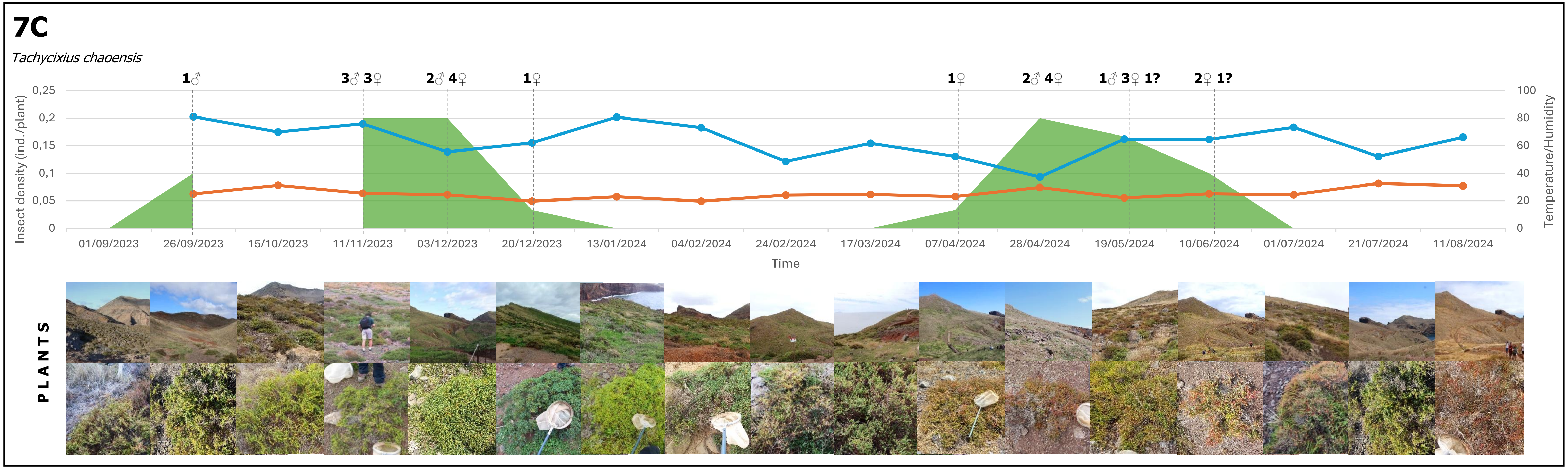


Figure 7 | Continuation.

The distribution of *T. chaoensis* across the study area was highly uneven. Some zones were entirely devoid of specimens (Fig. 8), and where present, densities remained consistently low, with a maximum of three individuals per plant. Adults of *T. chaoensis* were observed on plants of *Suaeda vera* irrespective of its size, health, or coloration. The presence of the species was recorded under different weather conditions (fig. 7C). The study area was frequently visited by tourists throughout the year, many of whom walked off designated paths, potentially damaging *Suaeda vera* shrubs.

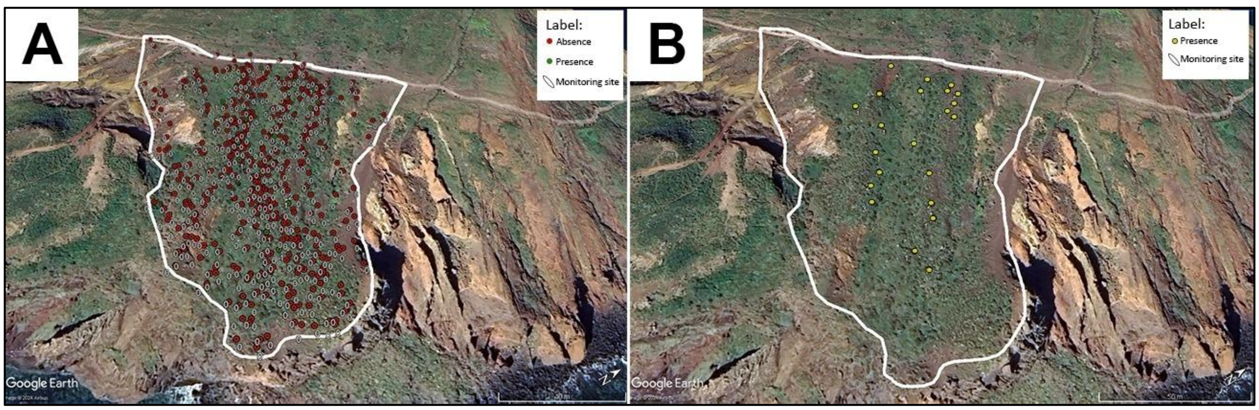


Figure 8 | Sampling area of *Tachycixius chaoensis* in Ponta de São Lourenço, delimited by a white line, indicating absence (A) and presence (B) records.

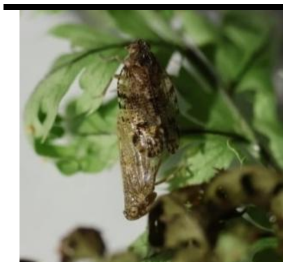
5.3 Population Abundancy

Data collected between 2022 and 2024, along with historical sampling records from the late 20th century to the present, indicate differences in abundance across genera and species. For each genus, the total number of individuals, capture rates per 100 beats, and site-specific capture frequencies were evaluated to understand their local rarity levels.

5.3.1 *Cixius* spp.

From 2022 to 2024, a total of 19 individuals were recorded across 12 sites. Standardized sampling yielded 13 individuals in seven sites, resulting in a capture rate of 1.15 individuals per 100 beats. Across all sampled sites (69), the overall capture rate was much lower, at 0.25 individuals per 100 beats. These rates were considerably much lower when compared with endemic species like *Cyphopterum* spp. (5.89 vs 2.78) and *Issus* *maderensis* (7.15 vs 5.74), both of which were collected at the same sampling sites (Table 10). Even when present, *Cixius* species were often encountered in small numbers.

Table 10 | Population density estimates based on capture rate per 100 beats in *Cixius* spp. and *Hyalesthes* spp. Sampling: Presence vs. Total Area. Source: sampling data from 2022-2024.

Species		Number of Specimens Collected	Only presences	Presences and Absences
	*Cixius* spp.	13	1.15	0.25
	Cyphopterum retusum	145	5.89	2.78
	Issus maderensis	299	7.15	5.74
	*Hyalesthes* spp.	61	5.02	0.90
	Cyphopterum sp.	38	2.03	0.57
	Issus maderensis	122	6.08	1.82

Records from the late 20th century to the present for *Cixius madeirensis* were limited, being present in only 12 sites with a total of 68 individuals. This maximum count at a single site was 28 individuals, and the mean number of individuals per site was 4.86, with the median of one, reflecting occasional clusters but an overall low-density presence. In comparison, *Cixius verticalis* and *Cixius wollastoni* were even more restricted both in range and population size. *Cixius verticalis* was recorded in only seven sites with a total of 32 individuals, reaching a maximum of 19 individuals at a single site, with a mean of 4.00 individuals per site and a median of one.

Cixius wollastoni, the rarest among the *Cixius* species, occurred in only 3 sites, with a total of 6 individuals, reaching a maximum of 4 individuals at one location. Both species showed a median count of 1 individual per site, suggesting very sparse populations (Table 11).

5.3.2 *Hyalesthes* spp.

From 2022 to 2024, *Hyalesthes* species were observed at 19 sites with a total of 61 individuals, resulting in a standardized capture rate of 5.02 individuals per 100 beats. Across all sampled points (89), the overall capture rate dropped to 0.90 individuals per 100 beats. These values were smaller than those for *Issus maderensis* (6.08 vs 1.82) but higher than for *Cyphopterum* (2.03 vs 0.57) (Table 10).

Surveys from the late 20th century to the present show that both *H. madeires* and *H. portonoves* displayed more concentrated distributions, with relatively high densities where they occur, though these densities vary by location. *Hyalesthes madeires* occured in 17 sites (130 individuals) with a maximum count of 58 individuals at single site, a mean of 7.65 individuals per site, and a median of 4. *Hyalesthes portonoves*, was found in 43 sites (256 individuals), with a maximum of 101 individuals at a single site. Its mean was 5.95 individuals per site, and its median was 2 (Table 11).

Table 11 | Total Number of sites with insects and individuals captured, including mean (± SD), median, and maximum individuals per site. Source: Sampling data from this study and recorded data from UMACI Collection.

Species	Total number		Maximum individuals recorded on one site	Individuals per site	
	Sites	Individuals		Mean ind/site	Median
Cixius madeirensis	12	68	28	4.86±2.03	1
Cixius verticalis	7	32	19	4.00±2.18	1.5
Cixius wollastoni	3	6	4	2.00±1.00	1
Hyalesthes madeires	17	130	58	7.65±3.40	4
Hyalesthes portonoves	43	256	101	5.95±2.34	2
Tachycixius chaoensis	46	71	6	1.51±0.14	1

5.3.3 *Tachycixius chaoensis*

Sampling from 2022-2024 on Ponta de São Lourenço (and islets) and Desertas Islands (Deserta Grande and Ilhéu Chão) highlighted the limited distribution of *Tachycixius chaoensis*. On Deserta Grande and Ilhéu do Farol, the species was absent from all sampled sites. On Ilhéu Chão, it was present in 27 of the 46 sampled areas, with a maximum of six individuals at a single site making it the island with the highest density per area (156.25 insects/km²) (Table 12).

On Ilhéu da Cevada, *T. chaoensis* appeared in only 3 areas, with a total of 3 individuals and a density of 9.38 insects/km². Finally on the rest of the Ponta de São Lourenço, sampled in 2022, *T. chaoensis* was found in two specific locations and with a total density of 17.31 insects/km².

Across all cixiid species surveyed from the late 20th century to the present, *Tachycixius chaoensis* had the narrowest distribution. The species' maximum count was six individuals at a single site, with a low mean of 1.51 individuals per site and a median of one, further highlighting its limited abundance (Table 12).

Table 12 | Total number of sites with insects and individuals captured, including mean (± SD), median, and maximum individuals per site. Source: sampling data from this study and recorded data from UMACI collection.

Location	80% Area (km²)	No. of Insects	Density	
			Insects/km²	Insects/m²
Ponta de São Lourenço	1.04	18	17.31	0.00001731
Ilhéu Cevada	0.32	3	9.38	0.000009375
Ilhéu Farol	0.08	0	0	0
Ilhéu Chão	0.32	50	156.25	0.00015625
Deserta Grande	0.000009	0	0	0

5.4 Distribution

5.4.1 Maps of Occurrence

a. *Cixius* spp.

Cixius species were restricted to the northern part of Madeira. *Cixius madeirensis* was recorded in 12 sites, *C. wollastoni* in three, and *C. verticalis* at seven (Fig. 9A,B). Additionally, females potentially belonging to *C. madeirensis* were recorded at six more sites, and females of *C. verticalis* at three sites. Most occurrences were in protected areas. The altitude ranges were: *Cixius madeirensis* between 426 and 1438 m a.s.l., *C. verticalis* between 144 and 871 m a.s.l., and *C. wollastoni* between 391 and 1119 m a.s.l. *Cixius wollastoni* was the only species to occur in the southern part of the island. Co-occurrence of *C. madeirensis* and *C. verticalis* occurred at Levada Ribeira da Janela (Porto Moniz) and *C. madeirensis* and *C. wollastoni* at Ribeiro Frio (Santana). *Cixius madeirensis* was recorded as early as 11th April (2003) at 723 m a.s.l. and as late as 12th September (2001) at 817 m a.s.l. *Cixius verticalis* was found between 28th April (2000) at 1119 m a.s.l. and 9th October (1998) at 723 m a.s.l. The earliest capture of *Cixius wollastoni* occurred on 16th April (2002) at 391 m a.s.l., while the latest was on 28th April (2000) at 1119 m a.s.l.

***b. Hyalesthes* spp.**

Species of the *Hyalesthes* genus were found during sampling conducted between 1997–2003, and in 2022 - 2023, at 63 sites. It was absent in 166 sites (Fig. 9C, D). Their distribution was patchy, with occurrences clustered in specific regions. *Hyalesthes* species were found throughout most of the coastal regions and central areas, particularly in the large valleys of Serra d'Água and Curral das Freiras but were absent in the western part of the island. *Hyalesthes portonoves* was found at 12 sites, all in the southern part of the island, while *H. madeires* was recorded at 11 sites in the north. Additional uncaptured individuals of *H. portonoves* were noted at 30 sites, and for *H. madeires,* at nine sites (Fig. 9D). *Hyalesthes madeires* was found at altitudes ranging from 61 to 621 m a.s.l., while *H. portonoves* occurred between 22 and 574 m a.s.l. Both *Hyalesthes* species had less than 30% of their individuals inside coastal protected areas, with occurrences located near urbanized areas. *Hyalesthes madeires* was recorded as early as 28th May (2001) at 596 m a.s.l. and as late as 9th July (2001) at 621 m a.s,l. *Hyalesthes portonoves* was found between 24th March (2024) at 48 m a.s.l. and 25th August (2022) at 338 and 447 m a.s.l.

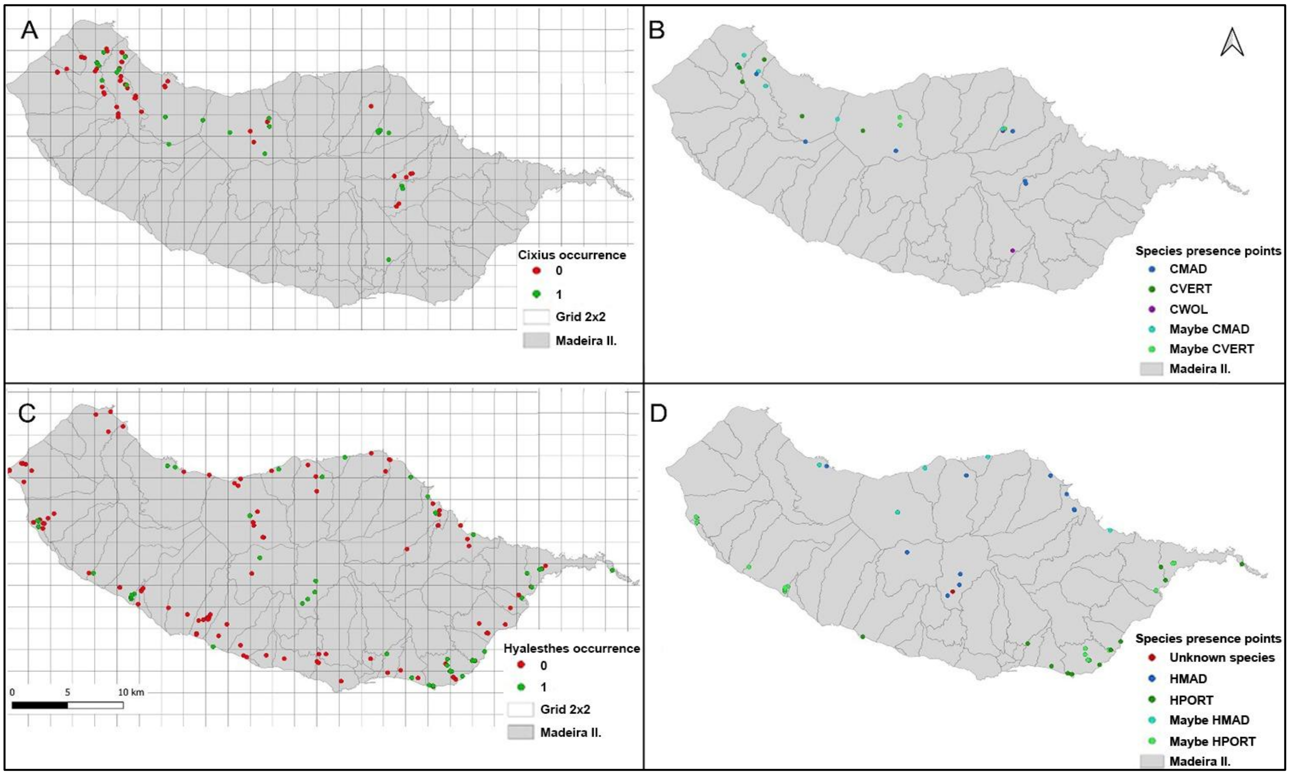


Figure 9 | Sampling points with presences and absences of *Cixius* spp. (A) and *Hyalesthes* spp. (C). Occurrence maps: (B) *Cixius madeirensis* (CMAD), *C. verticalis* (CVERT), and *C. wollastoni* (CWOL); (C) *Hyalesthes madeires* (HMAD) and *H. portonoves* (HPORT). "Maybe" are captures without males. Source: 2×2 km sampling from this study and previous records from publications and the UMACI collection.

c. Tachycixius chaoensis

Sampling conducted in 2022 and 2023 recorded *T. chaoensis* at 80 sites, with 570 sites showing no presence (Fig. 10). The species was confined to four small areas: two sites at Ponta de São Lourenço, and two on Ilhéu da Cevada and Ilhéu Chão, where most specimens were found. These locations exhibited the highest number of occurrences. Due to unfavorable weather conditions, sampling on Deserta Grande was limited to three sampling points, but neither *Tachycixius chaoensis* nor *Cyphopterum fauveli* were recorded. The species was found between 13 and 92 m a.s.l., with all individuals recorded within protected areas. *Tachycixius chaoensis* was found through occurrence sampling as early as 5th May (2024) at 51 m a.s.l. in Ilhéu Chão and as late as 18th June (2022) at 39 m a.s.l. in Ponta de São Lourenço.

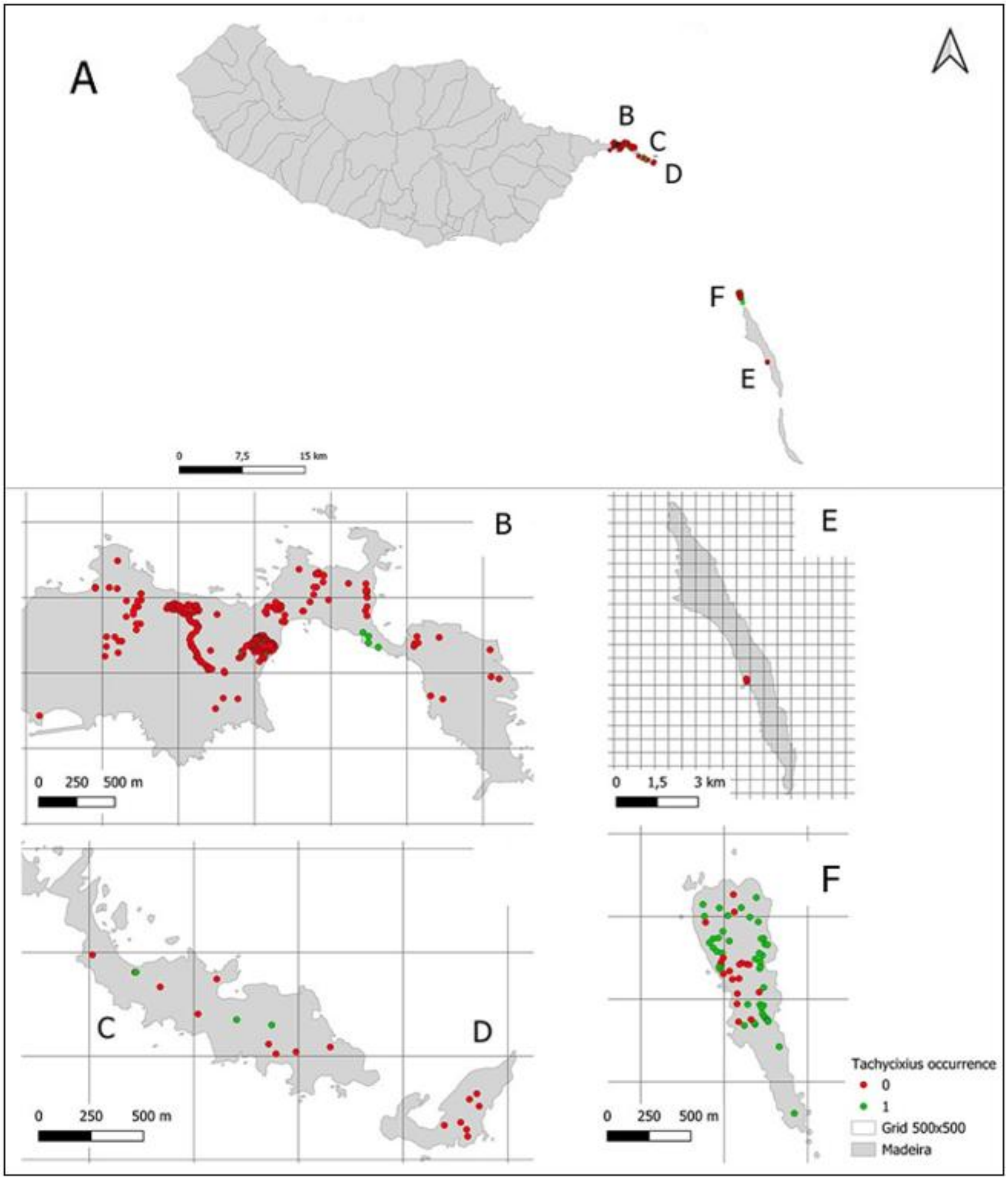


Figure 10 | Sampling points with presences and absences of *Tachycixius chaoensis* in the Madeira Archipelago (A). Madeira Island: Ponta de São Lourenço (B), Ilhéu da Cevada (C), and Ilhéu do Farol (D). Desertas Islands: Deserta Grande (E) and Ilhéu Chão (F). Sources: 500×500 m sampling from this study and previous records from the UMACI collection.

5.4.2 Modelling

a. *Cixius* spp.

The MaxEnt model for *Cixius* spp. used variables such as BIO7 (temperature annual range), the digital elevation model (DEM), and a floristic inventory layer, and indicated low habitat suitability across most of the island. The model identified higher suitability in the northern regions, particularly at medium to high altitudes. The irregular boundaries of suitable areas likely reflect the island's pronounced orogeny and floristic variability. The model achieved a sensitivity of 79.44% ± 4.34 and a specificity of 86.15% ± 2.12. The calibration yielded a mean validation value of 0.66 ± 0.05, slightly below the model's quality threshold. Consequently, only certain runs were incorporated into the final model assembly. The mean TSS score was 0.72 ± 0.12. The final model was weight to higher-scoring runs, which had a stronger influence on the output (Fig. 11A).

b. *Hyalesthes* spp.

For *Hyalesthes* spp., the distribution of its hostplant, *Globularia salicina,* was first modeled using variables like BIO6 (minimum temperature of the coldest month), BIO19 (precipitation of the coldest quarter), BIO7 (annual temperature range), DEM, soil association, lithology, and land-use. The resulting raster model was integrated into the *Hyalesthes* model as an additional variable. The model achieved an average validation score of 0.65 ± 0.02. The rate of accurate presence predictions was relatively high (87.83% ± 1.68), though specificity was slightly lower, 77.76% ± 1.75. *Globularia salicina* showed a preference for low-altitude coastal habitats (Fig. 11B).

For model evaluation of *Hyalesthes,* only the models surpassing a TSS > 0.6 threshold were considered for the final SDM. The optimal model incorporated the variables such a as *G. salicina* projection/model, shading, DEM, BIO11 (mean temperature of the coldest quarter), land-use, and soil association. Although the selected model assembly had a validation score of 0.65 ± 0.11 - slightly below the ideal threshold - it achieved a mean TSS score of 0.72 ± 0.05. This was largely due to high sensitivity, with some models achieving 100% accuracy for predictions. However, specificity remained a limiting factor, preventing higher overall performance. The final distribution map showed strong overlap with the *G. salicina* model but indicated a more restricted distribution for *Hyalesthes* (Fig. 11C).

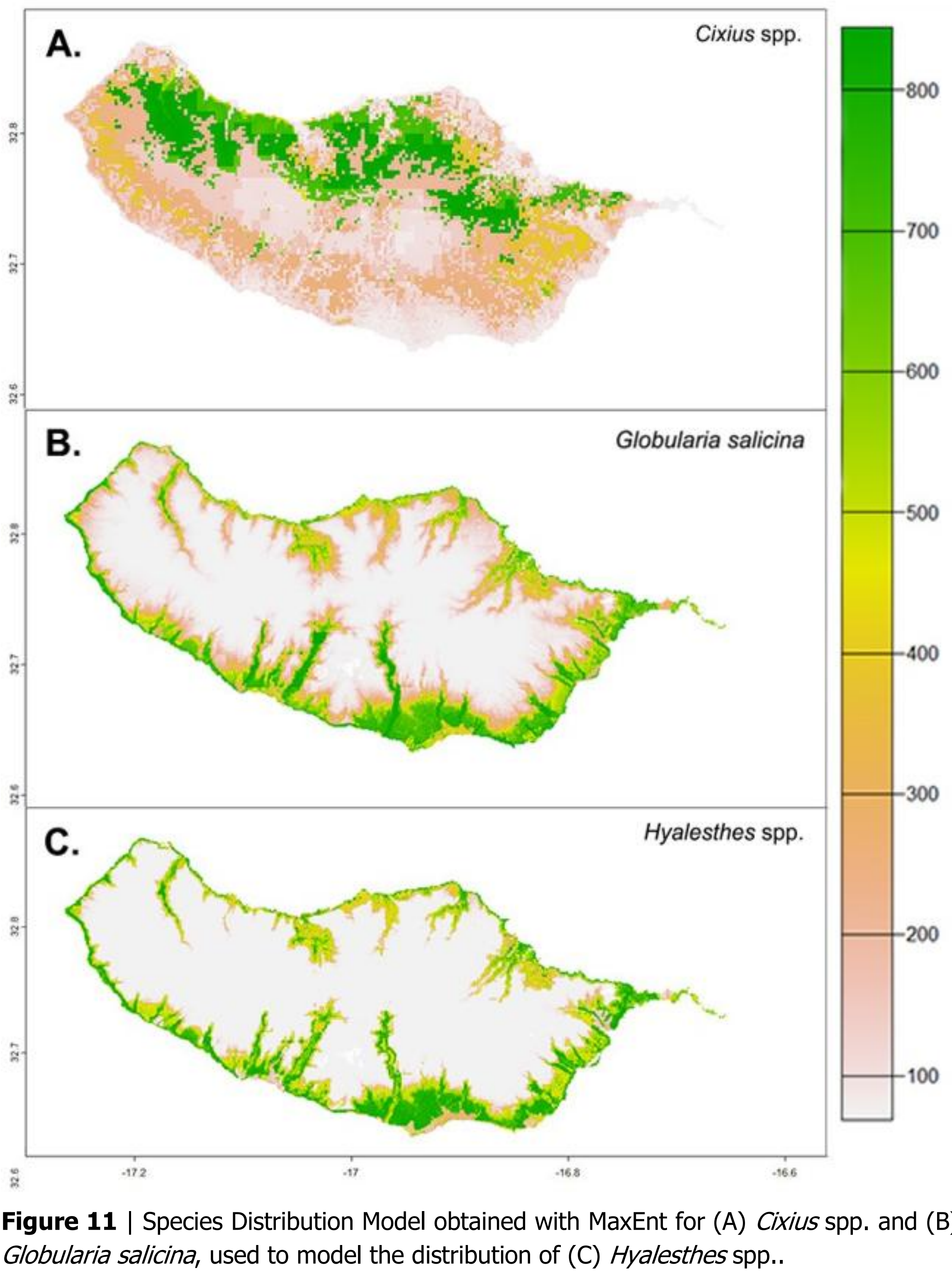


Figure 11 | Species Distribution Model obtained with MaxEnt for (A) *Cixius* spp. and (B) *Globularia salicina*, used to model the distribution of (C) *Hyalesthes* spp..

c. ***Tachycixius chaoensis***

Several *MaxEnt* model trials identified key variables for predicting habitat suitability in Madeira Island and its surrounding areas. The best validated models for Madeira Island incorporated BIO6 (minimum temperature of the coldest month), BIO12 (annual precipitation), BIO14 (precipitation of the driest month), DEM, soil association, and lithology. These models highlighted suitable habitat primarily along the coastal areas and the Ponta de São Lourenço peninsula (Fig. 12A). When expanded to include both Madeira Island and the Desertas Islands, the optimal model utilized BIO6, BIO12, BIO14, and DEM (Fig. 12B). Both models showed that suitable habitat for *Suaeda vera* was mainly confined to Ponta de São Lourenço and the lower altitudes of the Desert Islands, with near-perfect performance metrics: sensitivity and specificity approached 100%, and validation scores reached 1.0. Notably, the two modeling scenarios showed minimal differences in the extent of habitat suitability.

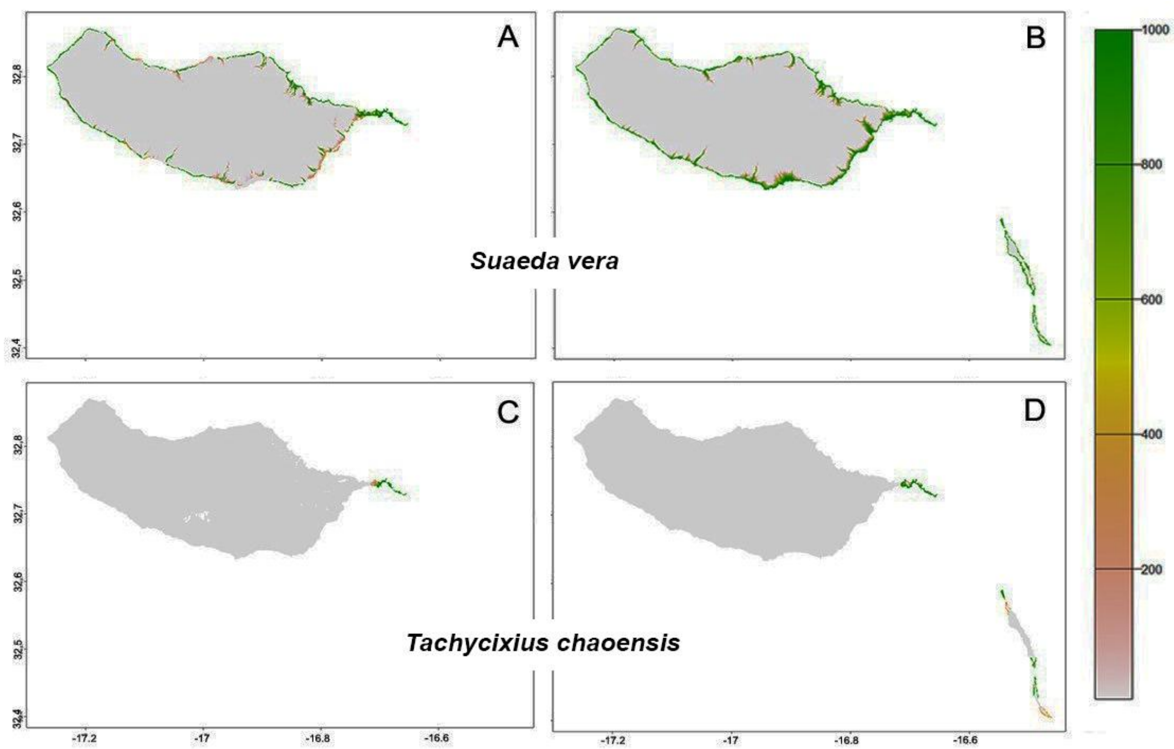


Figure 12 | Species Distribution Model obtained with MaxEnt for (A, B) *Suaeda vera* and (C, D) *Tachycixius chaoensis*, with (A, C) showing Madeira Island only, and (B, D) including the Desertas Islands.

For Madeira Island, the best model for *Tachycixius chaoensis* integrated *S. vera* projection with variables such as BIO7 (annual temperature range), BIO11 (mean temperature of the coldest quarter), DEM, soil association, land use, BIO12, and shading. Most of the models generated were incorporated into the final model. The validation score was 0.95 ± 0.08, with 100% accuracy in predicting presence points and 99.79% ± 0.05 in reading pseudo-absences. Calibration remained exceptionally high at 0.99 ± 0.00 (Fig. 12C). When combining both Madeira and Desertas islands, the model used a similar approach, incorporating *S. vera* projection, BIO7, BIO11, DEM, BIO3 (isothermality), BIO1 (annual mean temperature), BIO12, and shading. All 45 generated models surpassed the TSS > 0.6 threshold, achieving a mean validation score of 0.94 ± 0.09 (Fig. 12D).

5.4.3 Geographic Range

The geographic range of each species was assessed by comparing their observed Extent of Occurrence (EOO) and Area of Occupancy (AOO) across the target genera and reference species (Fig. 13, Table 13).

Cixius madeirensis shows a moderate observed range, occupying a small portion of the genus's overall modeled distribution. Its AOO is 40 km², and EOO spans 145.24 km². While it is less rare than *C. wollastoni* and *C. verticalis*, this species could potentially expand its range if suitable habitat becomes accessible (Fig. 13A).

Cixius verticalis has an AOO of 28 km² and an EOO of 75.42 km², occupying only a small portion of the *Cixius* genus modeled distribution. This indicates moderate rarity and some ecological constraints, though it is less restricted than *C. wollastoni.*

Cixius wollastoni has the smallest AOO (12 km²) and EOO (7.43 km²), indicating an extremely limited and fragmented range. Unlike the other evaluated species, its AOO is larger than its EOO, suggesting a highly fragmented presence. Although models for the genus predict a potential AOO of 388 km² and EOO of 548.63 km² (Fig. 13D), *C. wollastoni* occupies a tiny fraction of this range, reflecting its rarity and high vulnerability.

Hyalesthes madeires has an AOO of 48 km² and an EOO spanning 210.35 km² (Fig. 13B). It occupies a moderate distribution range, representing only a fraction of the genus modeled (AOO of 696 km²) and EOO of 925.66 km²) (Fig. 13E). While its distribution is likely restricted, it shows some potential for broader occupancy within Madeira's habitats.

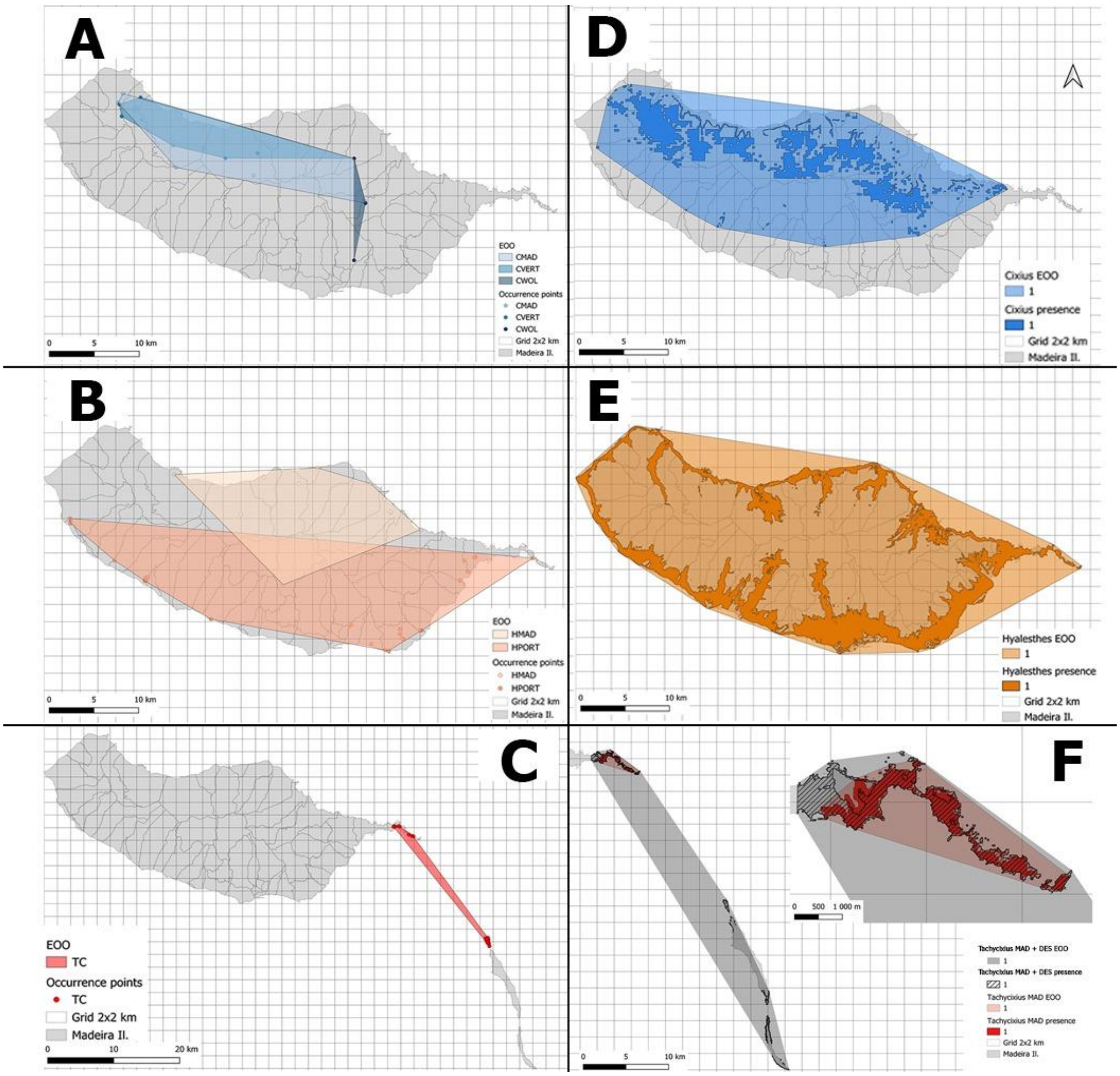


Figure 13 | Species Extent of Occurrence (EOO) and Distribution Models. (A-C) Species Extent of Occurrence (EOO) based on occurrence data: (A) *Cixius madeirensis*, *C. verticalis*, and *C. wollastoni*; (B) *Hyalesthes madeires* and *H. portonoves*; (C) *TachyCixius chaoensis*. (D-F) Species distribution model obtained with MaxEnt for genus *Cixius* (D), *Hyalesthes* (E), and species *T. chaoensis* (F), considering both Madeira and Desertas Islands models (all – MAD+DES) and the Madeira-only model (MAD). Results are shown in maps with a 2×2 km grid used for measuring the area of occupancy (AOO). Abbreviations: CMAD – *C. madeirensis*, CVERT – *C. verticalis*, CWOL – *C. wollastoni*, HMAD – *H. madeires*, HPORT – *H. portonoves,* TC – *T. chaoensis*. Source: 2×2 km sampling for *Cixius* and *Hyalesthes* and 500×500 m sampling for *T. chaoensis* from this study and previous records from publications and the UMACI.

Hyalesthes portonoves occupies a larger portion of the genus's potential range compared to *Hyalesthes madeires*. Wth an AOO of 64 km² and an EOO of 416.50 km², it suggests greater adaptability or resilience compared to other species of the genus, though its distribution is still limited.

Tachycixius chaoensis ranks second in terms of small geographic range, with an AOO of 16 km² and EOO of 23.41 km², showing an extremely restricted observed range (Fig. 13C). This suggests high habitat specialization. The modeled data aligns with the occurrence information, consistently showing low range estimates and vulnerability (Fig. 13F). Notably, much of its EOO extends over the ocean, meaning its actual terrestrial habitat is smaller than the model suggested.

Table 13 | Extent of Occurrence (EOO) and Area of Occupancy (AOO), in km^2, for Cixiidae species: Comparison of occurrence data with MaxEnt species distribution model. Source: This study, published records, and UMACI Collection.

Genera	Species	Occurrence distribution		Modeled distribution	
		AOO	EOO	AOO	EOO
Cixius	*madeirensis*	40	145.24	388	548.63
	verticalis	28	75.42		
	wollastoni	12	7.43		
Hyalesthes	*madeires*	48	210.35	696	925.66
	portonoves	64	416.50		
Tachycixius	*chaoensis*	16	23.41	MAD 24 ALL 56	MAD 6.22 ALL 179.41

5.5. Analysis of Rarity According to Rabinowitz

Each species was classified according to the Rabinowitz rarity matrix, which considers geographic range, local population size, and habitat specificity. The matrix consists of eight levels of rarity, with Level 1 representing the rarest and most vulnerable species, and Level 8 representing the least rare species. The results are as follows:

- Level 1 (Most Rare): *Cixius wollastoni* and *Tachycixius chaoensis* are classified at this level, representing the most vulnerable species. They exhibit small geographic ranges, small local populations, and narrow habitat specificity.
- Level 6: The *Hyalesthes* species (*H. madeires* and *H. portonovensis*) occupy this level. They have a large geographic range and large local populations, but their habitat specificity is narrow, making them less rare than species in Level 1.
- Level 7: *Cixius verticalis* and *Cixius madeirensis* fall into this category. These species have large geographic ranges and wide habitat specificity, but their local population size are small.

Table 14 | Evaluation of rarity based on Rabinowitz (1981) for Cixiidae species and endemic coexistent Auchenorrhyncha species *Issus maderensis* and *Cyphopterum* species.

<table>
<tr><th colspan="2">Geographic range</th><th colspan="2">Large</th><th colspan="2">Small</th></tr>
<tr><th colspan="2">Population size</th><th>Large</th><th>Small</th><th>Large</th><th>Small</th></tr>
<tr><td rowspan="2">Habitat specificity</td><td>Wide</td><td>8.
Cyphopterum spp.
Issus maderensis</td><td>7.
C. verticalis
C. madeirensis</td><td>4.</td><td>3.</td></tr>
<tr><td>Narrow</td><td>6.
H. madeires
H. portonoves</td><td>5.</td><td>2.
Cyphopterum fauveli</td><td>1.
C. wollastoni
Tachycixius chaoensis</td></tr>
</table>

5.6 Conservation: Threats and IUCN Assessment

5.6.1 Threats

The habitats of species from *Cixius*, *Hyalesthes*, and *Tachycixius chaoensis* face growing pressures from both natural and anthropogenic factors. Habitat loss, fragmentation, and degradation driven by urbanization, agricultural expansion, and tourism are significant threats. Additionally, natural events such as landslides and wildfires further threaten these species.

a. *Cixius* spp.

The Laurel Forest habitats, critical for *Cixius* species, are increasingly fragmented due to human activity. The conversion of natural forest into exotic forests, as well as livestock grazing-particularly cattle - at the transition zones from high-altitude Laurel Forest to other vegetation types, are key drivers of the decline *Cixius* occurs in small, remnant patches within exotic forest areas, such as eucalyptus plantations and transitional zones near cultivated lands (2 sites). This habitat loss has been ongoing, as highlighted by the first Madeira Forest Inventory, which reported a decrease in the natural forest area of Madeira from 16,143 hectares (47% of forested land) to 15,354 hectares (45%) in the second inventory. Specifically, Laurel Forest (Laurisilva) has been reduced from 15,868 hectares to 15,223 hectares over the same period.

b. *Hyalesthes* spp.

The habitat of *Hyalesthes portonoves* faces severe pressure, mainly from urban expansion and land use changes. Historical imagery from Google Earth (2004) and recent data shows significant urbanization in areas where the species occurs, such as São Vicente (north) and Santa Cruz (south) (Fig. 14 A-D). Habitats that once supported *Globularia salicina*, have been transformed into green spaces within urban areas or replaced by agricultural areas (e.g. bananas, grapes, sugarcane plantations). Additionally, the spread of acacia through colonization and plantation has further impacted these habitats, particularly in the southern part of the island (Fig. 14 E-G). Field observations corroborate these findings, as numerous previously reported occurrence points of *G. salicina* are no longer present.

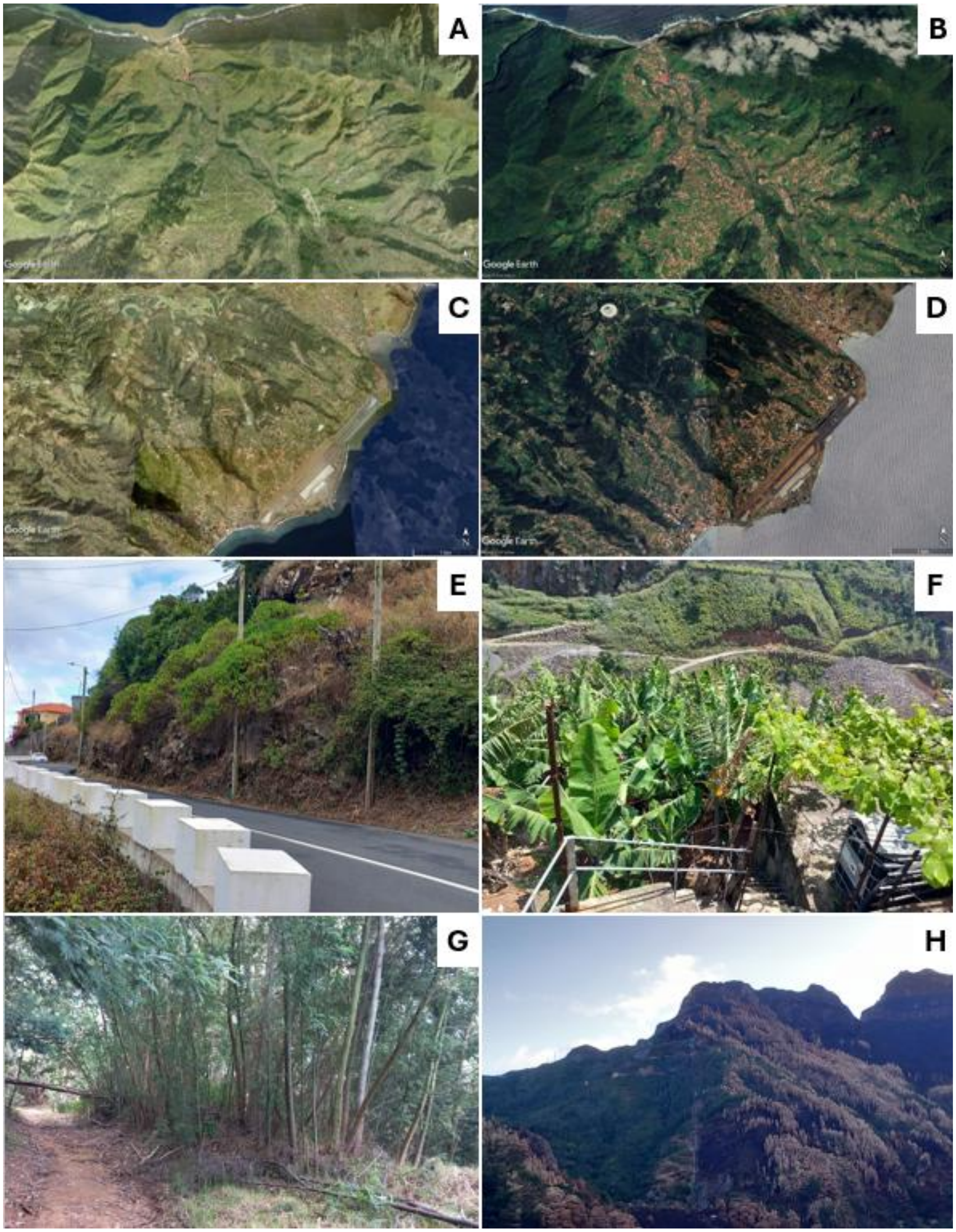


Figure 14 | Impacts on areas where *Hyalesthes* and/or *Globularia salicina* have been recorded recently and/or in the past. Urbanization from 2004 (A, C) to 2024 (B, D). Impacts include road construction (E), changes in land use for agriculture (F), production forestry (G), and wildfires (H). Localities: A-B, São Vicente; C-D, Santa Cruz (Aeroporto); E, Machico; F, Cª. de Lobos; G, Fajã da Ovelha; H, Serra d' Água (2024 wildfire). Source: Google Maps (A-D) and personal photographs (E-H).

In Funchal, notable examples of the removal of *G. salicina,* include the redevelopment of Avenida do Mar following the 20 February 2010 floods, as well as current construction projects, such as the building of a new hotel in Praia Formosa and a tunnel leading to the new hospital in Santa Rita.

Natural threats also endanger *G. salicina* and *Hyalesthes* habitats. Landslides triggered by heavy rainfall have destroyed slopes that supported *G. salicina* in areas like Ribeira dos Socorridos and Câmara de Lobos while grazing pressure, especially from goats (pers. obs.) in Madeira and Desertas Islands (IFCN guards' observations) exacerbates habitat degradation.

Furthermore, wildfires represent a significant threat, with coastal wildfires in October 2023 and September 2024 destroying many *G. salicina* habitats and devastating *Hyalesthes* populations (Fig. 14H).

c. *Tachycixius chaoensis*

The habitat of *T. chaoensis* is primarily threaten by the growing number of tourists visiting Ponta de São Lourenço. Tourism in Madeira has been steadily increasing reaching over 2 million visitors in 2023, and surpassing this figure in 2024, with almost 2 million guests (1,914,109) recorded until October alone (Annex 8). A survey conducted on 13 July 2023 at Baía d'Abra (Vereda da Ponta de São Lourenço) recorded 1,962 visitors between 9:00 AM and 6:00 PM, and only 14 identified as locals. During peak times, over 100 visitors were counted every 15 minutes (Fig. 15B). These numbers are likely underreported, as many visitors arrive as early as 6:30 AM (27 September 2023) and stay as late as 7:20 PM (7 January 2024) (pers. obs.).

This influx of tourists contributes to habitat degradation through erosion, small landslides, and trampling of fragile host plants. Many visitors stray from marked paths, stepping on the host plants which occupy already fragile ecosystems already stressed by strong winds, salt spray, and oceanic wave action (Fig. 15A, C).

Additionally, the proximity of *T. chaoensis* to unstable cliffs, some of which periodically collapse into the ocean, further threatens the species habitat (Fig. 15D).

These natural hazards, combined with human-induced pressures, create a significant challenge for the conservation of *Tachycixius chaoensis* and its environment.

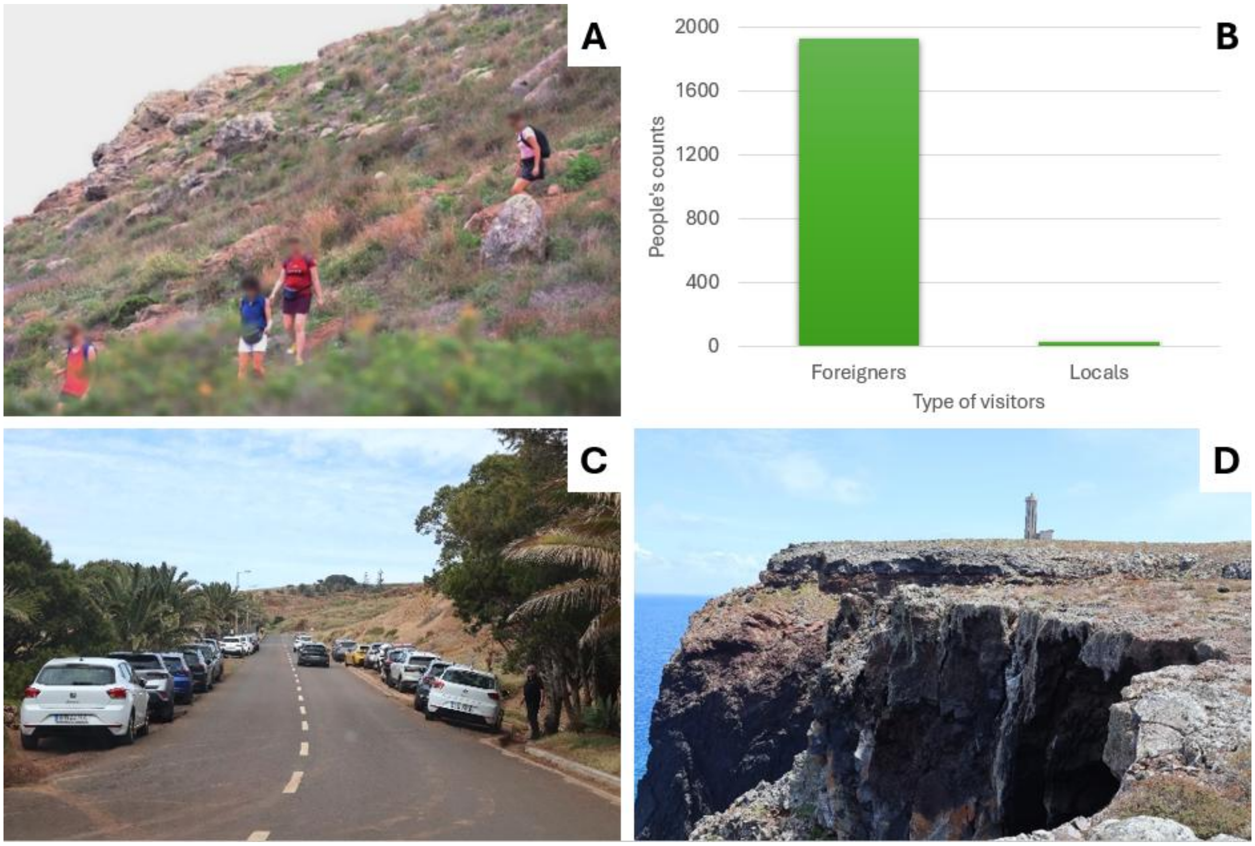


Figure 15 | Impacts observed during 2023-2024 on areas where *Tachycixius chaoensis* and *Suaeda vera* are present. Types of impacts: touristic pressure (A-C) and erosion (D). (A) Tourists leaving the trail and stepping on suitable habitat; (B) Number of tourists observed in a single day (13/07/2023); (C) Car parking on suitable habitat; (D) Soil erosion caused by coastal landslide due to marine erosion. Localities: Madeira Island, Ponta de São Lourenço (A, C) and Ilhéu Chão (D). Source: Personal photographs by the author (A, C, D) and data from Associação Insular de Geografia (AIG).

5.6.2 IUCN Assessment

The six species of the Cixiidae family were evaluated under Criterion B of the IUCN Red List, which considers geographic range, habitat fragmentation, number of locations occupied, threats impacting the extent of occurrence (B1) and area of occupancy (B2). Based on these factors, the species were assessed as follows:

Cixius madeirensis has an EOO (B1) ranging from 145 and 549 km² and an AOO (B2) from 40 to 388 km². The species is found in two locations: its main threat is habitat degradation, primarily caused by cattle grazing and the proliferation of invasive plant species. These threats are most pronounced in the laurel–heather transition zones, while the high-altitude laurel forest in the north is less affected. Key threats include the expansion of exotic wood and pulp plantations (e.g., *Eucalyptus globulus*), livestock grazing (e.g., small-holder cattle ranching), invasive species plant (e.g., *Acacia dealbata*, *Ulex europaeus*), and climate-induced habitat shifts. Due to this pressures, *C. madeirensis* is classified as **Endangered** under the IUCN criteria: B1ab(iii)+2ab(iii).

Cixius verticalis has an EOO (B1) from 75 to 549 km² and an AOO (B2) between 28 to 388 km². It also occurs in two locations, with its primary threat being habitat loss due to deforestation. This impact is more significant in the low-altitude laurel forest in the north, while the high-altitude areas are comparatively less affected. The threats are similar to those faced by *C. madeirensis*. As a result, *C. verticalis* is also classified as **Endangered**: B1ab(iii)+2ab(iii).

Cixius wollastoni has the smallest EOO (B1) at just 7 km² and an AOO (B2) of 12 km². In cases where EOO is smaller than AOO, the AOO value is used for both metrics. The species is found in two locations: high-altitude laurel forest areas in both the north and south, with the southern population being more severely impacted by deforestation. Due to its extremely limited range, the species is classified as **Critically Endangered**: B1ab(iii).

Hyalesthes madeires has an EOO (B1) between 210 and 463 km² and an AOO (B2) ranging from 48 to 348 km². Its distribution is highly fragmented, with key threats including urbanization, infrastructure development, agricultural expansion (e.g., vineyards and banana plantations), wildfires, landslides, invasive species (e.g., *Acacia dealbata*, *Eucalyptus globulus*, *Ageratina adenophora*, *Achyranthes aspera*), and climate change impacts such as droughts and storms. Based on these factors, *H. madeires* is classified as **Endangered**: B1ab(iii)+2ab(iii).

Hyalesthes portonoves has an EOO (B1) between 417 and 463 km² and an AOO (B2) from 64 to 348 km². It faces the same threats as *H. madeires*, and its population is equally fragmented. Thus, *H. portonoves* is also classified as **Endangered**: B1ab(iii)+2ab(iii).

Tachycixius chaoensis has an EOO (B1) between 23 and 179 km² and an AOO (B2) from 16 to 56 km². This species is found in four locations: two xerophytic habitats at Ponta de São Lourenço, one at Ilhéu da Cevada, and one at Ilhéu Chão. The threats to this species include tourism-related habitat trampling, invasive grass species (e.g., *Cenchrus ciliaris*), landslides, and climate-induced habitat shifts. Consequently, *T. chaoensis* is classified as **Endangered**: B1ab(iii)+2ab(iii).

6. Discussion

Assessing the global conservation status of species is vital for effective management and biodiversity protection. Reliable conservation strategies depend on comprehensive ecological data, including species distribution, population estimates, decline rates, and major threats (IUCN 2012). However, for many taxa in Madeira, knowledge and IUCN assessments remain limited (IUCN 2025). Addressing these gaps requires focused fieldwork to gather accurate data and observe threats directly.

A significant challenge in assessing Madeira's Cixiidae has been the lack of georeferenced historical data. Most prior studies were taxonomic or had limited non-georeferenced records, leaving substantial gaps in distribution knowledge (Nouhalier 1897, China 1938, Lindberg 1941, 1954, 1961, Hoch & Remane 1985, 1986). Information remained outdated until a 2021 study provided some updated data (Freitas & Aguín-Pombo 2021). To accurately evaluate their conservation status, filling these historical data gaps through standardized field sampling and opportunistic collections has been crucial. These efforts have provided updated distribution records, enabling a more precise vulnerability assessment.

6.1 Vulnerability and Conservation Status of Cixiidae

In this study, five Cixiidae species were evaluated as Endangered (EN), and one as Critically Endangered (CR). This level of vulnerability aligns with previous assessments of other species (IUCN 2025), reinforcing a broader pattern of vulnerability among cixiid species endemic to oceanic islands. These species have evolved within narrow ecological niches, making them exceptionally susceptible to environmental disturbances (Holzinger *et al.* 2002, Borges *et al.* 2019). Like many island endemics, they often lack the adaptive capacity to withstand habitat alterations caused by climate change, human activity, or the introduction of invasive species.

This pattern is also evident in studies on Azorean Cixiidae. For instance, *Cixius cavazoricus* (CR) and *Cixius azofloresi* (EN) are among the rarest, whereas *Cixius azoterceirae* (VU) remains relatively abundant, with 968 recorded individuals (Boieiro *et al.* 2018a, Rego *et al.* 2018a, 2018b, Lamelas-Lopez *et al.* 2022). Some species, such as *Cixius azoricus* (NT) and *Cixius insularis* (NT), are not currently classified as threatened due to their wider distribution across multiple locations (Boieiro *et al.* 2018b, Rego *et al.* 2018c). Given their restricted distributions and ecological specialization, the survival of Madeira's *Cixiidae* depends on the stability of their habitats (Borges *et al.* 2000). However, the same environmental pressures that threaten other endemic insects on the island are also driving *Cixiidae* populations toward further decline.

6.2 Major Threats to Cixiidae on Madeira Island

The threats affecting Cixiidae in Madeira closely resemble those impacting other endangered or near-endangered insects on the island. According to the IUCN Red List, the most significant threat is wildfires, followed by invasive species—both direct drivers of native habitats degradation (IUCN 2025) (Fig. 16).

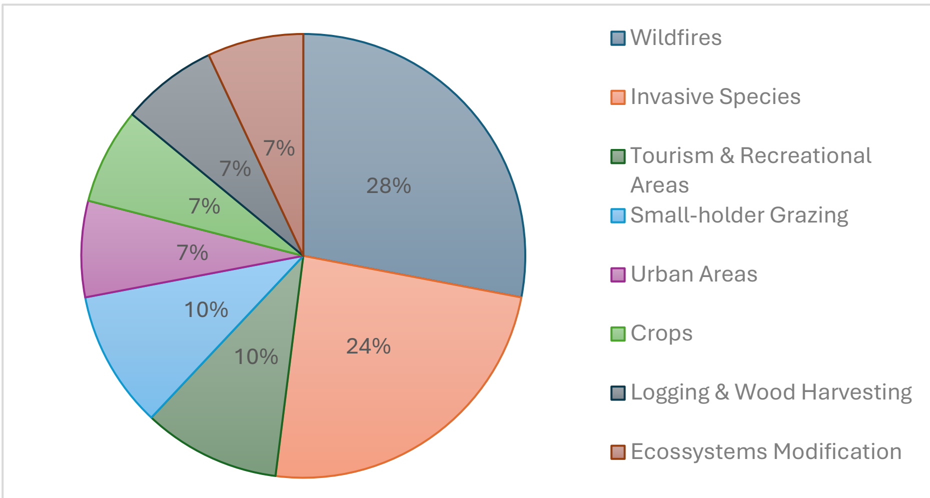


Figure 16 | Major threats to terrestrial insects evaluated by IUCN Red List in Madeira Island. Source: IUCN 2025.

Several endemic insect species to Madeira Island illustrate the severity of these threats. For example, *Pararge xiphia* Fabricius, 1775, classified as "Endangered" by the IUCN, is dependent on natural forests such as the Laurel Forest (van Swaay *et al.* 2010a). One of the primary threats of this butterfly is the expansion of agro-industrial plantations, a trend that has also affected *Cixius* species. Many native forest borders have been cleared and replaced with *Eucalyptus globulus*, *Acacia dealbata*, and *Pinus* spp. plantations (IFCN 2015). Similarly, the "Endangered" butterfly *Gonepteryx maderensis* Felder, 1862 is completely dependent on its host plant *Rhamnus glandulosa* growing on Laurel Forest. It faces habitat loss due to agriculture, livestock grazing — particularly from cattle in high-altitude areas — and urban expansion. These same pressures also threaten

Cixius madeirensis, as increasing tourism and urban development further disrupt their natural habitats (van Swaay *et al.* 2010b).

Beyond butterflies, other endemic insects to Madeira face similar dangers. *Myathropa usta* (Wollaston, 1858), a Laurel Forest hoverfly listed as an "Endangered" species (Aracil *et al.* 2021), shares many of the same threats as *Cixius* species. Expanding tourism, invasive plants such as *Pittosporum undulatum*, and climate change are expected to accelerate population declines. Likewise, *Psalmatophanes barretoi* Chopard, 1938, a forest-dwelling cricket classified as "Vulnerable", is affected by wildfires which are becoming increasingly frequent across the island (Hochkirch *et al.* 2016, Rhee *et al.* 2023, 2025).

While native Laurel Forest insects benefit from the protective humidity of the forest, coastal species are far more exposed to wildfires. For instance, the IUCN "Vulnerable" classified *Eumerus hispidus* Smit, Aguiar & Wakeham-Dawson, 2004, an endemic pollinating hoverfly from Madeira archipelago, with a similar distribution to *Hyalesthes* species, faces severe threats from fires. Recent events, such as the 2024 wildfire in Serra d'Água—an area known to harbor *Hyalesthes*—and the 2023 fires in western Madeira Island, have destroyed critical habitats (Grković 2021, Lusa 2023, 2024). Wildfires not only eliminate biodiversity but also eradicate the host plants essential for *Cixiidae* survival and alter soil composition, potentially affecting the eggs and nymphs of these species (López-Martín *et al.* 2016, Certini *et al.* 2021). Beyond wildfires, *E. hispidus* also faces additional threats shared with *Hyalesthes*, including infrastructure expansion (roads and tunnels), prolonged droughts, and invasive species. The growth of nature tourism is increasingly becoming a significant threat not only to *Tachycixius chaoensis*, but also to other endemic species in Madeira. One such example is *Xanthandrus babyssa* (Walker, 1849), an endemic syrphid fly classified as "Vulnerable" by the IUCN. The expansion of recreational activities in forested areas has been identified as a threat to this species (Nedeljković & Ricarte Sabater, 2021).

The growing pressures on Madeira's ecosystems emphasize the urgent need for conservation efforts to address habitat loss and environmental changes that jeopardize the island's endemic insect species. This also responds to the first hypothesis, which proposed that the insects studied are exposed to the same major threats as other insects on the island. Indeed, factors such as invasive species, tourism, and urbanization are key contributors to the decline of Madeira's Cixiidae populations, highlighting the necessity for targeted conservation measures to ensure their survival.

6.3 Challenges of Applying IUCN Criteria to Insects on Oceanic Islands

Assessing conservation status on oceanic islands presents unique challenges, particularly for insect species with restricted distributions and specialized ecological requirements (González-Mancebo *et al.* 2012, Romeiras *et al.* 2016). One of the primary difficulties is the reliance on geographic range as a key parameter for classification. In Madeira, where many endemic insects remain poorly studied, the lack of long-term population monitoring campaigns limits the ability to detect trends in population decline. Additionally, habitat changes on islands occur rapidly due to deforestation, invasive species, and climate shifts, requiring more nuanced conservation assessments beyond standard range-based criteria (Boieiro *et al.* 2015).

A critical issue is the use of Extent of Occurrence (EOO) and Area of Occupancy (AOO) as key metrics in species assessments. While these measurements can provide valuable insights, they often fail to reflect ecological realities for small-range species, particularly those confined to microhabitats. The IUCN's standard 2 km × 2 km grid system does not always align with the actual habitat size of species with limited dispersal abilities (González-Mancebo *et al.* 2012). For example, *Cixius wollastoni*, classified as Critically Endangered based on EOO, appears in three distinct grids, which, if assessed solely by AOO, would suggest a larger distribution and result in an Endangered status instead (Gaston & Fuller 2009) (see Table 13). However, the species' fragmented habitat structure justifies its higher-risk classification. Similarly, *Tachycixius chaoensis* is recorded in four grids, but much of this area consists of unsuitable oceanic zones, further emphasizing the limitations of these assessments.

This issue is particularly pronounced in Madeira, where the island's total area of 737 km² (Aguín-Pombo & Pinheiro de Carvalho 2009) means that many endemic species could automatically qualify as at least Vulnerable or Endangered under IUCN Criterion B (IUCN 2012). However, EOO calculations often overestimate viable habitat by including unsuitable areas such as ocean or highly urbanized regions (González-Mancebo *et al.* 2012). For instance, *T. chaoensis* appears to have an EOO of 23.41 km², but much of this consists of ocean, making its actual terrestrial habitat significantly smaller and more fragmented than the estimate suggests. This highlights the dangers of over-relying on broad spatial metrics, which can either overestimate or underestimate a species' vulnerability, complicating conservation planning. In essence, the IUCN criteria are not well-suited for small, more sedentary species (Cardoso *et al.* 2011b). This potentially disguises the true risk of species extinction, especially given their small distributions and the array of threats they face, as highlighted previously and questioned in hypothesis two. The vulnerability of Cixiidae species in Madeira is further exacerbated by their limited geographic distribution and specialized habitat requirements, rendering them highly susceptible to environmental disturbances and human-induced threats.

6.3.1 The Role and Limitations of Habitat Modelling

As previously discussed, the application of IUCN criteria to island endemics is complicated by limited data and the challenges of assessing species with restricted ranges. One tool that can help overcome these data gaps is habitat modeling, which estimates potential species distributions based on available occurrence data and environmental variables (Cardoso *et al.* 2011b). Its application to Cixiidae in Madeira was hampered by several constraints, particularly those associated with small sample sizes and the limited number of variables that could be incorporated into the models.

In Species Distribution Modeling (SDM), a general rule is that for every 10 occurrence records, only one variable can be used, meaning that with limited data, only a small subset of potential ecological factors can be included (Sillero *et al.* 2021). This approach risks overlooking important factors like soil composition or microclimate, which are especially relevant for species with specialized habitat requirements. However, introducing too many variables can lead to overfitting, where the model becomes too tailored to the known data and fails to predict suitable habitats where the species may still exist.

The small number of occurrences records available for Cixiidae further compounded these issues, making it impossible to model individual species separately. Instead, species within the genus *Cixius* had to be grouped together under the assumption that they shared similar habitat preferences. This approach, though practical, masked potential ecological differences and blurred the accuracy of the models. For example, the modeling of *Hyalesthes* species, which occupy distinct ecological niches, was also problematic. *Hyalesthes madeires* is typically found in rocky habitats in the north and center of Madeira, while *Hyalesthes portonoves* occurs in coastal areas. Grouping them together in one model led to inaccurate predictions.

Another key issue with the *Hyalesthes* model was the reliance on outdated host plant data, *Globularia salicina*, the primary food plant for these species. For example, historically, *G. salicina* was present in coastal habitats, including areas around Funchal. However, after a major flooding event in February 2010, significant urban redevelopment along the coastal areas of Funchal permanently altered the habitat, eliminating the presence of *G. salicina* in these areas (H. Silva pers. comm., CMF 2010). The model, relying on older data from sources like GBIF, included these coastal zones as suitable habitats for *Hyalesthes*, inaccurately predicting the presence of these species in areas where the host plant no longer exists. This example underscores one of the challenges of habitat modeling: outdated, incomplete, and time-misaligned data can lead to misleading conclusions, particularly in rapidly changing environments like Madeira, where human activities such as urbanization have drastically transformed the landscape (Liu *et al.* 2018, Feldman *et al.* 2021).

In contrast, the model for *Tachycixius chaoensis* presented a more reliable case, though it still faced its own challenges. This species was recorded in four separate populations, each geographically isolated from the others. Although its host plant is present in other areas, the model suggests that *T. chaoensis* could potentially inhabit these locations as well. This indicates that an unseen environmental factor—most likely related to soil composition—may be shaping the distribution of this species. Since Cixiidae nymphs develop underground, soil quality could be a crucial factor in determining suitable areas (Müller 1942, Panassiti *et al.* 2013). For instance, in areas like Ponta de São Lourenço and the Desertas Islands, past agricultural practices may have altered soil composition, making them unsuitable (Diário de Notícias 1876, Medeiros *et al.* 2010). This highlights the need for more nuanced environmental data, particularly regarding soil quality, in future habitat modeling.

To address these limitations, two separate models were developed for *Tachycixius chaoensis*—one focusing on Madeira and another including the Desertas Islands. The model for Madeira, based on more data, showed consistent results, suggesting that climatic factors may be more important for the species' survival in this region than other environmental variables. However, the model for the Desertas Islands faced significant gaps due to missing data, highlighting the challenges of modeling in poorly studied areas. Despite these gaps, the consistency between the two models suggests that climatic factors are the primary drivers of habitat suitability for *T. chaoensis* on Madeira, though other environmental factors, such as soil composition, also play a key role in fine-tuning predictions.

These examples highlight the complexities involved in applying habitat modeling to island endemics like Cixiidae. While these models provide valuable insights into species distributions, they also underscore the challenges posed by small sample sizes, outdated data, and the need for more detailed environmental variables. Future models could be enhanced by incorporating more accurate data on soil composition, moisture levels, and other microclimatic factors, as well as data on habitat fragmentation and human activity. This also reinforces the concerns raised in hypothesis three, which suggested that applying IUCN criteria to insects on oceanic islands like Madeira presents unique challenges due to data limitations.

6.4 Conservation Measures Based on Field Sampling and IUCN Assessment

6.4.1 *Cixius* spp.

All *Cixius* species studied share significant ecological similarities, with overlapping distributions and adult life stages in similar habitats. While some adaptations may be needed in conservation strategies, a unified framework can guide their protection.

A key priority is reinforcing legal protections for conservation areas. Fieldwork revealed that some presumed protected sites lacked native forest, suggesting that Madeira Natural Park and other zones are not always effectively managed. Without stronger enforcement, ongoing land-use changes — particularly the expansion of *Eucalyptus globulus* plantations — pose a severe threat. *Cixius* species are highly sensitive to habitat changes and do not occur in eucalyptus-dominated landscapes. Ensuring proper implementation of Madeira Natural Park regulations and stronger application of national and European legal frameworks is essential. Decree-Law No. 565/99, which restricts non-native species introductions, is insufficiently enforced, and the National Biodiversity and Nature Conservation Strategy requires more rigorous implementation (Presidência do Conselho de Ministros 2018). At the European level, the EU Habitats Directive (Council of the European Communities 1992) recognizes laurel forests as priority habitats, necessitating stricter conservation measures, while the EU Biodiversity Strategy and 30x30 Goal provide additional frameworks for strengthening protection (European Commission 2020).

Habitat restoration must also be a central focus, given the limited knowledge of *Cixius* egg and nymph stages (Panassiti *et al.* 2013). Invasive species removal, long-term soil quality studies, and early detection measures for new invaders are essential for maintaining viable populations (Corbin & D'Antonio 2012). A structured monitoring program should track population trends at key sites, such as Queimadas and Chão da Ribeira, where *Cixius* species have historically been observed in large numbers. However, some conservation efforts, such as vegetation management at Queimadas, may be counterproductive. In October 2023 and June 2024, ferns were removed for aesthetic reasons or to reduce fire risk, disturbing the soil and potentially harming *Cixius* populations in their egg and nymph stages. Since their eggs are laid in the topsoil near host plants, any disturbance could expose them to desiccation or decay (Müller 1942). Fern removal for fire prevention is unnecessary, as laurel forests are naturally fire-resistant due to high humidity and occult precipitation (Prada *et al.* 2009). If fern management is required, it should be scheduled for late October, after the adults' period of the *Cixius* species has finished, ensuring no disruption to overwintering eggs/nymphs. *Cixius wollastoni* is particularly vulnerable as it also occurs outside protected areas in southern Madeira (besides Ribeiro Frio). Identifying key conservation sites, monitoring their populations, and securing land for protection should be prioritized. For *Cixius verticalis*, which inhabits low-altitude areas in the north, habitat loss from creating new agriculture areas and production forestry expansion is a concern. Instead of clearing new land, rehabilitating abandoned agricultural fields for cultivation would help minimize impacts. *Cixius madeirensis*, found at higher altitudes, faces increasing pressure from cattle grazing. Livestock consume low-story vegetation while avoiding invasives like *Ulex europaeus*. Cattle droppings further alter soil composition, likely affecting subterranean egg and nymph development. Restricting free-ranging cattle and establishing fenced-off areas, similar to a fenced protected area created by IFCN in Fanal, could be solution.

Tourism is an emerging threat, particularly in high-altitude habitats, where foot traffic damages ferns and shrubs, and litter accumulates (Barreto 2024). Regulating visitor numbers based on ecological carrying capacity could mitigate these impacts (Mason 2005).

Beyond habitat loss, conservation efforts must raise public awareness of the ecological importance of *Cixius*, *Hyalesthes*, and *Tachycixius chaoensis,* which are members of the Hemiptera order. Efforts to change public perception include assigning common names as done with *Cixius verticalis* ("Cigarrinha-Grande-da-Laurissilva"), and producing educational materials (Cardoso *et al.* 2011a, Wang *et al.* 2021, Sitar & Rusu 2023). While concerns exist that promoting rare species might lead to over-collection, responsible interpretation—such as general information at trailheads rather than exact locations—can minimize risks (Wang *et al.* 2020). A field guide to Madeira's insects could further support conservation education.

Educational efforts should also target local communities and conservation staff. Technical training for IFCN rangers, park managers, and municipal workers is crucial to align maintenance practices with conservation goals. Long-term monitoring of *Cixius* populations, coupled with in-situ and ex-situ conservation programs, can provide the necessary data for effective management. Strengthening habitat protection in low-altitude laurel forests and ensuring better conservation policies within Madeira Natural Park will be essential to prevent further degradation.

6.4.2 *Hyalesthes* spp.

Hyalesthes portonoves and *Hyalesthes madeires* are two species that may face significant risks. *Hyalesthes portonoves* occur across much of Madeira's southern and some central areas with the island's highest human population (DREM 2024a). Rapid urban expansion in these zones has significantly reduced the availability of its host plant. Invasive species further threaten its habitat, not only in urban and agricultural areas but also within protected zones like the Garajau Natural Reserve, where *Opuntia* has displaced native vegetation (pers. obs.).

This species has the lowest percentage of its distribution within protected areas, with only 19% of known occurrences in conservation zones. *Hyalesthes madeires* has only 30% of its range protected. Coastal habitats, where these species reside, are more vulnerable to degradation than laurel forests (Jones *et al.* 2013, He & Silliman 2019). While laurel forests can regenerate naturally if left undisturbed, coastal ecosystems face constant human pressure, requiring active intervention for restoration.

Globularia salicina plays a key role in these ecosystems, acting as an indicator of vegetation transitions (Capelo *et al.* 2007). However, its habitat is highly sensitive, and invasive species are the main barrier to its recovery. Sampling data show that plants like *Acacia dealbata*, *Eucalyptus globulus*, *Ageratina adenophora*, *Achyranthes aspera*, *Bidens pilosa*, *Arundo donax*, *Vitis vinifera*, *Agapanthus*, *Kalanchoe* sp., *Opuntia tuna*, *Solanum mauritianum*, *Tropaeolum majus*, *Pittosporum undulatum*, *Musa* sp., *Cytisus scoparius*, *Castanea sativa*, *Pinus pinaster*, and *Hydrangea macrophylla* pose significant threats to its habitat.

To safeguard *Hyalesthes portonoves* and *Hyalesthes madeires*, the removal of invasive plants is the most critical step for recovering *Globularia* habitats. Conservation areas must be designated to prevent further habitat destruction caused by urbanization and agriculture. Future protection efforts should also consider potential altitudinal shifts, as *Globularia* may migrate upslope due to climate change.

Given the increasing wildfire risk in Madeira's coastal and low-altitude ecosystems, particularly in areas where *Hyalesthes portonoves* and *H. madeires* occur, effective wildfire prevention is essential. The removal of invasive species, such as *Acacia dealbata*, *Eucalyptus globulus*, and *Pittosporum undulatum*, is crucial, as these plants contribute to fire spread due to their volatile oils and dry biomass (Guerrero *et al.* 2021). Replacing them with native species like *Globularia salicina* can reduce fuel loads and aid in restoring *Hyalesthes* habitats. Strategic firebreaks should also be established in areas with flammable invasives to slow the spread of wildfires.

While controlled burns can be effective in reducing fire loads, they must be used with caution given Madeira's strong winds and steep terrain (Coimbra & Palma 2024). Community involvement and better regulation of agricultural burning, along with the implementation of early wildfire detection systems such as drones and fire-monitoring programs, are vital to enhancing prevention efforts (Honary & Kavehpour 2025).

Soil restoration efforts should not be overlooked, as improved moisture retention can accelerate vegetation recovery and reduce fire risk. However, before these efforts can begin, ex-situ biological studies are necessary to better understand the specific soil conditions required for *Hyalesthes* nymph development (Zema 2021).

Although existing laws, such as Regional Legislative Decree nº 18/98/M, regulate activities like agricultural burning and campfires during high-risk periods, enforcement gaps still allow illegal burns and habitat destruction to persist. Strengthening enforcement through increased ranger patrols, penalties, and satellite or drone monitoring is essential for ensuring compliance.

Further, the application of Decree-Law No. 565/99, which regulates invasive species, and Decree-Law No. 82/2021, which addresses fire management, could create a more integrated approach to both invasive species control and fire prevention. Greater coordination among government bodies, conservation agencies, and local communities is key to ensuring the long-term survival of Madeira’s coastal ecosystems.

6.4.3 *Tachycixius chaoensis*

Tourism poses the greatest threat to *T. chaoensis*, particularly in Ponta de São Lourenço, where visitor numbers have surged in recent years (Annex 8). Unlike the populations on Ilhéu Chão, which remain protected due to restricted access, those in Ponta de São Lourenço are highly vulnerable to environmental degradation. The lack of regulation in this area has made it difficult to control human impact, as visitors freely enter through both official and unofficial trails. Although the IFCN reports an annual average of 150 visitors per day (IFCN 2024c), real numbers are much higher (Fig. 15B), with tourist activity observed from early morning until late at night (pers. obs.).

While tourism is essential to Madeira’s economy, its rapid expansion has raised concerns about sustainability. Nature tourism depends on biodiversity but, when poorly managed, can degrade the very ecosystems it relies on (Jones 2022). This paradox is especially critical in Ponta de São Lourenço, where *T. chaoensis* faces significant threats from trampling, habitat fragmentation, invasive species introduced through seeds carried on shoes and backpacks, littering, and off-trail exploration for drone photography. Given that its host plant reaches a maximum height of only 30 cm, even minor disturbances can have severe consequences (pers. obs., see Fig. 15).

Despite being part of the Madeira Natural Park and the Ponta de São Lourenço Special Area of Conservation (Annex 2), the effectiveness of conservation measures depends on stronger enforcement. Stricter access control, increased ranger presence, effective visitor quotas, and fines for environmental violations are necessary steps. Implementing a permit system like Ilhéu Chão could further regulate tourism and minimize ecological damage. Without proper management, the long-term effects on this fragile ecosystem could be devastating (Belsoy *et al.*, 2012).

At the same time, these island populations, particularly on Ilhéu Chão, offer a rare opportunity to study *T. chaoensis* in an undisturbed habitat. Researchers can analyze habitat preferences by comparing soil chemistry and ecological conditions in occupied and unoccupied patches, providing valuable insights into its conservation needs. Expanding monitoring efforts and assessing the area's carrying capacity are crucial to ensuring the species' survival.

Education and awareness also play a key role in conservation. Well-placed informational signage along trails can help inform visitors about the ecological sensitivity of the area. Strengthening partnerships between conservation organizations and tourism operators can further promote sustainable practices (Mason, 2005; Unger *et al.*, 2024). As a flagship species for Ponta de São Lourenço, *T. chaoensis* highlights the region's ecological fragility and the urgent need for stronger conservation policies (Oberhauser & Guiney, 2009). By promoting it as a symbol of Madeira's rare biodiversity, greater awareness can be raised among both tourists and policymakers, encouraging more sustainable tourism practices.

6.5 Final Considerations and Future Directions

The conservation of Madeira's endemic planthoppers, including *Tachycixius chaoensis*, *Cixius wollastoni*, *Cixius verticalis*, and *Hyalesthes portonoves*, requires urgent attention due to their highly restricted distributions, fragmented populations, and increasing threats from habitat degradation, climate change, and human activities. While some of their habitats fall within protected areas, the lack of targeted conservation actions, combined with insufficient population data, places these species at risk. Moving forward, several key aspects must be addressed to ensure their long-term survival.

A major priority is the implementation of long-term monitoring programs to track population trends, detect early signs of decline, and assess habitat conditions. These efforts should focus on stable populations while also investigating the status of smaller, more vulnerable ones. Additionally, research on their ecological requirements - including host plant dependence, habitat specificity, and phenological patterns - is crucial to develop effective management strategies.

Habitat restoration and adaptive management must be strengthened, particularly in areas suffering from fragmentation, invasive plant encroachment, and human disturbance. In the southern Laurel Forest, where degradation is more pronounced, reforestation efforts should be prioritized to recover lost habitat. In coastal and xerophytic habitats, preventing further degradation from tourism-related trampling and livestock grazing is essential. Managing invasive plants, even those that are not yet a significant threat, should also be proactive rather than reactive to avoid further ecosystem imbalances.

Public awareness and education campaigns should be integrated into conservation efforts, especially in areas with high tourist foot traffic. Visitors should be informed about the ecological importance of these habitats and how their actions can impact fragile species like these planthoppers. Measures such as controlled access to sensitive areas and the promotion of responsible ecotourism could significantly reduce human-induced pressures.

Finally, climate change remains an overarching challenge. While the immediate effects may not yet be fully realized, increasing drought periods and shifts in suitable habitat must be considered in long-term conservation planning. Future studies should explore potential climate refugia where these species might persist if environmental conditions change drastically.

In conclusion, despite their small size and inconspicuous nature, these endemic planthoppers play a role in Madeira’s ecosystems and serve as indicators of habitat health. Their survival is closely tied to the preservation of native vegetation and the integrity of their ecosystems. By combining research, monitoring, habitat restoration, and sustainable land-use practices, it is possible to safeguard these unique species for the future. Conservation efforts must be proactive rather than reactive, ensuring that these insects do not silently disappear before their ecological significance is fully understood.

Bibliography

Adamson, A. (1932). Review of The Fauna of the Marquesas Islands and Discussion of its Origin. *Bernice P. Bishop Museum Bulletin* 159, 11-72.

Aguiar, C., Capelo, J., Costa, J.C., Fontinha, S., Espírito-Santo, D., Jardim, R., Lousã, M., Rivas-Martínez, S., Mesquita, S., Sequeira, M., Sousa, J. (2004). A Paisagem Vegetal da Ilha da Madeira. *Quercetea* 6, 3-200.

Aguín-Pombo, D. & Pinheiro De Carvalho, M. (2009). Madeira Archipelago. In: R. Gillespie & D. Clague (Ed.), *Encyclopedia of Islands*. Berkeley: University of California Press, 582-585.

Alagador, D., Cerdeira, J. O., Araújo, M. B. (2014). Shifting Protected Areas: Scheduling Spatial Priorities Under Climate Change. *Journal of Applied Ecology* 51(3), 703-713.

AMN (2024). Comando Regional da Polícia Marítima da Madeira <https://www.amn.pt/PM/Comandos/CRPMM/Paginas/Comando-Regional-Policia-Maritima-Madeira.aspx> [accessed on September 21, 2024].

Aparício, B. A., Cascalho, J., Cruz, M. J., Borges, P. A., Azevedo, E. B., Elias, R. B., & Ascensão, F. (2018). Assessing the landscape functional connectivity using movement maps: a case study with endemic Azorean insects. *Journal of Insect Conservation*, *22*, 257-265.

Aracil, A., Pérez, C., Rojo, S., Barkalov, A., Mazanek, L. & Vujić, A. (2021). *Myathropa usta*. The IUCN *Red List of Threatened Species* 2021: e.T149163644A152281554.

Araújo, M. B., Alagador, D., Cabeza, M., Nogués-Bravo, D., & Thuiller, W. (2011). Climate Change Threatens European Conservation Areas. *Ecology Letters* 14(5), 484-492.

Assembleia da República (1995). Lei n.º 13/95, de 5 de maio. *Diário da República* n.º 104/1995, Série I-A, 2514-2515.

Attié, M., Bourgoin, T., Veslot, J., Soulier-Perkins, A. (2008). Patterns of Trophic Relationships Between Planthoppers (Hemiptera: Fulgoromorpha) and their Host Plants on the Mascarene Islands. *Journal of Natural History* 42(23-24), 1591-1638.

Auguie, B. (2017). gridExtra: Miscellaneous Functions for "Grid" Graphics. R package version 2.3, <https://CRAN.R-project.org/package=gridExtra>.

Azorean Biodiversity Portal (2024). Cixiidae. Retrieved from <http://azoresbioportal.uac.pt/azorean-species/@s!@tx!-Animalia-Arthropoda-ND-Insecta-Hemiptera-Cixiidae-Cixius/> [accessed on November 11, 2024].

Barreto, R. (2024). Evento na Área Protegida do Fanal Deixa Rasto de Lixo. *Jornal de Notícias*. <https://www.jm-madeira.pt/regiao/evento-na-area-protegida-do-fanal-deixa-rasto-de-lixo-EL16597443> [accessed on February 11, 2025].

Bastos, L. F., Santos, A. V. F. D., Penner, F. V., Siqueira, L. M. M., Silva, A. G. D., Martins, I. C. F., Lins, P. M. P., & Batista, T. F. V. (2019). Spatial Analysis and Population Dynamics of *Haplaxius crudus* (Hemiptera: Cixiidae) in Coconut Amazon. *Journal of Agricultural Science* 11(14), 186-197.

Belsoy, J., Korir, J., Yego, J. (2012). Environmental Impacts of Tourism in Protected Areas. *Journal of Environment and Earth Science* 2(10), 64-73.

Beltrán-Aldana, I. J., Bustillo-Pardey, A. E., Morales-Rodriguez, A. (2020). Mass Rearing of *Haplaxius crudus* (Hemiptera: Cixiidae), an Important Insect Pest in the Palm Oil Industry of Colombia. *American Journal of Entomology* 4(2), 39-44.

Beltrán-Aldana, I. J., Fernández-Sánchez, A., Morales-Rodriguez, A. (2024). Population Parameters of *Haplaxius crudus* (Hemiptera: Cixiidae) under Semi-Controlled Conditions. *Insects* 15(2), 85-94.

Black, C. C. (1989). *Loss of Biological Diversity: A Global Crisis Requiring International Solutions: A Report to the National Science Board*, 17pp.

Boieiro, M., Aguiar, A. F., Rego, C., Borges, P. A. V., Serrano, A. R. (2015). The Biodiversity of Terrestrial Arthropods in Madeira and Selvagens Archipelagos. *Revista IDE@-SEA* 6, 1-20.

Boieiro, M., Borges, P. A. V., Rego, C. (2018a). *Cixius cavazoricus* (errata version published in 2018). *The IUCN Red List of Threatened Species 2018*: e.T97218908A135846668.

Boieiro, M., Rego, C., Borges, P.A.V. (2018b). *Cixius azoricus* (errata version published in 2018). *The IUCN Red List of Threatened Species 2018*: e.T97218194A135846022.

Borges, P. A. V., Serrano, A. R., Quartau, J. A. (2000). Ranking the Azorean Natural Forest Reserves for Conservation Using their Endemic Arthropods. *Journal of Insect Conservation* 4, 129-147.

Borges, P., Abreu, C., Aguiar, A., Carvalho, P., Fontinha, S., Jardim, R., Melo, I., Oliveira, P., Sequeira, M., Sérgio, C., Serrano, A., Sim-Sim, M., Vieira, P. (2008). Terrestrial and freshwater biodiversity of the Madeira and Selvagens archipelagos. In: P. A. V. Borges, C. Abreu, A. M. F. Aguiar, P. Carvalho, R. Jardim, I. Melo, P. Oliveira, C. Sérgio, A. R. M. Serrano, P. Vieira (Eds.). *A List of the Terrestrial Fungi, Flora, and Fauna of Madeira and Selvagens Archipelagos*. Direcção Regional do Ambiente da Madeira and Universidade dos Açores, 13-25.

Borges, P. A. V., Lamelas-Lopez, L., Amorim, I. R., Danielczak, A., Boieiro, M., Rego, C., Wallon, S., Nunes, R., Cardoso, P. and Hochkirch, A. (2019). Species Conservation Profiles of Cave-Dwelling Arthropods from Azores, Portugal. *Biodiversity Data Journal* 7, e32530.

Bowser, M. L. (2014). Notes on the Biology of the Cixiid Planthopper *Cixius meridionalis* (Hemiptera: Fulgoroidea). *Psyche: A Journal of Entomology* 2014(1): 769021.

Boyce, S. W., Boyce, W. R., Chamberlain, E. E., Cumber, R. A., Fry, P. R., Matthews, R. E. F., Newhook, F. J., Strzemienski, K. (1951). Preliminary Note on Yellow-leaf Disease of *Phormium*. *New Zealand Journal of Science and Technology A* 33, 76-77.

Bressan, A., Moral García, F. J., Sémétey, O., Boudon-Padieu, E. (2010). Spatio-temporal Pattern of *Pentastiridius leporinus* Migration in an Ephemeral Cropping System. *Agricultural and Forest Entomology* 12(1), 59-68.

Bucher, M., Condamine, F. L., Luo, Y., Wang, M., Bourgoin, T. (2023). Phylogeny and Diversification of Planthoppers (Hemiptera: Fulgoromorpha) Based on a Comprehensive Molecular Dataset and Large Taxon Sampling. *Molecular Phylogenetics and Evolution* 186, 107862.

Burckhardt, D., Ouvrard, D., Queiroz, D., Percy, D. (2014). Psyllid Host-plants (Hemiptera: Psylloidea): Resolving a Semantic Problem. *Florida Entomologist* 97(1), 242-246.

Butchart, S. H., Walpole, M., Collen, B., Van Strien, A., Scharlemann, J. P., Almond, R. E., Baillie, J. E., Bomhard, B., Brown, C., Bruno, J., Carpenter, K. E. (2010). Global Biodiversity: Indicators of Recent Declines. *Science* 328(5982), 1164-1168.

Capelo, J., Sequeira, M., Jardim, R., Mesquita, S., Costa, J. (2005). The Vegetation of Madeira Island (Portugal). A brief Overview and Excursion Guide. *Quercetea* 7, 95-122.

Capelo, J., Sequeira, M., Jardim, R., Mesquita, S. (2007). Madeira. In: LPN. *Árvores e florestas de Portugal: Açores de Madeira. A floresta das ilhas*. Público, Comunicação Social, SA. Fundação Luso-Americana para o Deseenvolvimento, 81-130.

Cardoso, P., Erwin, T. L., Borges, P. A., New, T. R. (2011a). The Seven Impediments in Invertebrate Conservation and how to Overcome them. *Biological Conservation* 144(11), 2647-2655.

Cardoso, P., Borges, P. A., Triantis, K. A., Ferrández, M. A., Martín, J. L. (2011b). Adapting the IUCN Red List Criteria for Invertebrates. *Biological Conservation* 144(10), 2432-2440.

Cardoso, P., Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Samways, M. J. (2020). Scientists' Warning to Humanity on Insect Extinctions. *Biological Conservation* 242, 108426.

Casimiro, J. M. (2017). *Conservation of the Macaronesian Endemic Species: Patterns Among Archipelagos and Taxonomic Groups Based on IUCN Lists*. Master's dissertation, Lisbon University, Sciences Faculty, Animal Biology Department.

Caujapé-Castells, J., Tye, A., Crawford, D., Santos-Guerra, A., Sakai, A., Beaver, K., Lobin, W., Florens, F., Moura, M., Jardim, R., Gómes, I., Kueffer, C. (2010). Conservation of Oceanic Island Floras: Present and Future Global Challenges. *Perspectives in Plant Ecology, Evolution and Systematics* 12, 107-130.

Certini, G., Moya, D., Lucas-Borja, M. E., Mastrolonardo, G. (2021). The Impact of Fire on Soil-Dwelling Biota: A Review. *Forest Ecology and Management* 488, 118989.

Chapman, A. D. & Wieczorek, J. R. (2020). *Georeferencing Best Practices*. Version 1.0. Copenhagen: GBIF Secretariat. <https://doi.org/10.15468/doc-gg7h-s853>

China, W. E. 1938 - Die Arthropodenfauna von Madeira nach den Ergebnissender Reise von Prof. Dr. O. Lundblad Juli-August 1935. III. Terrestrial Hemiptera (Hemiptera and Homoptera Auchenorrhyncha). *Arkiv for Zoologi. Utgifvet af K. Svenska Vetenskaps-akademien. Stockholm* 30(2), 1-68.

CMF (2010). *Estratégia de Reabilitação Urbana e Operações Prioritárias*. Proposta para Programa Estratégico de Reabilitação Urbana. Centro Histórico do Município do Funchal. Funchal.

Coimbra, I. L., & Palma, J. M. L. M. (2024). Challenges in Simulating the Wind over a Coastal Complex-Shaped Site: Madeira Island. *Journal of Physics: Conference Series* 2767, 052014.

Corbin, J. D., & D'Antonio, C. M. (2012). Gone but not Forgotten? Invasive Plants' Legacies on Community and Ecosystem Properties. *Invasive Plant Science and Management* 5(1), 117-124.

Costa, H., Bettencourt, M. J., Silva, C. M., Teodósio, J., Gil, A., Silva, L. (2013). Chapter 17: Invasive Alien Plants in the Azorean Protected Areas: Invasion Status and Mitigation Actions. In: Foxcroft, L. C., Pyšek, P., Richardson, D. M., Genovesi, P. (2013). *Plant invasions in Protected Areas: Patterns, Problems and Challenges* (Vol. 7). Springer Science & Business Media, 375-394.

Council of the European Communities. (1992). Council Directive 92/43/EEC of 21 May. *Official Journal of the European Communities* L 206, 7–50.

Couto, F. T., Salgado, R., Costa, M. J. (2012). Analysis of Intense Rainfall Events On Madeira Island during the 2009/2010 Winter. *Natural hazards and earth system sciences* 12(7), 2225-2240.

Couto, F. T., Ducrocq, V., Salgado, R., Costa, M. J. (2016). Numerical Simulations of Significant Orographic Precipitation in Madeira Island. *Atmospheric Research* 169, 102-112.

Couto, F. T., Ducrocq, V., Salgado, R., Costa, M. J. (2017). Understanding Significant Precipitation in Madeira Island using High-resolution Numerical Simulations of Real Cases. *Quarterly Journal of the Royal Meteorological Society* 143(702), 251-264.

Couto, F. T., Salgado, R., Guiomar, N. (2021). Forest Fires in Madeira Island and the Fire Weather Created by Orographic Effects. *Atmosphere* 12(7), 827.

Cowie, R. H., Bouchet, P., Fontaine, B. (2022). The Sixth Mass Extinction: Fact, Fiction, or Speculation? *Biological Reviews* 97(2), 640-663.

Cropper, T. (2013). The Weather and Climate of Macaronesia: Past, Present and Future. *Weather* (00431656) 68(11).

Cruz, M. J., Aguiar, R., Correia, A., Tavares, T., Pereira, J. S., Santos, F. D. (2009). Impacts of Climate Change on the Terrestrial Ecosystems of Madeira. *International Journal of Design & Nature and Ecodynamics* 4(4), 413-422.

Cumber, R. A. (1952). Studies on *Oliarus atkinsoni* Myers (Hemiptera: Cixiidae), Vector of the "Yellow Leaf" Disease of *Phormium tenax* Forst. *New Zealand Journal of Science and Technology* 34, 92-98.

Daru, B. H., le Roux, P. C., Gopalraj, J., Park, D. S., Holt, B. G., Greve, M. (2019). Spatial Overlaps Between the Global Protected Areas Network and Terrestrial Hotspots of Evolutionary Diversity. *Global Ecology and Biogeography* 28(6), 757-766.

De Lima, M. I. P., & De Lima, J. L. M. P. (2009). Investigating the Multifractality of Point Precipitation in the Madeira Archipelago. *Nonlinear Processes in Geophysics* 16(2), 299-311.

De Martonne, E. (1926). Aréisme et Indice d'Aridité. *Comptes Rendus de L'Academy of Science*, Paris, 1395-1398.

De Polanía, I. Z. & Lopez, A. (1977). Apuntes sobre la Biología y Hábitos del *Haplaxius pallidus*, Transmisor de la 'Marchitez Sorpresiva' en Palma Africana. *Revista Colombiana de Entomología* 3(1-2), 49-62.

Deus, E., Silva, J. S., Castro-Díez, P., Lomba, A., Ortiz, M. L., Vicente, J. (2018). Current and Future Conflicts Between Eucalypt Plantations and High Biodiversity Areas in the Iberian Peninsula. *Journal for Nature Conservation* 45, 107-117.

Diário de Notícias (1876, October 28). Diário de Notícias nº 16.

Dias-Silva, K., Moreira, F. F. F., Giehl, N. D., Nobrega, C. C., & Cabette, H. S. R. (2013). Gerromorpha (Hemiptera: Heteroptera) of Eastern Mato Grosso State, Brazil: Checklist, new records, and Species Distribution Modeling. *Zootaxa* 3736(3), 201-235.

DREM (2024a). *Movimento da População na Região Autónoma da Madeira*, 2023. Direção Regional de Estatística da Madeira.

Dudley, N. (2008). *Guidelines for Applying Protected Area Management Categories*. Gland, Switzerland: IUCN. 86pp.

Dunn, R. R. (2005). Modern Insect Extinctions: The Neglected Majority. *Conservation Biology* 19(4), 1030-1036.

Early, R., Rwomushana, I., Chipabika, G., Day, R. (2022). Comparing, Evaluating, and Combining Statistical Species Distribution Models and CLIMEX to Forecast the Distributions of Emerging Crop Pests. *Pest Management Science* 78(2), 671-683.

EC (2020). *EU Biodiversity Strategy for 2030: Bringing nature back into our lives*. Brussels, COM(2020) 380 final [accessed on November 13, 2024].

EC (2024). Press release: *Nature - Commission Decides to Refer Portugal Back to the Court of Justice of the European Union for Failure to Comply with Previous Judgment on Conservation of Natura 2000 Sites*. Brussels, 7 February 2024 [accessed on November 13, 2024].

EEA (2024). *Terrestrial Protected Areas in Europe*. <https://www.eea.europa.eu/en/analysis/indicators/terrestrial-protected-areas-in-europe> [accessed on November 13, 2024].

Emeljanov, A. (2002). Contribution to Classification and Phylogeny of the Family Cixiidae (Hemiptera: Fulgoromorpha). *Denisia* 4, 103-112.

Emeljanov, A. F. (2007). New and Little Known Taxa of the Family Cixiidae (Hemiptera: Fulgoroidea). *Entomologicheskoe Obozrenie* 86(1), 107-131.

European Commission. (2020). *EU Biodiversity Strategy for 2030: Bringing Nature back into our Lives*. <https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en> [accessed on November 15, 2024].

Feldman, M. J., Imbeau, L., Marchand, P., Mazerolle, M. J., Darveau, M., & Fenton, N. J. (2021). Trends and Gaps in the Use of Citizen Science Derived Data as Input for Species Distribution Models: A Quantitative Review. *PloS One* 16(3), e0234587.

Fennah, R. G. (1967). New and Little Known Fulgoroidea from South Africa (Hemiptera). *Annals of the Natal MuseuM* 18(3), 655-714.

Fernández-Palacios, J. M. (2010). The Islands of Macaronesia. In: A. R. M. Serrano, P. A. V. Borges, M. Boieiro, P. Oromí (Eds.), *Terrestrial Arthropods of Macaronesia – Biodiversity, Ecology, and Evolution*. Sociedade Portuguesa de Entomologia, Lisboa, 1-327.

Ferreira, M. T., Cardoso, P., Borges, P. A., Gabriel, R., de Azevedo, E. B., Elias, R. B. (2019). Implications of Climate Change to the Design of Protected Areas: The Case Study of Small Islands (Azores). *Plos One* 14(6), e0218168.

Ferreira, M., Cardoso, P., Borges, P., Gabriel, R., Azevedo, E., Reis, F., Araújo, M., Elias, R. (2016). Effects of Climate Change on the Distribution of Indigenous Species in Oceanic Islands (Azores). *Climate Change* 138(3-4), 603-615.

Fivaz, F. P., & Gonseth, Y. (2014). Using Species Distribution Models for IUCN Red Lists of Threatened Species. *Journal of Insect Conservation* 18, 427-436.

Flora-On (2025). Flora-On Madeira <https://madeira.flora-on.pt/>

Florencio, M., Patiño, J., Nogué, S., Traveset, A., Borges, P. A., Schaefer, H., Amorim, I. R., Arnedo, M., Ávila, S. P., Cardoso, P., de Nascimento, L. (2021). Macaronesia as a Fruitful Arena for Ecology, Evolution, and Conservation Biology. *Frontiers in Ecology and Evolution* 9, 718169.

Fonseca, C. R. (2009). The Silent Mass Extinction of Insect Herbivores in Biodiversity Hotspots. *Conservation Biology* 23(6), 1507-1515.

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (Hemiptera, Fulgoromorpha) from the Madeira Archipelago. *European Journal of Taxonomy* 744, 1-37.

Gao, Q., Zeman, C., Vergara-Temprado, J., Lima, D. C., Molnar, P., Schär, C. (2023). Vortex Streets to the Lee of Madeira in a Kilometre-Resolution Regional Climate Model. *Weather and Climate Dynamics* 4(1), 189-211.

Gaston, K. J., & Fuller, R. A. (2009). The Sizes of Species' Geographic Ranges. *Journal of Applied Ecology* 46(1), 1-9.

GBIF (2025a). *Suaeda vera* GBIF Occurrence Download. DOI: 10.15468/dl.gmvvmc

GBIF (2025b). *Globularia salicina* GBIF Occurrence Download. DOI:10.15468/dl.x5bdyc

González-Mancebo, J. M., Dirkse, G. M., Patino, J., Romaguera, F., Werner, O., Ros, R. M., Martín, J. L. (2012). Applying the IUCN Red List Criteria to Small-Sized Plants on Oceanic Islands: Conservation Implications for Threatened Bryophytes in the Canary Islands. *Biodiversity and conservation* 21, 3613-3636.

Goulson, D. (2019). The Insect Apocalypse, and Why it Matters. *Current Biology* 29(19), R967–R971.

Guerrero, F., Hernández, C., Toledo, M., Espinoza, L., Carrasco, Y., Arriagada, A., Muñoz, A., Taborga, L., Bergmann, J. and Carmona, C. (2021). Leaf Thermal and Chemical Properties as Natural

Drivers of Plant Flammability of Native and Exotic Tree Species of the Valparaíso Region, Chile. *International Journal of Environmental Research and Public Health* 18(13), p.7191.

Guisan, A., Thuiller, W., Zimmermann, N. E. (2017). *Habitat Suitability and Distribution Models: With Applications in R*. Cambridge University Press.

Gullan, P. J., & Cranston, P. S. (2014). *The Insects: an Outline of Entomology*. John Wiley & Sons.

Halbert, S. E., Wilson, S. W., Bextine, B., Youngblood, S. B. (2014). Potential Planthopper Vectors of Palm Phytoplasmas in Florida With a Description of a New Species of the Genus *Omolicna* (Hemiptera: Fulgoroidea). *Florida Entomologist* 97(1), 90–97.

Hallmann, C.A., Hörren, T., Ssymank, A., Sumser, H., Schwan, H., Stenmans, W., Vischer-Leopold, M., Schäffler, L., Sorg, M. (2022). Spatial, Temporal and Taxonomic Patterns of Insect Extinction in Germany. *bioRxiv* 12.

He, Q., & Silliman, B. R. (2019). Climate Change, Human Impacts, and Coastal Ecosystems in the Anthropocene. *Current Biology* 29(19), 1021-1035.

Heleno, S., Matias, M., Pina, P., Sousa, A. J. (2016). Semiautomated Object-based Classification of Rain-induced Landslides with VHR Multispectral Images on Madeira Island. *Natural Hazards and Earth System Sciences* 16(4), 1035-1048.

Hernangómez, D. (2023). Using the tidyverse with terra Objects: the tidyterra Package. *Journal of Open Source Software* 8(91), 5751. ISSN 2475-9066, <https://doi.org/10.21105/joss.05751>, <https://doi.org/10.21105/joss.05751>.

Hijmans, R. (2023). raster: Geographic Data Analysis and Modeling. R package version 3.6-26, <https://CRAN.R-project.org/package=raster>.

Hoch H. & Remane R. (1985). Evolution und Speziation der Zikaden-Gattung *Hyalesthes* Sign., 1865 (Homoptera Auchenorrhyncha Fulgoroidea Cixiidae). *Marburger Entomologische Publikationen* 2 (2): 1-427.

Hoch, H. (1991). Cave-dwelling Cixiidae (Homoptera, Fulgoroidea) from the Azores. *Boccagiana* 149, 1–9.

Hoch, H., & Asche, M. (1993). Evolution and Speciation of Cave-dwelling Fulgoroidea in the Canary Islands (Homoptera: Cixiidae and Meenoplidae). *Zoological Journal of the Linnean Society* 109(1), 53–101.

Hoch, H., Oromi, P., Arechavaleta, M. (1999). *Nisia subfogo* sp. n., a New Cave-dwelling Planthopper from the Cape Verde Islands (Hemiptera: Fulgoromorpha: Meenoplidae). *Revista de la Academia Canaria de Ciencias* 11(3–4), 189–199.

Hoch, H. (2002). Hidden from the Light of Day: Planthoppers in Subterranean Habitats (Hemiptera: Auchenorrhyncha: Fulgoromorpha). *Denisia* 4, 139–146.

Hoch, H., Porter, M. L., Slay, C. M., Slay, M. E., Steck, M., & Chong, R. A. (2024). From the Dark Side of Paradise: A New Natural Replication of Cave Planthopper Evolution from Hawaiian Lava

Tubes (Hemiptera: Fulgoromorpha: Cixiidae). *Zoological Journal of the Linnean Society* 202, 1–13.

Hochkirch, A. (2016). The Insect Crisis we Can't Ignore. *Nature* 539(7628), 141.

Hochkirch, A., Aguiar, A., Oromi, P. (2016). *Psalmatophanes barretoi*. The IUCN Red List of Threatened Species 2016: e.T68460092A75340675.

Holzinger, W., Emeljanov, A., Kammerlander, I. (2002). The Family Cixiidae Spinola 1839 (Hemiptera: Fulgoromorpha) – A Review. *Denisia* 4, 113–138.

Honary, R., Shelton, J., & Kavehpour, P. (2025). A Review of Technologies for the Early Detection of Wildfires. *ASME Open Journal of Engineering* 4.

Howard, F. W., Moore, D., Giblin-Davis, R. M., Abad, R.G. (2001). *Insects on Palms*. Wallingford, UK: CABI Publishing, 128-160.

IFCN (2015). *IFRAM2: 2º Inventário Florestal da Região Autónoma da Madeira - Relatório Final*. Secretaria Regional do Ambiente e dos Recursos Naturais Direção Regional de Florestas e Conservação da Natureza, Funchal.

IFCN (2024a). IFCN <https://ifcn.madeira.gov.pt/> [accessed on September 21, 2024]

IFCN (2024b). *Planos de Gestão e Ordenamento*. <https://ifcn.madeira.gov.pt/areas-protegidas/planos-de-ordenamento-e-gestao-pog.html> [accessed on September 23, 2024].

IFCN (2024c). *Ponta de São Lourenço*. <https://ifcn.madeira.gov.pt/pt/areas-protegidas/parque-natural-da-madeira/ponta-de-sao-lourenco.html> [accessed on January 16, 2025]

INIAV (2019). *REGIS - Conservação de Recursos Genéticos Florestais na Madeira*. Ficha do Projeto para Divulgação. PRODERAM20-15.2.1-FEADER-01416

IUCN. (2012). *IUCN Red List Categories and Criteria*. Version 3.1. Second Edition. Gland, Switzerland, and Cambridge, UK: IUCN.

IUCN. (2016). *A Global Standard for the Identification of Key Biodiversity Areas*. Version 1.0. Gland, Switzerland: IUCN.

IUCN Standards and Petitions Committee (2024). *Guidelines for Using the IUCN Red List Categories and Criteria*. Version 16. Prepared by the Standards and Petitions Committee.

IUCN (2025). *The IUCN Red List of Threatened Species*. Version 2024-2. <https://www.iucnredlist.org>

Jaenike, J. (1990). Host Specialization in Phytophagous Insects. *Annual Review of Ecology and Systematics* 21, 243–273.

Japan Aerospace Exploration Agency (2021). Distributed by OpenTopography. <https://doi.org/10.5069/G94M92HB>

Jiménez-Valverde, A., Hortal, J., Lobo, J. M., Borges, P. A., Abreu, C., Aguiar, A. F., Azevedo, E. B., Boieiro, M., Fontinha, S., Jardim, R., Oliveira, P. (2008). Using Predictive Models of Species

Distribution to Validate Biodiversity Data: Case Studies for Madeira Island. In: P. A. V. Borges, C. Abreu, A. M. F. Aguiar, P. Carvalho, R. Jardim, I. Melo, P. Oliveira, C. Sérgio, A. R. M. Serrano, P. Vieira (Eds.). *A List of the Terrestrial Fungi, Flora, and Fauna of Madeira and Selvagens Archipelagos*. Direcção Regional do Ambiente da Madeira and Universidade dos Açores, 27-56.

Jones, L., Garbutt, A., Hansom, J., Angus, S. (2013). Impacts of Climate Change on Coastal Habitats. *MCCIP Science Review*, 167-179.

Jones, P. (2022). Tourism and biodiversity: A paradoxical relationship. *Athens Journal of Tourism* 9(3), 151-162.

Joppa, L. N., & Pfaff, A. (2009). High and far: Biases in the location of protected areas. *Plos One* 4(12), e8273.

Jović, J., Cvrković, T., Mitrović, M., Krnjajić, S., Petrović, A., Redinbaugh, M. G., Pratt, R. C., Hogenhout, S. A., Toševski, I., (2009). Stolbur Phytoplasma Transmission to Maize by *Reptalus panzeri* and the Disease Cycle of Maize Redness in Serbia. *Phytopathology* 99(9), 1053-1061.

Kati, V., Hovardas, T., Dieterich, M., Ibisch, P. L., Mihok, B., Selva, N. (2015). The challenge of implementing the European network of protected areas Natura 2000. *Conservation Biology* 29(1), 260–270.

Kessler, S., Schaerer, S., Delabays, N., Turlings, T. C., Trivellone, V., Kehrli, P. (2011). Host Plant Preferences of *Hyalesthes obsoletus*, the Vector of the Grapevine Yellows Disease ‘Bois Noir’, in Switzerland. *Entomologia Experimentalis et Applicata* 139(1), 60-67.

Klein, M., Weintraub, P.G., Davidovich, M., Kuznetsova, L., Zahavi, T., Ashanova, A., Orenstein, S., Tanne, E. (2001). Monitoring Phytoplasma-bearing Leafhoppers/Planthoppers in Vineyards in the Golan Heights, Israel. *Journal of Applied Entomology* 125(1-2), 19-23.

Kramer, J. P. (1983). Taxonomic Study of the Planthopper Family Cixiidae in the United States (Homoptera: Fulgoroidea). *Transactions of the American Entomological Society* 1–57.

Lamelas-Lopez, L., Stüben, P. E., Ros-Prieto, A., Gabriel, R., Boieiro, M., Tsafack, N., & Ferreira, M. T. (2022). SLAM Project-Long Term Ecological Study of the Impacts of Climate Change in the Natural Forest of Azores: II-A Survey of Exotic Arthropods in Disturbed Forest Habitats. *Biodiversity Data Journal* 10, e81410.

Lamigueiro, O.P. & Hijmans, R. (2023). rasterVis. R package version 0.51.6.

Langer, M., Darimont, H., Maixner, M. (2003). Control of Phytoplasma Vectors in Organic Viticulture. *IOBC/WPRS Bulletin* 26(8), 197–202.

Leandro, C., Jay-Robert, P., Vergnes, A. (2017). Bias and Perspectives in Insect Conservation: A European-scale Analysis. *Biological Conservation* 215, 213–224.

Leather, S. R. (2009). Taxonomic Chauvinism Threatens the Future of Entomology. *Biologist* 56(1), 10-13.

Lee, W. H., Song, J. W., Yoon, S. H., Jung, J. M. (2022). Spatial Evaluation of Machine Learning-based Species Distribution Models for Prediction of Invasive Ant Species Distribution. *Applied Sciences* 12(20), e10260.

Liang, A. P. (2005). A New Structure on the SubantennaL Process of *Borysthenes* species (Hemiptera: Fulgoromorpha: Cixiidae: Borystheninae). *Proceedings of the Biological Society of Washington* 118(4), 809–814.

Lindberg, H. (1941) - Die Hemipteren der Azorischen Inseln. Nebst Anhang: Zur Kenntis der Hemipterenfauna von Madeira. *Commentationes Biologicae* 8(8), 1-32.

Lindberg, H. (1954) - Entomologische Ergebnisse der finländischen Kanaren-Expedition 1947-1951. No 1. Hemiptera insularum canariensium. Systematik, Oekologie und Verbreitung der kanarischen Heteropteren und Cicadinen. *Commentationes Biologicae*. *Societas Scientiarum Fennica*. *Helsingfors* 14(1), 1-304.

Lindberg H. (1961). Hemiptera Insularum Madeirensium. *Commentationes Biologicae* 24 (1), 1-82.

Liu, C., White, M., Newell, G. (2018). Detecting Outliers in Species Distribution Data. *Journal of Biogeography* 45(1), 164-176.

Lopes, A., Lopes, S., Matzarakis, A., Alcoforado, M. J. (2011). The influence of the Summer Sea Breeze on Thermal Comfort in Funchal (Madeira): a Contribution to Tourism and Urban Planning. *Meteorologische Zeitschrift* 5(20), 553-564.

López-Martín, M., Velasco-Molina, M., Knicker, H. (2016). Variability of the Quality and Quantity of Organic Matter in Soil Affected by Multiple Wildfires. *Journal of Soils and Sediments* 16, 360-370.

Lousada, S., Cabezas, J., Castanho, R. A., Gómez, J. M. N. (2022). Land-use Changes in Insular Urban Territories: A Retrospective Analysis from 1990 to 2018. The Case of Madeira Island—Ribeira Brava. *Sustainability* 14(24), e16839.

Luo, Y., Bourgoin, T., Szwedo, J., Feng, J. N. (2021). Acrotiarini trib. nov., in the Cixiidae (Insecta, Hemiptera, Fulgoromorpha) from mid-Cretaceous Amber of Northern Myanmar, with New Insights in the Classification of the Family. *Cretaceous Research* 128, e104959.

Luo, Y., Bourgoin, T., Zhang, J. L., Feng, J. N. (2022). Distribution Patterns of Chinese Cixiidae (Hemiptera, Fulgoroidea), Highlighting their High Endemic Diversity. *Biodiversity Data Journal* 10, 1–81.

Lusa (2023). Mais de mMetade do Concelho da Calheta já Ardeu, diz Autarca. Público. <https://www.publico.pt/2023/10/12/sociedade/noticia/oito-pessoas-receberam-assistencia-medica-devido-fogos-madeira-2066589> [accessed on February 11, 2025].

Lusa (2024). Área Ardida no Incêndio da Madeira Ultrapassou os 5100 Hectares. Público. <https://www.publico.pt/2024/08/27/sociedade/noticia/area-ardida-incendio-madeira-ultrapassou-5100-hectares-2101964> [accessed on February 11, 2025].

Macadam, C. (2022). *Cixius caledonicus*. *The IUCN Red List of Threatened Species 2022*: e.T123672002A123674334.

Machado, A., Rodríguez-Expósito, E., López, M., Hernández, M. (2017). Phylogenetic Analysis of the Genus *Laparocerus*, with Comments on Colonisation and Diversification in Macaronesia (Coleoptera, Curculionidae, Entiminae). *ZooKeys* 651.

Madruga, L., Wallenstein, F., Azevedo, J. M. N. (2016). *Regional Ecosystem Profile–Macaronesian region*. EU Outermost Regions and Overseas Countries and Territories. BEST, European Commission, 233.

Majdak, P., Mosz, J., & de Almeida, A. M. M. (2022). Overtourism: The Impact of Tourism on Madeira's Social and Economic Environment. *Studia Ecologiae et Bioethicae* 20(2), 79-88.

Manteghi, G., bin Limit, H., Remaz, D. (2015). Water Bodies an Urban Microclimate: A Review. *Modern Applied Science* 9(6).

Martins, A. M., & Cró, S. (2021). The Impact of Tourism on Solid Waste Generation and Management Cost in Madeira Island for the Period 1996–2018. *Sustainability* 13(9), e5238.

Mason, P. (2005). Visitor Management in Protected Areas: From 'hard' to 'soft' Approaches?. *Current Issues in Tourism* 8(2-3), 181-194.

Mata, J., Fonseca, P.E., Prada, S., Rodrigues, D., Martins, S., Ramalho, R., Madeira, J., Cachão, M., Silva, C. M., Matias, M. J. (2013). O Arquipélago da Madeira. In: Dias, R., Araújo, A., Terrinha, P., Kulberg, J. C. *Geologia de Portugal*, vol II, Geologia Meso-cenozóica de Portugal. Escolar Editora, Lisboa, 691–718.

Mazzoni, E., Aldini, R. N., Pavesi, F., Cravedi, P. (2006). Surveys of the Presence of *Hyalesthes obsoletus* Signoret (Rhynchota: Cixiidae) and other Hoppers in Lombardy (Northern Italy). *IOBC WPRS Bulletin* 29(11), 183.

Medeiros A., Santos C., Menezes D., Gouveia L., Oliveira P., Pires R. (2010). *Ponta de São Lourenço*. Secretaria Regional do Ambiente e dos Recursos Naturais – Serviço do Parque Natural da Madeira.

Meng, Y., & Qin, D. (2019). Structure and Sensilla of the Antennae and Mouthparts of *Loxocephala perpunctata* Jacobi (Hemiptera: Fulgomorpha: Eurybrachidae). *Acta Zoologica* 100(2), 135-152.

Merow, C., Smith, M.J., Silander, J.A. (2013). A Practical Guide to MaxEnt for Modeling Species' Distributions: What It Does, and Why Inputs and Settings Matter. *Ecography* 36, 1058-1069.

Miličić, M., Vujić, A., Jurca, T., Cardoso, P. (2017). Designating Conservation Priorities for Southeast European Hoverflies (Diptera: Syrphidae) Based on Species Distribution Models and Species Vulnerability. *Insect Conservation and Diversity* 10(4), 354-366.

Minghetti, E., Dellapé, P. M., Montemayor, S. I. (2024). *Orsillus depressus* (Heteroptera: Lygaeidae), an Invasive Circum-Mediterranean Species Recently Reported from America. Are the Endemic and Already Endangered Cupressaceae Trees from the Andean Region Facing a New Challenge? *Biological Invasions*, 1-16.

Ministério da Agricultura, Pescas e Alimentação (1990). *Decreto-Lei n.º 142/90*, de 4 de maio. Diário da República n.º 102/1990, Série I, 2100-2103.

Ministério do Ambiente (1999). *Decreto-Lei n.º 565/99*, de 21 de dezembro. Diário da República n.º 295/1999, Série I-A de 1999-12-21, 9100 – 9115.

Ministérios da Marinha e da Economia (1971). *Decreto n.º 458/71*, de 29 de outubro. Diário do Governo n.º 255/1971, Série I, 1644-1646.

Montgomery, G. A., Dunn, R. R., Fox, R., Jongejans, E., Leather, S. R., Saunders, M. E., Shortall, C. R., Tingley, M. W., Wagner, D. L. (2020). Is the Insect Apocalypse Upon Us? How to Find Out. *Biological Conservation* 241, 108327.

Morin, J. P. (1994). Elevage et Biologie de *Myndus taffini* Bonfils (Homoptera: Cixiidae), Vecteur du Déperissement Foliaire du Cocotier au Vanuatu. *ANPP*.

Muir, F. (1925). On the Genera of Cixiidae, Meenoplidae and Kinnaridae (Fulgoroidea, Homoptera). *Pan-Pacific Entomologist* 1(3), 97-110.

Müller, H. J. (1942). Über Bau und Funktion des Legeapparates der Zikaden (Homoptera Cicadina). (Zugleich erster Teil der Beiträge zur Biologie mitteleuropäischer Zikaden). *Zeitschrift für Morphologie und Ökologie der Tiere* 38(3), 534-629.

Myers, N., Mittermeier, R., Mittermeier, C., Fonseca, G., Kent, J. (2000). Biodiversity Hotspots for Conservation Priorities. *Nature* 403, 853-858.

Navarro, G., Caballero, I., Silva, G., Parra, P. C., Vázquez, Á., Caldeira, R. (2017). Evaluation of Forest Fire on Madeira Island Using Sentinel-2A MSI Imagery. *International Journal of Applied Earth Observation and Geoinformation* 58, 97-106.

Navarro-Pérez, E., & Barton, E. D. (2001). Seasonal and Interannual Variability of the Canary Current. *Scientia Marina* 65(S1), 205-213.

Nedeljković, Z. & Ricarte Sabater, A. R. (2021). *Xanthandrus babyssa*. The IUCN Red List of Threatened Species 2021: e.T149172407A149172411.

Neilson, R. P., Pitelka, L. F., Solomon, A.M., Nathan, R. A. N., Midgley, G. F., Fragoso, J. M., Lischke, H. and Thompson, K. E. N. (2005). Forecasting Regional to Global Plant Migration in Response to Climate Change. *Bioscience* 55(9), 749-759.

Nguyen, H. T., Wiatr, T., Fernández-Steeger, T. M., Reicherter, K., Rodrigues, D. M., & Azzam, R. (2013). Landslide Hazard and ascading efEfects Following the Extreme Rainfall Event on Madeira Island (February 2010). *Natural Hazards* 65, 635-652.

Nickel, H., & Remane, R. (2002). Check List of the Planthoppers and Leafhoppers of Germany, with Notes on Food Plants, Diet Width, Life Cycles, Geographic Range and Conservation Status (Hemiptera, Fulgoromorpha and Cicadomorpha). *Beiträge zur Zikadenkunde* 5, 27-64.

Nouhalier M. (1897). Hemipteres Recueillis par M.A. Fauvel a Madere en mai et en juin 1896. *Revue d'Entomologie* 16, 76-80.

Oberhauser, K., & Guiney, M. (2009). Insects as Flagship Conservation Species. *Terrestrial Arthropod Reviews* 1(2), 111-123.

ObsMap (2025) Observation International App. Version 9.6.4 <https://observation.org/>.

Oromi, P., De la Cruz, S., Báez, M. (2010). Hemiptera. In Arechavaleta, M., Rodríguez, S., Zurita, N., García, A. Lista de Especies Silvestres de Canarias. Hongos, Plantas y Animales Terrestres. Gobierno de Canarias, 234-253.

Panassiti, B., Breuer, M., Marquardt, S., Biedermann, R. (2013). Influence of Environment and Climate on Occurrence of the Cixiid Planthopper *Hyalesthes obsoletus*, the Vector of the Grapevine Disease 'Bois Noir'. *Bulletin of Entomological Research* 103(6), 621-633.

Pedrol, J. & S. Castroviejo. (1988). A Propósito del Tratamiento Taxonómico y Nomenclatural del Género *Suaeda* en "Flora Iberica". *Anales del Jardín Botánico de Madrid* 45: 93–102.

Pereira, A. (2023). Áreas Protegidas em Portugal até ao Início do Século XXI - Do Direito do Património Natural. 1st Edition. ETEP - Edições Técnicas e Profissionais.

Pfitzer, R., Varrelmann, M., Schrameyer, K., Rostás, M. (2022). Life History Traits and a Method for Continuous Mass Rearing of the Planthopper *Pentastiridius leporinus*, a Vector of the Causal Agent of Syndrome 'Basses Richesses' in Sugar Beet. *Pest Management Science 78*(11), 4700-4708.

Picanço, A., Rigal, F., Borges, P. A. (2017). Area Prioritization for Insect Pollinator Communities on an Oceanic Island. *Arquipélago-Life and Marine Sciences 34*, 85-104.

PlantNet (2025). PlantNet Software. <https://identify.plantnet.org/>.

Prada, S. N., & Serralheiro, A. (2000). Stratigraphy and Evolutionary Model of Madeira Island. *Bocagiana, Museu Municipal do Funchal (História Natural)* 200, ISSN 0523-7904.

Prada, S., de Sequeira, M. M., Figueira, C., da Silva, M. O. (2009). Fog Precipitation and Rainfall Interception in the Natural Forests of Madeira Island (Portugal). *Agricultural and Forest Meteorology, 149*(6-7), 1179-1187.

Presidência do Conselho de Ministros. (2018). Resolução do Conselho de Ministros n.º 55/2018 de 7 de maio. Diário da República n.º 87/2018, Série I de 2018-05-07, 1835 – 1880.

Presidência do Conselho de Ministros (2021). Decreto-Lei n.º 82/2021 de 13 de outubro. Diário da República, 1.ª série, N.º 199, 2-74.

Press, J. R., Short, M. J. (1994). *Flora of Madeira*. The Natural History Museum. London: HMSO.

Protected Planet (2024). Protected Area Statistics Updated: Aug 2024. <https://www.protectedplanet.net/en>

Pullen, J., Caldeira, R., Doyle, J. D., May, P., Tomé, R. (2017). Modeling the Air-Sea Feedback System of Madeira Island. *Journal of Advances in Modeling Earth Systems 9*(3), 1641-1664.

Rabinowitz, D. (1981). Seven Forms of Rarity. In: Synge H. *The Biological Aspects of Rare Plant Conservation*. John Wiley & Sons Ltd.

Ran, W., Chen, J., Zhao, Y., Zhang, N., Luo, G., Zhao, Z., Song, Y. (2024). Global Climate Change-Driven Impacts on the Asian Distribution of *Limassolla* Leafhoppers, With Implications for Biological and Environmental Conservation. *Ecology and Evolution 14*(7), e70003.

Região Autónoma da Madeira - Assembleia Regional (1982). Decreto Regional n.º 14/82/M, de 10 de novembro. Diário da República n.º 260/1982, Série I de 1982-11-10, páginas 3770 – 3774.

Região Autónoma da Madeira - Assembleia Legislativa Regional (1985). Decreto Legislativo Regional n.º 11/85/M, de 23 de maio. Diário da República n.º 118/1985, Série I de 1985-05-23, 1404 – 1405.

Região Autónoma da Madeira - Assembleia Legislativa Regional (1990). Decreto Legislativo Regional n.º 14/90/M, de 23 de maio. Diário da República n.º 118/1990, Série I de 1990-05-23, 2336 – 2338.

Região Autónoma da Madeira - Assembleia Legislativa Regional (1998). Decreto Legislativo Regional n.º 18/98/M, de 18 de agosto. Diário da República n.º 189/1998, Série I-A de 1998-08-18, 4066 – 4069.

Região Autónoma da Madeira - Assembleia Legislativa (2023). Decreto Legislativo Regional n.º 9/2023/M, de 18 de janeiro. Diário da República n.º 13/2023, Série I de 2023-01-18, 25 – 73.

Rego, C., Boieiro, M. Borges, P.A.V. 2018a. *Cixius azofloresi* (errata version published in 2018). *The IUCN Red List of Threatened Species* 2018: e.T97217487A135845342.

Rego, C., Boieiro, M. Borges, P.A.V. 2018b. *Cixius azoterceirae* (errata version published in 2018). *The IUCN Red List of Threatened Species* 2018: e.T97218887A135846353.

Rego, C., Boieiro, M. Borges, P.A.V. 2018c. *Cixius insularis* (errata version published in 2018). *The IUCN Red List of Threatened Species* 2018: e.T97219031A135847032.

Remane, R., & Asche, M. (1979). Evolution und Speziation der Gattung *Cixius* Latreille 1804 (Homoptera Auchenorrhyncha Fulgoromorpha Cixiidae) auf den Azorischen Inseln. *Marburger Entomologische Publikationen 1*(2), 1-264.

Remane, R., & Hoch, H. (1986). Sechs Neue Arten der Gattung *Hyalesthes* Signoret, 1865 (Homoptera Fulgoroidea Cixiidae) von den Mittelatlantischen Inseln und aus dem Irak. *Marburger Entomologische Publikationen 2*(3), 123-151.

Rhee, H., Hauth, K., Greis, K., Elle, O., Dellinger, T., Miller, A., Hochkirch, A. (2023). Strong Negative Effects of Recent Wildfires on Two Endemic Macaronesian Bush-Crickets. *Insect Conservation & Diversity 16*(2), 54296.

Rhee, H., Naber, S., Krehenwinkel, H., Hochkirch, A. (2025). Wildfires Induce a Reduction in Body Size and Morphological Variation of an Insular Endemic Insect. *Ecological Entomology*, 1-10.

Ribeiro, C., & Neves, P. (2020). Habitat Mapping of Cabo Girão Marine Park (Madeira Island): A Tool for Conservation and Management. *Journal of Coastal Conservation 24*(2), 22.

Ricketts, T. H., Dinerstein, E., Boucher, T., Brooks, T. M., Butchart, S. H., Hoffmann, M., Lamoreux, J. F., Morrison, J., Parr, M., Pilgrim, J. D., Rodrigues, A. S. (2005). Pinpointing and Preventing Imminent Extinctions. *Proceedings of the National Academy of Sciences 102*(51), 18497-18501.

Rocha-Ortega, M., Rodriguez, P., Córdoba-Aguilar, A. (2021). Geographical, Temporal, and Taxonomic Biases in Insect GBIF Data on Biodiversity and Extinction. *Ecological Entomology 46*(4), 718-728.

Romeiras, M. M., Catarino, S., Filipe, A. F., Magalhaes, M. F., Duarte, M. C., Beja, P. (2016). Species Conservation Assessments in Oceanic Islands: The Consequences of Precautionary Versus Evidentiary Attitudes. *Conservation Letters 9*(4), 275-280.

Samways, M. J. (2018). Insect Conservation for the Twenty-First Century. In *Insect Science—Diversity, Conservation, and Nutrition*. IntechOpen, 73864.

Sempere-Valverde, J., Guerra-García, J. M., García-Gómez, J. C., Espinosa, F. (2023). Coastal Urbanization: An Issue for Marine Conservation. In *Coastal Habitat Conservation*. Academic Press, 41-79.

Sforza, R., Bourgoin, T., Wilson, S. W., Boudon-Padieu, E. (2013). Field Observations, Laboratory Rearing, and Descriptions of Immatures of the Planthopper *Hyalesthes obsoletus* (Hemiptera: Cixiidae). *EJE 96*(4), 409-418.

Sillero, N., Arenas-Castro, S., Enriquez-Urzelai, U., Vale, C. G., Sousa-Guedes, D., Martínez-Freiría, F., Real, R., Barbosa, A. M. (2021). Want to Model a Species Niche? A Step-by-Step Guideline on Correlative Ecological Niche Modelling. *Ecological Modelling 456*, 109671.

Silva, L., & Tavares, J. (1995). Phytophagous Insects Associated With Endemic, Macaronesian, and Exotic Plants in the Azores. *Museo Nacional de Ciencias Naturales (CSIC) y Universidad Autónoma de Madrid*, 179-188.

Silva, L., Sardos, J., Sequeira, M., Silva, L., Crawford, D., Moura, M. (2016). Understanding Intra- and Inter-Archipelago Population Genetic Patterns Within a Recently Evolved Insular Endemic Lineage. *Plant Systematics and Evolution 302*, 367-384.

Sim-Sim, M., Ruas, S., Fontinha, S., Hedenäs, L., Sérgio, C., Lobo, C. (2014). Bryophyte Conservation on a North Atlantic Hotspot: Threatened Bryophytes in Madeira and Selvagens Archipelagos (Portugal). *Systematics and Biodiversity 12*(3), 315-330.

Sitar, G. M., & Rusu, A. S. (2023). The Impact of Environmental Educational Programs in Promoting Insect Conservation Awareness: A Scoping Review. *Journal of Educational Sciences 24*, 74-92.

Sotiriou, P., & Nunes, P. (2024). The Geoheritage of Madeira: Implications for Natural Heritage and Geotourism. *Geoheritage 16*(3), 74.

SRAPA (n.d.) Secretaria Regional de Agricultura, Pescas e Ambiente. <https://www.madeira.gov.pt/srapa>.

Stoll-Kleemann, S. (2010). Evaluation of Management Effectiveness in Protected Areas: Methodologies and Results. *Basic and Applied Ecology 11*(5), 377-382.

Stork, N. E. (2018). How Many Species of Insects and Other Terrestrial Arthropods Are There on Earth? *Annual Review of Entomology 63*(1), 31-45.

Strauss, B., & Biedermann, R. (2005). The Use of Habitat Models in Conservation of Rare and Endangered Leafhopper Species (Hemiptera, Auchenorrhyncha). *Journal of Insect Conservation 9*, 245-259.

Szwedo, J., Bourgoin, T., Lefebvre, F. (2006). New *Mnemosynini* Taxa (Hemiptera, Fulgoromorpha: Cixiidae) From the Palaeogene of France With Notes on Their Early Association With Host Plants. *Zootaxa 1122*(1), 25-45.

Tabor, J. A., & Koch, J. B. (2021). Ensemble Models Predict Invasive Bee Habitat Suitability Will Expand Under Future Climate Scenarios In Hawai'i. *Insects 12*(5), 443.

huiller, W., Georges, D., Gueguen, M., Engler, R., Breiner, F., Lafourcade, B., & Patin, R. (2023). *biomod2: Ensemble Platform For Species Distribution Modeling* (R Package Version 4.2-4).

Triantis, K. A., Borges, P. A., Hortal, J., Whittaker, R. J. (2010). The Macaronesian Province: Patterns of Species Richness and Endemism of Arthropods. In *Terrestrial Arthropods of Macaronesia: Biodiversity, Ecology And Evolution*, 49–71.

UNESCO (1999). The Laurisilva of Madeira. *WHC Nomination Documentation*. Report of the 23rd Session of the World Heritage Committee.

Unger, S., Rollins, M., Barrios, N. (2024). "Signs, Signs, Everywhere the Signs": Interpretive Trail Signage for Biodiversity Education. *Journal of College Science Teaching* 53(1), 78-86.

Van Stalle, J. (1986). Revision of Afrotropical Pentastirini (Homoptera, Cixiidae) II: The genus *Pentastiridius* Kirschaum, 1868. *Bulletin et Annales de la Société Royale Belge d'Entomologie* 122, 81-105.

Van Stalle, J. (1987a). A Review of the Genus *Caffrocixius* Fennah, 1967 with Description of Four New Species (Homoptera, Cixiidae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 60, 347-353.

Van Stalle, J. (1987b). Revision of Afrotropical Pentastirini (Homoptera, Cixiidae) 5: The genus *Oliarus* Stål, 1862. Musée Royal de l'Afrique Centrale Tervuren, Belgique. *Annales: Sciences Zoologiques* 252, 1-173.

van Swaay, C., Wynhoff, I., Verovnik, R., Wiemers, M., López Munguira, M., Maes, D., Sasic, M., Verstrael, T., Warren, M. Settele, J. (2010a). *Pararge xiphia*. *The IUCN Red List of Threatened Species* 2010: e.T173215A6975247.

van Swaay, C., Wynhoff, I., Verovnik, R., Wiemers, M., López Munguira, M., Maes, D., Sasic, M., Verstrael, T., Warren, M. Settele, J. (2010b). *Gonepteryx maderensis*. *The IUCN Red List of Threatened Species* 2010: e.T39485A10228166.

Wagensommer, R. F., Medalie, P., Turco, A., Perrino, E. B. (2020). IUCN Red List Evaluation of the Orchidaceae Endemic to Apulia (Italy) and Considerations on the Application of the IUCN Protocol to Rare Species. *Nature Conservation Research* 5(S1), 90-101.

Wang, W. L., Suman, D. O., Zhang, H. H., Xu, Z. B., Ma, F. Z., Hu, S. J. (2020). Butterfly Conservation in China: from Science to Action. *Insects* 11(10), 661.

Wang, Z., Zeng, J., Meng, W., Lohman, D., Pierce, N. (2021). Out of sight, Out of Mind: Public and Research Interest in Insects is Negatively Correlated with their Conservation Status. *Insect Conservation and Diversity* 14(5), 700-708.

Watson, J. E., Dudley, N., Segan, D. B., Hockings, M. (2014). The Performance and Potential of Protected Areas. *Nature* 515(7525), 67-73.

Wen, X., Fang, G., Chai, S., He, C., Sun, S., Zhao, G., Lin, X. (2024). Can Ecological Niche Models be used to Accurately Predict the Distribution of Invasive Insects? A Case Study of *Hyphantria cunea* in China. *Ecology and Evolution* 14(3), e11159.

White, O. W., Reyes-Betancort, J. A., Chapman, M. A., & Carine, M. A. (2020). Geographical Isolation, Habitat Shifts and Hybridisation in the Diversification of the Macaronesian Endemic Genus *Argyranthemum* (Asteraceae). *New Phytologist* 228(6), 1953-1971.

Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York.

Wilke, C, Wiernik, B. (2022). ggtext: Improved Text Rendering Support for 'ggplot2'. R package version 0.1.2, <https://CRAN.R-project.org/package=ggtext>.

Worldclim (2024). WorldClim Database (https://www.worldclim.org/data/bioclim.html) https://www.worldclim.org/data/index.html

Zbyszewski G., Medeiros A., Ferreira O., Rodrigues L., Rodrigues A., Aires-Barros L. (1975). *Carta Geológica da Ilha da Madeira: Folha A e B e Notícia Explicativa*. *Carta geológica de Portugal à escala 1/50.000,* Missão dos Serviços Geológicos. Descarregada em <https://geoportal.lneg.pt/pt/dados_abertos/cartografia_geologica/cartografia_geologica_madeira/> [accessed on January 28, 2023].

Zema, D. A. (2021). Postfire Management Impacts on Soil Hydrology. *Current Opinion in Environmental Science & Health* 21, 100252.

Zermoglio, P. F., Chapman, A. D., Wieczorek, J.R., Luna, M. C. Bloom, D. A. (2020). *Georeferencing Quick Reference Guide*. Copenhagen: GBIF Secretariat.

Zhou, Y., Zhang, H., Liu, D., Khashaveh, A., Li, Q., Wyckhuys, K. A., Wu, K. (2023). Long-term Insect Censuses Capture Progressive Loss of Ecosystem Functioning in East Asia. *Science Advances* 9(5), eade9341.

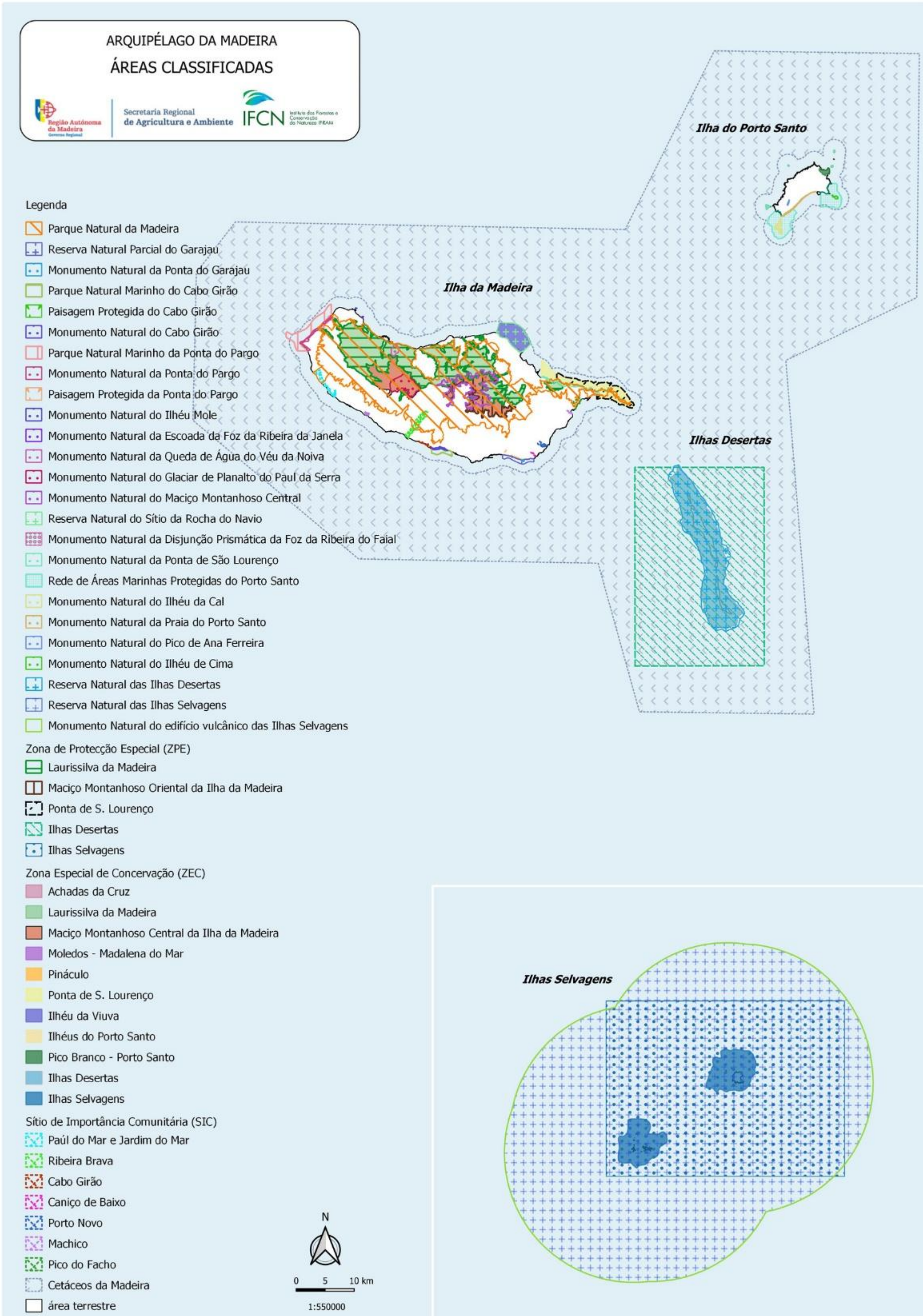
Zhu, G., Bu, W., Gao, Y., Liu, G. (2012). Potential Geographic Distribution of Brown Marmorated Stink Bug Invasion (*Halyomorpha halys*). *PLoS One* 7(2), e31246.

Annexes

Annex 1 | Compilation of life history traits for species of the Cixiidae family. GN = Generation Duration, GY = Generations per Year, EDP = Egg Stage Duration and Presence, NI = Number of Nymphal Instars, NDP = Nymphal Duration and Presence, LN = Location of Nymphs, AS = Adult Stage, MPL = Mating Period and Location, OL = Oviposition Location, HP = Host Plants, D = Distribution, Mr = March, Ap = April, M= May, Jn = June, J = July, A = August, S = September, N = November.

Species	GN	GY	EDP	NI	NDP	LN	AS	MPL	OL	HP	D	Source
Cixius meridionalis (Beirne, 1950)	-	1	Late summer	5	M-S	-	♂ J-S ♀ J-A	-	Loose moist moss, near tree holes	*Picea mariana*, *Sphagnum*, *Vaccinium vitis-idaea*	Alaska	Bowser (2014)
Haplaxius crudus (van Duzee, 1907)	63.7 ± 3.6 days	Multivoltine	15.4 ± 0.9 days	4-5	48.3 ± 2.7 days	-	Live more with less temperature	Near palm base	Soil near grass stalks, lower leaf sheaths	*Stenotaphrum secundatum*, *Paspalum notatum*, *Eremochloa ophiuroides*	Southern Florida, Cuba, Cayman Islands	de Polanía & Lopez (1977), Howard *et al.* (2001), Beltrán-Aldana *et al.* (2020), Beltrán-Aldana *et al.* (2024)
Hyalesthes obsoletus (Signoret, 1865)	27 ± 4 weeks	1-2	7 ± 1.2 weeks	5	125 days	Soil 9-26 cm depth	M-A	10 days after emergence	2–3 cm below soil surface	*Convolvulus arvensis*, *Urtica dioica*	Europe, Middle East, North Africa, Asia Minor	Sforza *et al.* (1999), Klein *et al.* (2001), Kessler *et al.* (2011)
Myndus taffini (Bonfils, 1983)	15-20 weeks	-	20–29 days	6	12-15 weeks	Superficial roots	Mature in 3 days peak Ap–M	-	Superficial roots of *Hibiscus*, under moist debris	*Hibiscus tiliaceus*, *Cocos nucifera*	Vanuatu, Banks Islands, Tanna Island	Morin (1994)
Pentastiridius leporinus (Linnaeus, 1761)	7 months	1	J	5	-	Soil 30 cm depth	M-A	-	Topsoil, near maize and sugar beet roots	*Beta vulgaris*, *Zea mays*	China, Iran, Afghanistan, Algeria	Bressan *et al.* (2010), Pfitzer *et al.* (2022)
Reptalus panzeri (Löw, 1883)	-	-	J-A	5	Ag-Jn	Maize roots	Jn-A	J	Soil surrounding maize roots	*Zea mays*, Poaceae	Southern/ central Europe, Mediterranean, Asia Minor	Jović *et al.* (2009)
Zeoliarus atkinsoni (Myers, 1924)	2 years	1	12 weeks	5	90 weeks	Roots, leaf bases	N-Mr	Leaves	Dry spot between leaf bases	*Phormium* bushes	New Zealand	Boyce *et al.* (1951), Cumber (1952), Liefting *et al.* (1997)

Annex 2 | Map of the protected areas of the Madeira archipelago (IFCN 2024).



Annex 3. Sampling sheet for occurrence data for *Cixius* and *Hyalesthes* genera.

Colecção de Insectos

Universidade da Madeira

Field sheet – Cixiidae: ________

Trip code: UMACI TCIX___ Grid number _____

Sampling point number _____

Locality: __________________ Parish: __________________ County: __________________

Coordinates (WGS84): Latitude___________ Longitude__________ DD ☐ DMS ☐
Precision_______ Hard/software ___________

Altitude (m)______ Hard/software _____________

Vereda ☐ Trail ☐ Levada ☐ Road ☐ Name:______________________________________

Date:____/____/______ Time________ Weather______________________________________

Air ºC_____ Rh (%)_____ **Soil** ºC_____ Rh (%)_____ pH_____

Luminosity: Exposed ☐ Not exposed ☐ Intermediate ☐ value (lux)______

Wind: Exposed☐Not exposed☐Light☐ Value (m/s)___ (Beaufort scale__) Direction: ___ºN (__)

Photos: _________________ Video: _________________ Herbarium: _________________

Collector(s)____

General veg. cover: very high (75-100)☐ high (50-75)☐ intermediate (25-50)☐ low (0-25)☐

Type of sampled vegetation: sparse ☐ dense ☐ very dry ☐ medium dry ☐ little dry ☐

Litter: thick ☐ thin ☐ no litter ☐ Composition:_____________________________

Substrate: Rock ☐ Soil ☐ Firmness: compact ☐ loose ☐ Granulometry – homogeneity: homogeneous☐ heterogeneous ☐; sediment size: coarse ☐ medium☐ moderate thin ☐ thin ☐

Habitat type: Coastal ☐Exotic ☐Low alt. Laurel forest ☐High alt. Laurel forest ☐Laurel/heather thrives ☐ Grassland ☐ Water path ☐ Heather thrives ☐ Altitude vegetation ☐ Pteridium zone ☐ Xerophytic zone ☐ Slopes ☐ Cultivation zone ☐ Urban area ☐

Host/food plant(s): ____

Observations:____

Possible natural predators and others	Flies: Mosquitos: Spiders: Ants:
Exotic plants	
Others	

Collection field code	Plant name	Beats	Cixiidae no	*Cyphopterum* no	*Issus maderensis* no

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Annex 4. Ombrothermic charts of P=2T, differences in monthly thermal amplitudes lines and occult monthly dryness chart for the three sample sites of the adult monitoring program, with data from 2021 - 2023. A. Santana, B. Cancela, C. Caniçal

Annex 5 | Sampling sheet for adult monitoring. A. *Cixius* spp. and *Hyalesthes portonoves*, B. *Tachycixius chaoensis*.

A

Phenology sheet: **Genus**______________ **sheet number**______

Locality: ____________________________ Parish: _________________________ County: _________________________

Coordinates (WGS84): Latitude____________ Longitude____________ Precision___ Hard/Software________ Altitude (m)_____ Hard/Software_________

Date:___/___/_____ Weather________________ (1) **Air** ºC____ %Rh____ **Soil** ºC____ %Rh____pH____ (2) **Air** ºC____ %Rh____ **Soil** ºC____ %Rh____pH____

Observer(s)_____________________________ (3) **Air** ºC____ %Rh____ **Soil** ºC____ %Rh____pH____ (4) **Air** ºC____ %Rh____ **Soil** ºC____ %Rh____pH____

Site observations (vegetation state, soil, litter, exotic organisms, predators, other animals, luminosity):

Time	Where	Stage/gender	Quantity	Activity/behaviour

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B

____

Time: __h__ – __h__

Air: Temp ____°C, RH% ____ **Wind**:___ m/s (_)(___°N), ___°C **Other**: ___ dewpoint, _____ hPa, _____ lux

Soil: ___ °C, ___ RH%, ____pH, ____________________________

___________________________. __________. [Plant __]

No plant	Lat.	Lng.	*Tachycixius* presence	Sex/Life stage	Other	Notes
1	32.74	-16.69				
2	32.74	-16.69				
3	32.74	-16.69				
4	32.74	-16.69				
5	32.74	-16.69				
6	32.74	-16.69				
7	32.74	-16.69				
8	32.74	-16.69				
9	32.74	-16.69				
10	32.74	-16.69				
11	32.74	-16.69				
12	32.74	-16.69				
13	32.74	-16.69				
14	32.74	-16.69				
15	32.74	-16.69				
16	32.74	-16.69				
17	32.74	-16.69				
18	32.74	-16.69				
19	32.74	-16.69				
20	32.74	-16.69				
21	32.74	-16.69				
22	32.74	-16.69				
23	32.74	-16.69				
24	32.74	-16.69				
25	32.74	-16.69				
26	32.74	-16.69				
27	32.74	-16.69				
28	32.74	-16.69				
29	32.74	-16.69				
30	32.74	-16.69				

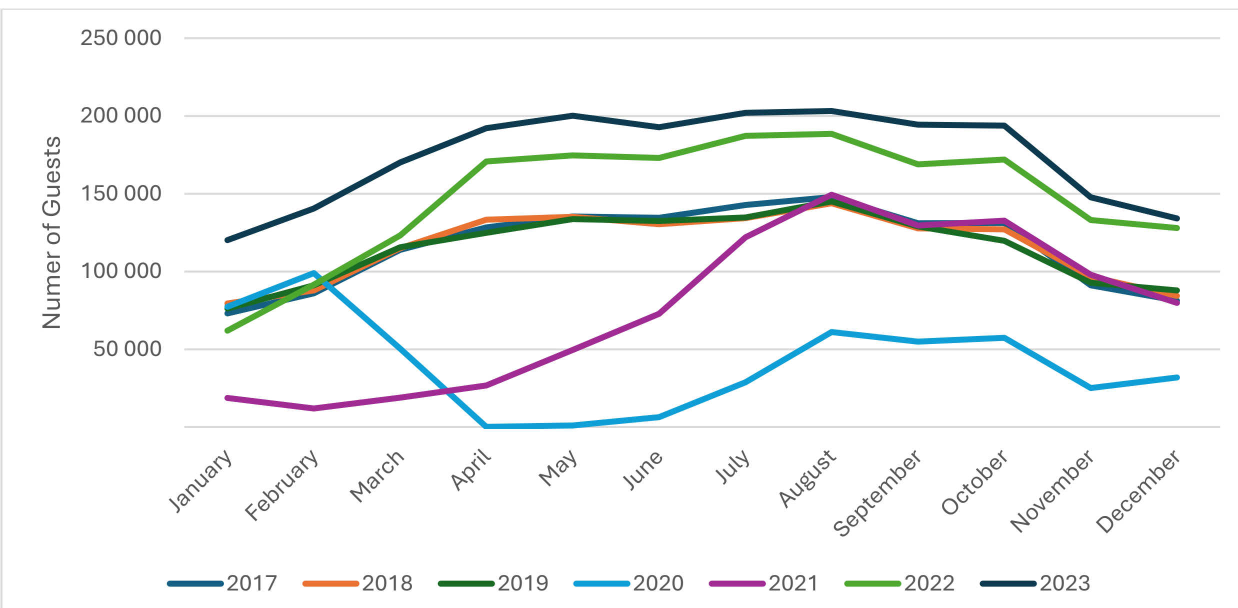
Annex 6 | Published information on cixiids regarding their activity period, altitude occurrences and environmental conditions used to rank the variables for modeling the target genus/species. * Panassity *et al.* (2013) is the only study published on modeling of cixiids referring to as important Mean Temperature of Coldest Quarter (bio 11, table 8).

Species	Daily adult activity period	Environment				Topography	References
		Air temperature	Rainfall (mm)	Air humidity	Soil humidity	Altitude (m)	
Haplaxius crudus (van Duzee, 1907)	7-9 am 4-6 pm	25.7–26.5ºC	2,454 rainfal/year	58.1–85%	-	227	Tsai & Kirsch (1978) Halbert *et al.* (2014) Bustillo & Arango (2017)
Hyalesthes obsoletus (Signoret, 1865)	-	23.1ºC BIO11	Annual precipitation	70±10%	-	300–350	Sforza *et al.* (1998) Klein *et al.* (2001) Kessler *et al.* (2011) Panassity *et al.* (2013)*
Myndus taffini (Bonfils, 1983)	Females more active in evening	21–27ºC	-	-	Moderate humidity, not dry	-	Morin (1994)
Pentastiridius leporinus (Linnaeus, 1761)	Day and night, preferably at 4 pm	16-22ºC	-	-	Moist to moderate watering	-	Bressan *et al.* (2010) Pfitzer *et al.* (2022)
Reptalus panzeri (Löw, 1883)	-	16–26ºC	-	-	-	-	Jović *et al.* (2009),
Zeoliarus atkinsoni (Myers, 1924)	After mid-day	-	-	-	Too much water harmful	-	Boyce *et al.* (1951) Cumber (1952) Liefting *et al.* (1997)

Annex 7 | Comparative species data for Rabinowitz Rarity Index Evaluation: Geographic Range, Local Population Size, and Habitat Specificity Metrics. Columns correspond to the following metrics: (1) Area of Occupancy (AOO), (2) Extent of Occurrence (EOO), (3) Number Captured per 100 Beats/Area Only in the Areas They Were Caught (2022–2024), (4) Number Captured per 100 Beats/Area in All Sampled Areas (2022–2024), (5) Mean Individuals per Site (All Data), (6) Number of Habitats—Adaptability, (7) Resilience to Degradation, (8) Number of Plants Used, and (9) Possible True Host Plants. Species abbreviations: CyFAU – Cyphopterum fauveli, Cypho – Cyphopterum spp., IM – Issus maderensis. Source: Sampling data from this study (2022–2024).

Species	Geographic range		Local population size			Habitat specificity			
	1	2	3	4	5	6	7	8	9
CyFAU	32	38.82	9.1	7.63	5.95±0.66	1	1	1	1
Cypho	160	644.13	2.03+5.89	0.57+2.78	4.02±1.38	8	4	13	9
IM	164	707.14	6.08+7.15	5.74+1.82	7.65±0.83	7	4	11	9

Annex 8 | Number of tourists in Madeira Island from 2017 to 2023, with monthly records. Source: Direção Regional de Estatística da Madeira (DREM).



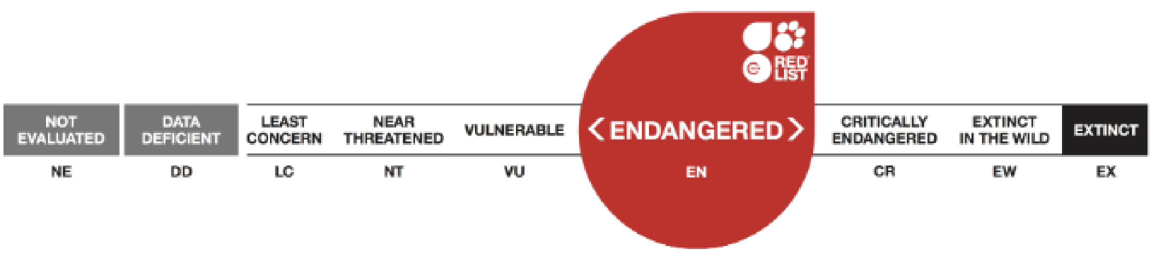
Annex 9 | Preliminary IUCN Red List Assessment Report on Endemic Cixiidae Species of Madeira Archipelago

The IUCN Red List of Threatened Species™
ISSN ___-___ (online)
IUCN 20__: __________________
Scope: Global
Language: English

Cixius verticalis

Preliminary version

Assessment by: Soraya, L.



View on www.iucnredlist.org

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Hemiptera	Cixiidae

Taxon Name: *Cixius verticalis* Noualhier, 1897

Synonym(s): ---

Common Name(s):

- English: Planthopper
- Portuguese: Cigarrinha grande da Laurissilva

Taxonomic Source(s):

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (*Hemiptera*, Fulgoromorpha) from the Madeira archipelago. *European Journal of Taxonomy, 744*, 1-37.

Nouhalier M. 1897. Hémiptères recueillis par M.A. Fauvel à Madere en mai et en juin 1896. Revue d'Entomologie 16: 76–80

Taxonomic Notes: Wrongly recorded for Azores in Lindberg 1941

Identification Information:

The largest *Cixius* species in Madeira Island (7.57 mm) with a darker brown body and larger, more pronounced wing punctuations. The vertex is sharper on the anterior margin than in C. *madeirensis*. Males have pale yellow eyes and a glossy mesonotum. The tegmina have faint, vestigial bands. The male genitalia have a broad, hump-shaped velum expansion and a rounded or subtriangular medioventral projection on the aedeagus.

Assessment Information

Red List Category & Criteria: Endangered B1ab(iii)+2ab(iii)

Date Assessed: November, 2024

Justification:

Cixius verticalis is an endemic planthopper confined to Madeira Island, Portugal, where it inhabits high and low-altitude laurel forests. It primarily occurs on endemic trees and shrubs, with a lesser presence on ferns. The species has a restricted distribution, with an Area of Occupancy (AOO) between 28 and 388 km² and an Extent of Occurrence (EOO) ranging from 75 to 549 km². The main threats to *C. verticalis* include habitat loss due to the conversion of laurel forests into production forests and the spread of invasive plants. Increasing tourism further degrades habitat quality, while fire control measures involving vegetation clearance may disrupt the species' phenology and reduce recruitment success. Climate change could gradually shift its suitable habitat to higher altitudes, though immediate impacts remain uncertain. To support conservation, regular monitoring of stable populations is essential, along with adaptive habitat management that balances public use with the species' ecological needs. Managing tourism in line with ecosystem capacity and preserving high-quality habitat are also key to ensuring its long-term survival.

Geographic Range

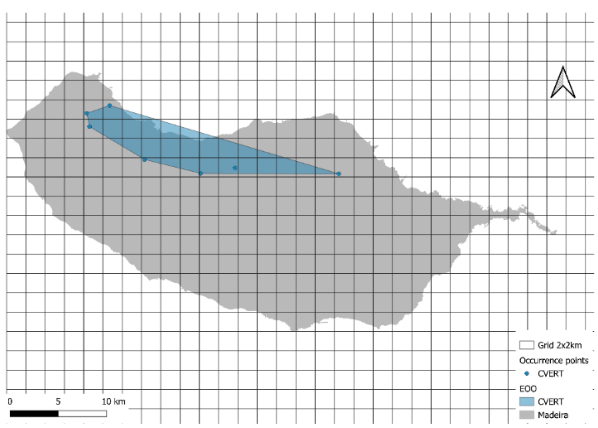
Range Description:

Cixius verticalis is an endemic planthopper found exclusively on Madeira Island, Portugal, where it occupies laurel forests at both high and low altitudes. Its distribution is limited, with an Area of Occupancy (AOO) ranging from 28 to 388 km² and an Extent of Occurrence (EOO) between 75 and 549 km².

Country Occurrence:

Native Extant (resident): Portugal (Madeira)

Distribution Map



Population

The species is confined to high and low-altitude laurel forests, with historical records lacking sufficient data to assess population trends. According to records in the Insect Collection of Madeira Island (UMACI), adults are present from late April to early October.

Current Population Trend: Unknown

Habitat and Ecology

The species inhabits high and low-altitude laurel forests, primarily associated with endemic trees and shrubs but also found on ferns. It is polyphagous, feeding on a variety of these plants. The plants where the species was found are: *Clethra arborea*, *Argyranthemum pinnatifidium*, *Adiantum* spp., *Diplazium caudatum, Dryopteris affinis, Polypodium* spp., *Festuca donax, Euphorbia mellifera*, and *Persea indica.*

Systems: Terrestrial

Use and Trade

The species is not utilised.

Threats

The main threat to *Cixius verticalis* is the continued loss and fragmentation of its habitat due to the conversion of laurel forests into production forests. This degradation is further intensified by increasing tourism, which heightens human disturbance and diminishes habitat quality and availability. Fire prevention measures, such as vegetation clearance, may also disrupt the species' phenology and reproduction, potentially reducing recruitment success. In the long term, climate change could push the species' suitable habitat to higher altitudes, though this shift is unlikely to pose an immediate risk.

Conservation Actions

The species currently lacks national or regional legal protection, although its habitat falls within the Madeira Natural Park. Due to limited data on its population size and ecological requirements, further research is needed to better understand its dynamics, ecological role, and the impact of threats on its survival.

To support conservation, long-term monitoring—particularly in stable and peripheral populations—should be conducted to track trends and detect early signs of decline. Adaptive habitat management is essential, ensuring that public use is balanced with the species' life cycle, including adjusting vegetation clearance schedules to avoid disturbing adults during critical periods. Additionally, regulating tourism to align with the ecosystem's carrying capacity and maintaining high-quality habitat are fundamental to its long-term preservation.

Tables

Habitat	**Season**	**Suitability**	**Major importance?**
1. Forest -> 1.4. Forest – Temperate	Resident	Suitable	Yes
1. Forest -> 1.6. Forest – Subtropical/tropical moist lowland	Resident	Suitable	Yes
7. Caves & Subterranean Habitats (non-aquatic) -> 7.2. Caves and Subterranean Habitats (non-aquatic) – Other subterranean habitats (roots)	Resident	Suitable	Yes

Threat	**Timing**	**Scope**	**Severity**
1 Residential & commercial development -> 1.3 Tourism & recreation areas	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
2 Agriculture & aquaculture -> 2.2 Wood & pulp plantations -> 2.2.2 Agro-industry plantations or 2.2.3 Scale Unknown/Unrecorded	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.3 Livestock farming & ranching -> 2.3.2 Small-holder grazing, ranching or farming	In the past but now suspended and likely to return	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
5 Biological resource use -> 5.3 Logging & wood harvesting -> 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target)[harvest *Laurus*]	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		

8 Invasive & other problematic species, genes & diseases -> 8.1 Invasive non-native/alien species/diseases -> 8.1.2 *Acacia dealbata, Eucalyptus globulus, Agapantus, Hedychium gardnerianum*	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
10 Geological events -> 10.3 Avalanches/landslides	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
11 Climate change & severe weather -> 11.1 Habitat shifting & alteration	Future	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		

Conservation Actions in Place
Monitoring & Planning
Action Recovery plan: No
Systematic monitoring scheme: No
Land/Water Protection and Management
Conservation sites identified: Yes, over part of range
Occur in at least one PA: Yes
Percentage of population protected by PAs (0-100): 70-90
Area based regional management plan: Yes
Invasive species control/prevention: Yes
Species Management
Harvest management plan: No
Successful reintroduced: No
Ex-situ conservation: No
Education & Legislation
Subject of any recent education/awareness programmes: No
Included in international legislation: No
Included in international management/trade controls: No

Conservation Actions Needed

2. Land/water management -> 2.1. Site/area management
2. Land/water management -> 2.2. Invasive/problematic species control
4. Education & awareness -> 4.1. Formal education
4. Education & awareness -> 4.2. Training
4. Education & awareness -> 4.3. Awareness & communications
5. Law & policy -> 5.1. Legislation -> 5.1.3. Sub-national level
5. Law & policy -> 5.4. Compliance and enforcement -> 5.4.3. Sub-national level

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology
1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
2. Conservation Planning -> 2.1. Species Action/Recovery Plan
2. Conservation Planning -> 2.2. Area-based Management Plan
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.4. Habitat trends

Additional Data Fields

Distribution
Estimated area of occupancy (AOO) (km²): 28-388
Continuing decline in area of occupancy (AOO): Unknown
Extreme fluctuations in area of occupancy (AOO): Unknown
Estimated extent of occurrence (EOO) (km²): 75-549
Continuing decline in extent of occurrence (EOO): Unknown
Extreme fluctuations in extent of occurrence (EOO): Unknown
Number of Locations: 2
Continuing decline in number of locations: Unknown
Extreme fluctuations in the number of locations: Unknown
Lower elevation limit (m): 144
Upper elevation limit (m): 871

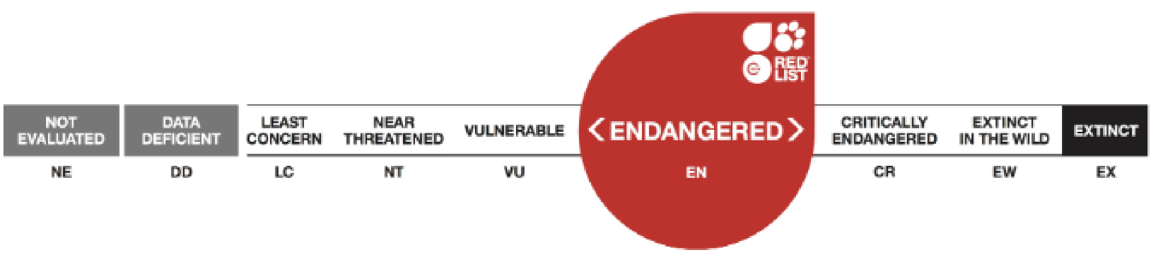
Population
Number of mature individuals: Unknown
Continuing decline of mature individuals: Unknown
Extreme fluctuations: Unknown
Population severely fragmented: Unknown
No. of individuals in largest subpopulation: Unknown
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): 1
Movement patterns: Not a Migrant
Congregatory: Congregatory (year-round)

The IUCN Red List of Threatened Species™
ISSN ___-___ (online)
IUCN 20__: __________________
Scope: Global
Language: English

Cixius madeirensis

Preliminary version

Assessment by: Soraya, L.



View on www.iucnredlist.org

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Hemiptera	Cixiidae

Taxon Name: *Cixius madeirensis* China, 1938

Synonym(s): ---

Common Name(s):

- English: Planthopper
- Portuguese: Cigarrinha pequena da Laurissilva

Taxonomic Source(s):

China W. E. 1938 - Die Arthropodenfauna von Madeira nach den Ergebnissender Reise von Prof. Dr. O. Lundblad Juli-August 1935. III. Terrestrial Hemiptera (Hemiptera and Homoptera Auchenorrhyncha). Arkiv for Zoologi. Utgifvet af K. Svenska Vetenskaps-akademien. Stockholm 30(2): 1-68 [51].

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (*Hemiptera*, Fulgoromorpha) from the Madeira archipelago. *European Journal of Taxonomy, 744*, 1-37.

Taxonomic Notes: ----

Identification Information:

A small species (5.27 mm) with a light golden brown body. The vertex is rounded, and the frons has a ridged medial carina. The tegmina are yellowish and translucent, sometimes with faint brown oblique stripes. Females are darker than males. The male genitalia feature a distinctive digitiform projection on the theca, and the basal half of the velum is hump-shaped but narrower than in related species.

Assessment Information

Red List Category & Criteria: Endangered B1ab(iii)+2ab(iii)

Date Assessed: November, 2024

Justification:

Cixius madeirensis is an endemic planthopper restricted to Madeira Island (Portugal), occurring specifically within the high-altitude Laurel Forest and the transition zone to hugh altitude heather (*Erica* spp.) zones, mainly on ferns but also on native and endemic trees and shrubs. This species has a limited Area of Occupancy (AOO) ranging from 40 to 388 km² and an Extent of Occurrence (EOO) between 145 and 549 km². The primary threat to *C. madeirensis* is habitat loss due to the conversion of Laurel forest to production forests, compounded by increasing tourism that degrades habitat quality and availability. Fire control measures that involve vegetation clearance may also impact the species' phenology, potentially reducing recruitment success. Additionally, climate change may push the species' suitable habitat to higher altitudes over time, although this is unlikely to immediately affect the population. To support conservation, regular monitoring of stable populations is recommended, alongside adaptive habitat management that considers both public needs and species phenology. Controlling tourism in line with ecosystem capacity and maintaining high-quality habitat are also critical for the species' preservation.

Geographic Range

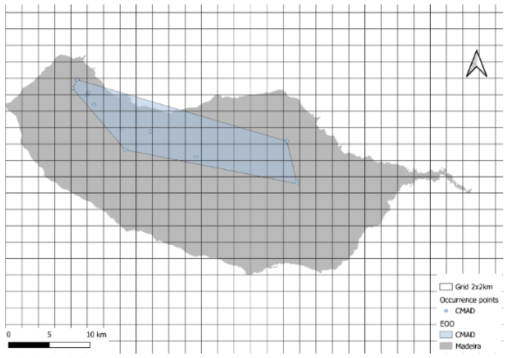
Range Description:

Cixius madeirensis is a single island endemic planthopper species from Madeira Island (Madeira, Portugal), where it is restricted to the high-altitude Laurel Forest. Its Area of Occupancy (AOO) ranges from 40 to 388 km² and its Extent of Occurrence (EOO) between 145 and 549 km².

Country Occurrence:

Native Extant (resident): Portugal (Madeira)

Distribution Map



Population

The species is fragmented and is restricted to high-altitude Laurel Forests on Madeira Island. Historical records are insufficient to determine population trends. According to records in the Insect Collection of Madeira Island (UMACI), adults are present from mid-April to mid-September.

Current Population Trend: Unknown

Habitat and Ecology

The species inhabits the Laurel Forest and its transition zones, primarily on ferns, but also on native and endemic trees and shrubs (Freitas & Aguín-Pombo, 2021) and is polyphagous. Plants where they were found are: *Diplazium caudatum*, *Pteridium aquilinum*, *Adiantum* spp., *Dryopteris affinis, Pteris incomplete*, *Cedronella canariensis*, *Rubus* spp., *Argyranthemum pinnatifidum*, *Clethra arborea* and *Hydrangea macrophile*.

Systems: Terrestrial

Use and Trade

The species is not utilised.

Threats

The primary threat to *Cixius madeirensis* is the ongoing loss of its natural habitat due to the conversion of Laurel forests into production forests, which leads to significant habitat fragmentation and degradation. This is further exacerbated by the rising tourism in the region, which not only increases human activity but also disrupts the integrity of the habitat, reducing both its quality and availability for the species. Additionally, fire control measures, which involve clearing vegetation to prevent wildfires, may interfere with the species' phenology and reproduction cycles, potentially limiting successful recruitment. Long-term, climate change poses an additional risk, as it could shift the species' suitable habitat to higher altitudes. While this shift may not immediately threaten the species, it could lead to changes in population dynamics over time, particularly if higher-altitude areas become unsuitable (because of the grazing of cows at higher altitudes).

Conservation Actions

The species is not currently protected by national or regional legislation, although its habitat lies within the regionally protected area of the Madeira Natural Park. Given the lack of detailed data on its population size and ecological requirements, further research is essential to better understand the species' population dynamics, its ecological role, and the specific impacts of existing threats on its survival.

To support conservation efforts, it is recommended that long-term monitoring be conducted, particularly in stable and peripheral populations, to track trends and detect early signs of decline. Additionally, adaptive management of its habitat should be implemented, taking into account both public needs and the species' phenological patterns, including fine-tuning vegetation clearance schedules to avoid disturbing adult populations during critical periods. Managing tourism to align with the ecosystem's carrying capacity and ensuring the preservation of high-quality habitat are also fundamental to the long-term conservation of the species.

Tables

Habitat	Season	Suitability	Major importance?

1. Forest -> 1.4. Forest – Temperate	Resident	Suitable	Yes
7. Caves & Subterranean Habitats (non-aquatic) -> 7.2. Caves and Subterranean Habitats (non-aquatic) – Other subterranean habitats (roots)	Resident	Suitable	Yes

Threat	**Timing**	**Scope**	**Severity**
1 Residential & commercial development -> 1.3 Tourism & recreation areas	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
2 Agriculture & aquaculture -> 2.2 Wood & pulp plantations -> 2.2.2 Agro-industry plantations or 2.2.3 Scale Unknown/Unrecorded	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.3 Livestock farming & ranching -> 2.3.2 Small-holder grazing, ranching or farming	In the past but now suspended and likely to return	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
5 Biological resource use -> 5.3 Logging & wood harvesting -> 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target)[harvest *Laurus*]	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
8 Invasive & other problematic species, genes & diseases -> 8.1 Invasive non-native/alien species/diseases -> 8.1.2 *Acacia dealbata, Eucalyptus globulus, Agapantus, Ulex europeus*	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
10 Geological events -> 10.3 Avalanches/landslides	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
11 Climate change & severe weather -> 11.1 Habitat shifting & alteration	Future	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		

Conservation Actions in Place
Monitoring & Planning

Action Recovery plan: No
Systematic monitoring scheme: No
Land/Water Protection and Management
Conservation sites identified: Yes, over part of range
Occur in at least one PA: Yes
Percentage of population protected by PAs (0-100): 70-90
Area based regional management plan: Yes
Invasive species control/prevention: Yes
Species Management
Harvest management plan: No
Successful reintroduced: No
Ex-situ conservation: No
Education & Legislation
Subject of any recent education/awareness programmes: No
Included in international legislation: No
Included in international management/trade controls: No

Conservation Actions Needed
2. Land/water management -> 2.1. Site/area management
2. Land/water management -> 2.2. Invasive/problematic species control
4. Education & awareness -> 4.1. Formal education
4. Education & awareness -> 4.2. Training
4. Education & awareness -> 4.3. Awareness & communications
5. Law & policy -> 5.1. Legislation -> 5.1.3. Sub-national level
5. Law & policy -> 5.4. Compliance and enforcement -> 5.4.3. Sub-national level

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology
1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
2. Conservation Planning -> 2.1. Species Action/Recovery Plan

2. Conservation Planning -> 2.2. Area-based Management Plan
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.4. Habitat trends

Additional Data Fields

Distribution
Estimated area of occupancy (AOO) (km^2): 40-388
Continuing decline in area of occupancy (AOO): Unknown
Extreme fluctuations in area of occupancy (AOO): Unknown
Estimated extent of occurrence (EOO) (km^2): 145-549
Continuing decline in extent of occurrence (EOO): Unknown
Extreme fluctuations in extent of occurrence (EOO): Unknown
Number of Locations: 2
Continuing decline in number of locations: Unknown
Extreme fluctuations in the number of locations: Unknown
Lower elevation limit (m): 426
Upper elevation limit (m): 1438
Population
Number of mature individuals: Unknown
Continuing decline of mature individuals: Unknown
Extreme fluctuations: Unknown
Population severely fragmented: Unknown
No. of individuals in largest subpopulation: Unknown
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): 1
Movement patterns: Not a Migrant
Congregatory: Congregatory (year-round)

The IUCN Red List of Threatened Species™

ISSN ___-___ (online)

IUCN 20__: __________________

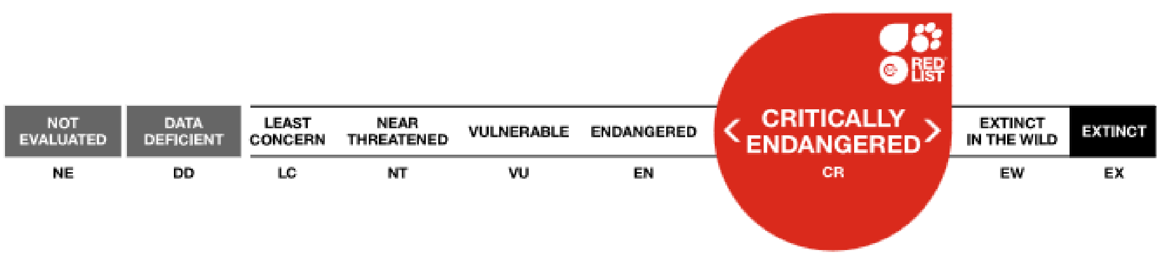
Scope: Global

Language: English

Cixius wollastoni

Preliminary version

Assessment by: Soraya, L.



View on www.iucnredlist.org

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Hemiptera	Cixiidae

Taxon Name: *Cixius wollastoni* Freitas & Aguín-Pombo, 2021

Synonym(s): ---

Common Name(s):

- English: Planthopper

Taxonomic Source(s):

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (*Hemiptera*, Fulgoromorpha) from the Madeira archipelago. *European Journal of Taxonomy, 744*, 1-37.

Taxonomic Notes: ---

Identification Information:

A medium-sized species (6.71 mm), primarily dark brown to black. The vertex has a large black spot medially with small yellowish side spots. The tegmina are hyaline with dark brown veins and sometimes brown stripes. The vertex is concave with an acute anterior margin. The male genitalia have a hooked ventral spine, asymmetrical lateral lobes, and a slightly curved right spinose process.

Assessment Information

Red List Category & Criteria: Critically Endangered B1ab(iii)

Date Assessed: November, 2024

Justification:

Cixius wollastoni is an endemic planthopper restricted to Madeira Island, Portugal, where it occurs in fragmented populations across laurel forests in both the north and south. It inhabits herbs and trees within these forests and has a highly limited distribution, with an Area of Occupancy (AOO) of 12 km² and an Extent of Occurrence (EOO) of 7 km². The species faces significant threats, primarily habitat loss due to the conversion of laurel forests into production forests. Increasing tourism further degrades habitat quality and availability, while vegetation clearance for fire prevention may disrupt its phenology, potentially reducing recruitment success. In the long term, climate change could push the species' suitable habitat to higher altitudes, though immediate impacts remain uncertain. For conservation, regular monitoring of stable populations is essential, along with adaptive habitat management that balances public use with the species' ecological needs. Restoring laurel forests in the south and controlling invasive plant species are key priorities. Additionally, regulating tourism to align with the ecosystem's carrying capacity and preserving high-quality habitat are crucial for the species' long-term survival.

Geographic Range

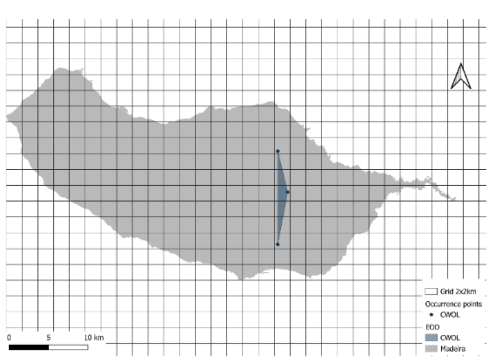
Range Description:

Cixius wollastoni is a planthopper endemic to Madeira Island, Portugal, found in scattered populations within laurel forests in both the north and south. Its distribution is extremely restricted, with an Area of Occupancy (AOO) of just 12 km² and an Extent of Occurrence (EOO) of 7 km².

Country Occurrence:

Native Extant (resident): Portugal (Madeira)

Distribution Map



Population

The species occurs in fragmented populations, confined to laurel forests in the north and south of Madeira Island. Historical records are limited, making it difficult to assess population trends. According to records from the Insect Collection of Madeira Island (UMACI), adults are active from mid-April to late August.

Current Population Trend: Unknown

Habitat and Ecology

The species inhabits the laurel forest, where it is found on both herbs and trees, displaying a polyphagous feeding behavior. Those plants are *Digitalis pupurea*, *Pteridium aquilinum* and *Clethra arborea*.
Systems: Terrestrial

Use and Trade

The species is not utilised.

Threats

The primary threat to *Cixius wollastoni* is the ongoing loss and degradation of its natural habitat, primarily due to the conversion of laurel forests into production forests, leading to severe fragmentation. This impact is especially critical in the south of the island, where only small patches of laurel forest remain. Invasive plants, widespread across the island but particularly dominant in the degraded southern habitats, may further intensify these pressures. Due to the high level of degradation, southern populations may also be more vulnerable to frequent wildfires, which occur more often in this region. Rising tourism exacerbates habitat disturbance, increasing human activity and further reducing habitat quality and availability. Additionally, fire control measures involving vegetation clearance may disrupt the species' phenology and reproduction cycles, potentially limiting recruitment. In the long term, climate change poses an additional risk by shifting suitable habitat to higher altitudes, though this transition may not pose an immediate threat.

Conservation Actions

The species currently lacks national or regional legal protection, and only half of its habitat falls within the Madeira Natural Park's protected area. Due to limited data on its population size and ecological requirements, further research is crucial to better understand its dynamics, ecological role, and the impact of ongoing threats.

For effective conservation, long-term monitoring is recommended, especially in stable and peripheral populations, to detect trends and identify early signs of decline. Habitat management should be adapted to balance public needs with the species' phenology, ensuring that vegetation clearance schedules do not disrupt adult populations during critical periods. Regulating tourism in accordance with the ecosystem's capacity and maintaining high-quality habitat are also vital for the species' long-term survival. Additionally, the removal of invasive plants is of utmost importance.

Tables

Habitat	**Season**	**Suitability**	**Major importance?**
1. Forest -> 1.4. Forest – Temperate	Resident	Suitable	Yes
7. Caves & Subterranean Habitats (non-aquatic) -> 7.2. Caves and Subterranean Habitats (non-aquatic) – Other subterranean habitats (roots)	Resident	Suitable	Yes

Threat	**Timing**	**Scope**	**Severity**
1 Residential & commercial development -> 1.3 Tourism & recreation areas	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
2 Agriculture & aquaculture -> 2.2 Wood & pulp plantations -> 2.2.2 Agro-industry plantations or 2.2.3 Scale Unknown/Unrecorded	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		

2 Agriculture & aquaculture -> 2.3 Livestock farming & ranching -> 2.3.2 Small-holder grazing, ranching or farming	In the past but now suspended and likely to return	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
5 Biological resource use -> 5.3 Logging & wood harvesting -> 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target)[harvest *Laurus*]	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
7 Natural system modifications -> 7.1 Fire & fire suppression -> 7.1.1 Increase in fire frequency/intensity	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
8 Invasive & other problematic species, genes & diseases -> 8.1 Invasive non-native/alien species/diseases -> 8.1.2 *Acacia dealbata, Eucalyptus globulus, Agapantus, Hydrangea macrophylla*	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
10 Geological events -> 10.3 Avalanches/landslides	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
11 Climate change & severe weather -> 11.1 Habitat shifting & alteration	Future	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		

Conservation Actions in Place
Monitoring & Planning
Action Recovery plan: No
Systematic monitoring scheme: No
Land/Water Protection and Management
Conservation sites identified: Yes, over part of range
Occur in at least one PA: Yes
Percentage of population protected by PAs (0-100): 50
Area based regional management plan: Yes
Invasive species control/prevention: Yes

Species Management
Harvest management plan: No
Successful reintroduced: No
Ex-situ conservation: No
Education & Legislation
Subject of any recent education/awareness programmes: No
Included in international legislation: No
Included in international management/trade controls: No

Conservation Actions Needed
2. Land/water management -> 2.1. Site/area management
2. Land/water management -> 2.2. Invasive/problematic species control
4. Education & awareness -> 4.1. Formal education
4. Education & awareness -> 4.2. Training
4. Education & awareness -> 4.3. Awareness & communications
5. Law & policy -> 5.1. Legislation -> 5.1.3. Sub-national level
5. Law & policy -> 5.4. Compliance and enforcement -> 5.4.3. Sub-national level

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology
1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
2. Conservation Planning -> 2.1. Species Action/Recovery Plan
2. Conservation Planning -> 2.2. Area-based Management Plan
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.4. Habitat trends

Additional Data Fields

Distribution
Estimated area of occupancy (AOO) (km^2): 12
Continuing decline in area of occupancy (AOO): Unknown
Extreme fluctuations in area of occupancy (AOO): Unknown
Estimated extent of occurrence (EOO) (km^2): 7
Continuing decline in extent of occurrence (EOO): Unknown

Extreme fluctuations in extent of occurrence (EOO): Unknown
Number of Locations: 2
Continuing decline in number of locations: Unknown
Extreme fluctuations in the number of locations: Unknown
Lower elevation limit (m): 371
Upper elevation limit (m): 871
Population
Number of mature individuals: Unknown
Continuing decline of mature individuals: Unknown
Extreme fluctuations: Unknown
Population severely fragmented: Yes
No. of individuals in largest subpopulation: Unknown
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): 1
Movement patterns: Not a Migrant
Congregatory: Congregatory (year-round)

The IUCN Red List of Threatened Species™
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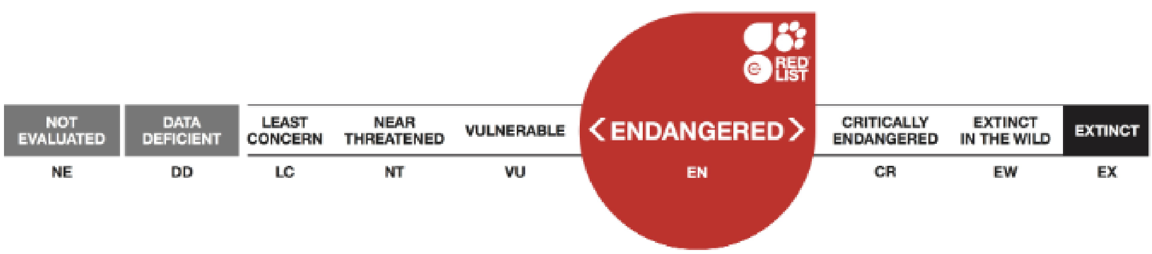
Scope: Global
Language: English

Hyalesthes madeires

Preliminary version

Assessment by: Soraya, L.



View on www.iucnredlist.org

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Hemiptera	Cixiidae

Taxon Name: *Hyalesthes madeires* Remane & Hoch, 1986

Synonym(s): *Hyalesthes angustulus* Horváth, 1909; *Hyalesthes flavipennis* Horvath, 1909

Common Name(s):

- English: Planthopper
- Portuguese: Cigarrinha de renda do Norte

Taxonomic Source(s):

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (*Hemiptera*, Fulgoromorpha) from the Madeira archipelago. *European Journal of Taxonomy, 744*, 1-37.

Remane R. & Hoch H. 1986. Sechs neue Arten der Gattung *Hyalesthes* Signoret, 1865 (Homoptera Fulgoroidea Cixiidae) von den Mittelatlantischen Inseln und aus dem Irak. Marburger Entomologische Publikationen 2 (3): 123–151.

Taxonomic Notes: misidentified by Lindberg (1941) as *H. angustulus* and by the same author (1961) as *H. flavipennis*

Identification Information:

A small-sized species (3.43 mm) with a shorter vertex and lateral margins that usually converge anteriorly. The tegmina extend beyond the abdomen, with sporadic bristles along the veins. The dorsal thorn of the aedeagus is wider and longer than the ventral thorn, with both thorns converging distally.

Assessment Information

Red List Category & Criteria: Endangered B1ab(iii)+2ab(iii)

Date Assessed: November, 2024

Justification:

Hyalesthes madeires is an endemic planthopper found along the north and central coast of Madeira Island, Portugal, in highly fragmented populations. Its Area of Occupancy (AOO) ranges from 48 to 348 km², while its Extent of Occurrence (EOO) spans 210 to 463 km². The species faces many threats, including habitat loss due to urban expansion, road construction, conversion of its host plant (*Globularia salicina*) habitat into production forests and agricultural land, increasing wildfires, and the spread of invasive plants. To aid conservation, regular monitoring of stable populations is essential, along with adaptive habitat management that balances public and ecological needs. Controlling invasive species is also crucial for its preservation.

Geographic Range

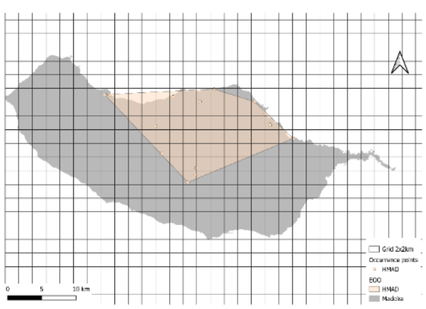
Range Description:

Hyalesthes madeires is an endemic planthopper inhabiting the highly fragmented coastal areas of northern and central Madeira Island, Portugal. Its Area of Occupancy (AOO) ranges from 48 to 348 km², with an Extent of Occurrence (EOO) between 210 and 463 km².

Country Occurrence:

Native Extant (resident): Portugal (Madeira)

Distribution Map



Population

The species exists as a single fragmented population, with historical records insufficient to determine its trends. According to records from the Insect Collection of Madeira Island (UMACI), adults are active from late May to early July.

Current Population Trend: Unknown

Habitat and Ecology

The species inhabits rocky habitats with *Globularia salicina*, including coastal cliffs and inner rocky slopes near rivers and valleys. Some individuals have been recorded in low-altitude laurel forests. The species is mainly found in northern and central Madeira Island.

Systems: Terrestrial

Use and Trade

The species is not utilised.

Threats

The primary threat to *Hyalesthes madeires* is the ongoing loss and fragmentation of its habitat. The conversion of laurel forests into production forests and agricultural zones, along with the spread of invasive species, has significantly degraded its environment. In the north, urban expansion and road construction further reduce the natural habitat of its host plant, *Globularia salicina*. Increasing wildfire frequency destroys critical habitat, while climate change poses long-term risks by altering the host plant's phenology and intensifying regional droughts. Additionally, natural events such as storms and avalanches can devastate large habitat areas near slopes and cliffs, further increasing fragmentation.

Conservation Actions

The species is not currently protected by national or regional legislation, and much of its habitat falls outside regionally protected areas. Due to the lack of detailed data on its population size and ecological needs, further research is crucial to understand its population dynamics, ecological role, and the impact of existing threats.

For conservation, long-term monitoring—especially in stable and peripheral populations—is recommended to track trends and detect early signs of decline. Adaptive habitat management should also be implemented, balancing public needs with the species' life cycle, and including measures such as invasive plant removal and regular habitat patrols.

Tables

Habitat	**Season**	**Suitability**	**Major importance?**
1. Forest -> 1.6. Forest – Subtropical/tropical moist lowland	Resident	Suitable	Yes
3. Shrubland -> 3.5. Shrubland – Subtropical/tropical dry	Resident	Suitable	Yes
6. Rocky Areas (e.g., inland cliffs, mountain peaks)	Resident	Suitable	Yes
7. Caves & Subterranean Habitats (non-aquatic) -> 7.2. Caves and Subterranean Habitats (non-aquatic) – Other subterranean habitats (roots)	Resident	Suitable	Yes

Threat	**Timing**	**Scope**	**Severity**
1 Residential & commercial development -> 1.1 Housing & urban areas, 1.2 Commercial & industrial areas, 1.3 Tourism & recreation areas	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
2 Agriculture & aquaculture -> 2.1 Annual & perennial non-timber crops -> 2.1.2 Small-holder farming, 2.1.3 Agro-industry farming	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.2 Wood & pulp plantations -> 2.2.2 Agro-industry plantations or 2.2.3 Scale Unknown/Unrecorded	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.3 Livestock farming & ranching -> 2.3.2 Small-holder grazing, ranching or farming	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		

4 Transportation & service corridors -> 4.1 Roads & railroads	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion and 1.2. Ecosystem degradation		
7 Natural system modifications -> 7.1 Fire & fire suppression -> 7.1.1 Increase in fire frequency/intensity	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
8 Invasive & other problematic species, genes & diseases -> 8.1 Invasive non-native/alien species/diseases -> 8.1.2 *Acacia dealbata, Eucalyptus globulus, Ageratina adenophora, Achyranthes aspera, Bidens pilosa, Arundo donax, Vitis vinifera, Agapanthus, Kalanchoe, Opuntia tuna, Solanum mauritianum, Tropaeolum majus, Pitosporum undulatum, Musa, Citisus scoparius, Castanea sativa, Pinus pinaster*, *Hydrangea macrophylla*	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
10 Geological events -> 10.3 Avalanches/landslides	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
11 Climate change & severe weather -> 11.1 Habitat shifting & alteration	Future	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
11 Climate change & severe weather -> 11.2 Droughts	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
11 Climate change & severe weather -> 11.4 Storms & flooding	In the past but now suspended and likely to return	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		

Conservation Actions in Place
Monitoring & Planning
Action Recovery plan: No
Systematic monitoring scheme: No
Land/Water Protection and Management

Conservation sites identified: Yes, over part of range
Occur in at least one PA: Yes
Percentage of population protected by PAs (0-100): 31
Area based regional management plan: Yes
Invasive species control/prevention: Yes
Species Management
Harvest management plan: No
Successful reintroduced: No
Ex-situ conservation: No
Education & Legislation
Subject of any recent education/awareness programmes: No
Included in international legislation: No
Included in international management/trade controls: No

Conservation Actions Needed
2. Land/water management -> 2.1. Site/area management
2. Land/water management -> 2.2. Invasive/problematic species control
4. Education & awareness -> 4.1. Formal education
4. Education & awareness -> 4.2. Training
4. Education & awareness -> 4.3. Awareness & communications
5. Law & policy -> 5.1. Legislation -> 5.1.3. Sub-national level
5. Law & policy -> 5.4. Compliance and enforcement -> 5.4.3. Sub-national level

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology
1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
2. Conservation Planning -> 2.1. Species Action/Recovery Plan
2. Conservation Planning -> 2.2. Area-based Management Plan
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.4. Habitat trends

Additional Data Fields

Distribution
Estimated area of occupancy (AOO) (km^2): 48-348
Continuing decline in area of occupancy (AOO): Unknown

Extreme fluctuations in area of occupancy (AOO): Unknown
Estimated extent of occurrence (EOO) (km^2): 210-463
Continuing decline in extent of occurrence (EOO): Unknown
Extreme fluctuations in extent of occurrence (EOO): Unknown
Number of Locations: 1
Continuing decline in number of locations: Unknown
Extreme fluctuations in the number of locations: Unknown
Lower elevation limit (m): 61
Upper elevation limit (m): 591
Population
Number of mature individuals: Unknown
Continuing decline of mature individuals: Unknown
Extreme fluctuations: Unknown
Population severely fragmented: Yes
No. of individuals in largest subpopulation: Unknown
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): 1
Movement patterns: Not a Migrant
Congregatory: Congregatory (year-round)

The IUCN Red List of Threatened Species™

ISSN ___-___ (online)

IUCN 20__: ___________________

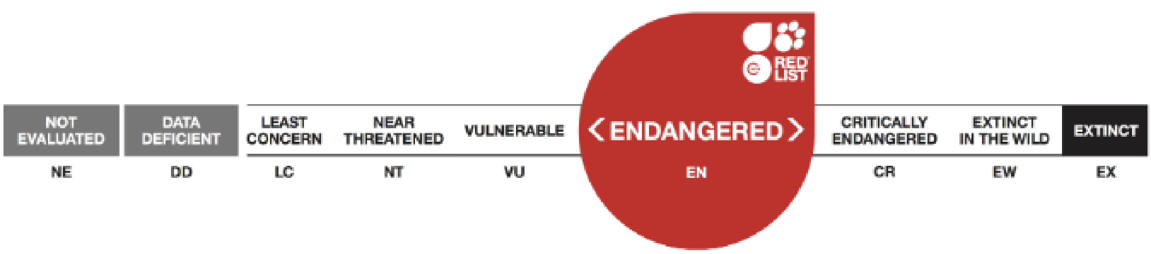
Scope: Global

Language: English

Hyalesthes portonoves

Preliminary version

Assessment by: Soraya, L.



View on www.iucnredlist.org

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Hemiptera	Cixiidae

Taxon Name: *Hyalesthes portonoves* Remane & Hoch, 1986

Synonym(s): ---

Common Name(s):

- English: Planthopper
- Portuguese: Cigarrinha de renda do sul

Taxonomic Source(s):

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (*Hemiptera*, Fulgoromorpha) from the Madeira archipelago. *European Journal of Taxonomy, 744*, 1-37.

Remane R. & Hoch H. 1986. Sechs neue Arten der Gattung *Hyalesthes* Signoret, 1865 (Homoptera Fulgoroidea Cixiidae) von den Mittelatlantischen Inseln und aus dem Irak. Marburger Entomologische Publikationen 2 (3): 123–151.

Taxonomic Notes: ---

Identification Information:

A small planthopper species (3.45 mm) with a long vertex and parallel lateral margins. The tegmina are hyaline with yellow ochre veins, and the legs are faded brown. The dorsal thorn of the aedeagus is slender and shorter than the ventral thorn, with both thorns distally parallel or divergent.

Assessment Information

Red List Category & Criteria: Endangered B1ab(iii)+2ab(iii)

Date Assessed: November, 2024

Justification:

Hyalesthes portonoves is an endemic planthopper primarily found in the south of Madeira Island, Portugal, with a few records from the central region. It occurs in highly fragmented populations, with an Area of Occupancy (AOO) between 64 and 348 km² and an Extent of Occurrence (EOO) ranging from 417 to 463 km².

The species faces multiple threats, including habitat loss due to urban expansion, road construction, and the transformation of its host plant's (Globularia salicina) habitat into production forests and agricultural land. Increasing wildfires and the spread of invasive plants further contribute to habitat degradation. Conservation efforts should focus on regular monitoring of stable populations, adaptive habitat management that considers both ecological and public needs, and effective control of invasive species.

Geographic Range

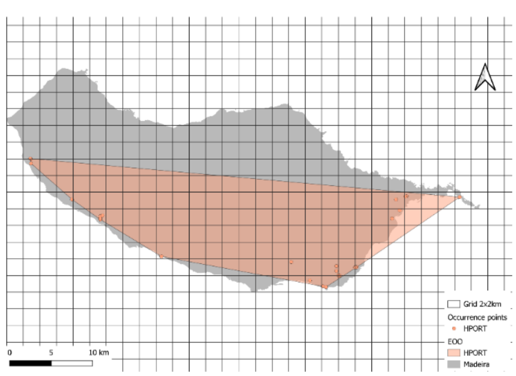
Range Description:

Hyalesthes portonoves is an endemic planthopper mainly distributed in the south of Madeira Island, Portugal, with occasional records from the central region. It inhabits highly fragmented populations, with an Area of Occupancy (AOO) of 64–348 km² and an Extent of Occurrence (EOO) of 417–463 km².

Country Occurrence:

Native Extant (resident): Portugal (Madeira)

Distribution Map



Population

The species persists as a single, fragmented population, with historical records lacking sufficient data to assess its trends. According to records in the Insect Collection of Madeira Island (UMACI), adults are observed from late March to late August.

Current Population Trend: Unknown

Habitat and Ecology

Hyalesthes portonoves is primarily restricted to southern coastal habitats of Madeira Island, favoring soil substrates over rocky ones. It is always associated with its host plant, *Globularia salicina*, though habitat quality varies from well-preserved to degraded areas impacted by urbanization, agriculture, and invasive plants. Population densities appear higher at inland sites, possibly due to reduced human pressures, despite the species' primary coastal distribution.

Systems: Terrestrial

Use and Trade

The species is not utilised.

Threats

The main threat to *Hyalesthes portonoves* is habitat loss and fragmentation. The conversion of laurel forests into production forests and agricultural land, combined with the spread of invasive species, has led to significant environmental degradation. In the south, urban expansion and road construction further reduce the availability of its host plant, *Globularia salicina*. Increasing wildfire frequency destroys critical habitat, while climate change may alter the host plant's phenology and intensify regional droughts. Additionally, natural events like storms and avalanches can severely damage habitat near slopes and cliffs, exacerbating fragmentation.

Conservation Actions

The species is not protected under national or regional legislation, and much of its habitat lies outside protected areas. Limited data on its population size and ecological requirements make further research essential to understanding its dynamics, ecological role, and the full impact of threats. To support conservation, long-term monitoring—particularly in stable and peripheral populations—is necessary to track trends and detect early signs of decline. Adaptive habitat management should also be implemented, ensuring a balance between public land use and the species' ecological needs. Key measures include controlling invasive plants and conducting regular habitat assessments.

Tables

Habitat	**Season**	**Suitability**	**Major importance?**
3. Shrubland -> 3.8. Shrubland – Mediterranean-type shrubby vegetation	Resident	Suitable	Yes
6. Rocky Areas (e.g., inland cliffs, mountain peaks)	Resident	Suitable	Yes
7. Caves & Subterranean Habitats (non-aquatic) -> 7.2. Caves and Subterranean Habitats (non-aquatic) – Other subterranean habitats (roots)	Resident	Suitable	Yes

Threat	Timing	Scope	Severity
1 Residential & commercial development -> 1.1 Housing & urban areas, 1.2 Commercial & industrial areas, 1.3 Tourism & recreation areas	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
2 Agriculture & aquaculture -> 2.1 Annual & perennial non-timber crops -> 2.1.2 Small-holder farming, 2.1.3 Agro-industry farming	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.2 Wood & pulp plantations -> 2.2.2 Agro-industry plantations or 2.2.3 Scale Unknown/Unrecorded	Ongoing	Minority (50%)	Unknown

	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.3 Livestock farming & ranching -> 2.3.2 Small-holder grazing, ranching or farming	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
4 Transportation & service corridors -> 4.1 Roads & railroads	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion and 1.2. Ecosystem degradation		
7 Natural system modifications -> 7.1 Fire & fire suppression -> 7.1.1 Increase in fire frequency/intensity	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
8 Invasive & other problematic species, genes & diseases -> 8.1 Invasive non-native/alien species/diseases -> 8.1.2 *Acacia dealbata, Eucalyptus globulus, Ageratina adenophora, Achyranthes aspera, Bidens pilosa, Arundo donax, Vitis vinifera, Agapanthus, Kalanchoe, Opuntia tuna, Solanum mauritianum, Tropaeolum majus, Pitosporum undulatum, Musa, Citisus scoparius, Castanea sativa, Pinus pinaster*, *Hydrangea macrophylla*	Ongoing	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
10 Geological events -> 10.3 Avalanches/landslides	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
11 Climate change & severe weather -> 11.1 Habitat shifting & alteration	Future	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
11 Climate change & severe weather -> 11.2 Droughts	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
11 Climate change & severe weather -> 11.4 Storms & flooding	In the past but now suspended and likely to return	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		

Conservation Actions in Place
Monitoring & Planning
Action Recovery plan: No
Systematic monitoring scheme: No
Land/Water Protection and Management
Conservation sites identified: Yes, over part of range
Occur in at least one PA: Yes
Percentage of population protected by PAs (0-100): 19
Area based regional management plan: Yes
Invasive species control/prevention: Yes
Species Management
Harvest management plan: No
Successful reintroduced: No
Ex-situ conservation: No
Education & Legislation
Subject of any recent education/awareness programmes: No
Included in international legislation: No
Included in international management/trade controls: No

Conservation Actions Needed
1. Land/water protection -> 1.1. Site/area protection
1. Land/water protection -> 1.2. Resource & habitat protection
2. Land/water management -> 2.1. Site/area management
2. Land/water management -> 2.2. Invasive/problematic species control
2. Land/water management -> 2.3. Habitat & natural process restoration
4. Education & awareness -> 4.1. Formal education
4. Education & awareness -> 4.2. Training
4. Education & awareness -> 4.3. Awareness & communications
5. Law & policy -> 5.1. Legislation -> 5.1.3. Sub-national level
5. Law & policy -> 5.4. Compliance and enforcement -> 5.4.3. Sub-national level

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology

1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
2. Conservation Planning -> 2.1. Species Action/Recovery Plan
2. Conservation Planning -> 2.2. Area-based Management Plan
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.4. Habitat trends

Additional Data Fields

Distribution
Estimated area of occupancy (AOO) (km^2): 64-348
Continuing decline in area of occupancy (AOO): Unknown
Extreme fluctuations in area of occupancy (AOO): Unknown
Estimated extent of occurrence (EOO) (km^2): 417-463
Continuing decline in extent of occurrence (EOO): Unknown
Extreme fluctuations in extent of occurrence (EOO): Unknown
Number of Locations: 1
Continuing decline in number of locations: Unknown
Extreme fluctuations in the number of locations: Unknown
Lower elevation limit (m): 48
Upper elevation limit (m): 574
Population
Number of mature individuals: Unknown
Continuing decline of mature individuals: Unknown
Extreme fluctuations: Unknown
Population severely fragmented: Yes
No. of individuals in largest subpopulation: Unknown
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): 1
Movement patterns: Not a Migrant
Congregatory: Congregatory (year-round)

The IUCN Red List of Threatened Species™

ISSN ___-___ (online)

IUCN 20__: __________________

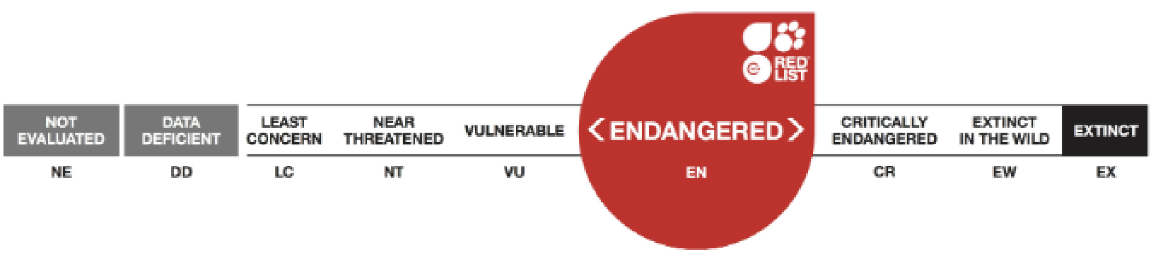
Scope: Global

Language: English

Tachycixius chaoensis

Preliminary version

Assessment by: Soraya, L.



View on www.iucnredlist.org

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Hemiptera	Cixiidae

Taxon Name: *Tachycixius chaoensis* (China, 1938)

Synonym(s): *Cixius chaoensis* China, 1938

Common Name(s):

- English: Planthopper
- Portuguese: Cigarrinha rendada das Desertas

Taxonomic Source(s):

China W. E. 1938 - Die Arthropodenfauna von Madeira nach den Ergebnissender Reise von Prof. Dr. O. Lundblad Juli-August 1935. III. Terrestrial Hemiptera (Hemiptera and Homoptera Auchenorrhyncha). Arkiv for Zoologi. Utgifvet af K. Svenska Vetenskaps-akademien. Stockholm 30(2): 1-68 [51].

Freitas, É., & Aguín-Pombo, D. (2021). Taxonomy of the Cixiidae (*Hemiptera*, Fulgoromorpha) from the Madeira archipelago. *European Journal of Taxonomy, 744*, 1-37.

Taxonomic Notes: ----

Identification Information:

The small planthopper (4.05 mm) is light brown in males and darker in females. The vertex has two pale spots, and the tegmina are translucent with a possible faint stripe. The aedeagus has a hump-shaped velum, a bifurcated apex with a straight dorsal spine, and a sharply left-bent scythe-like ventral expansion. Two small curved spines are at the base. On female genitalia, the seventh sternite has a concave caudal margin, and the IX tergite has a deeply excavated channel. It differs from related species by the unique shape of the aedeagus and velum.

Assessment Information

Red List Category & Criteria: Endangered B1ab(iii)+2ab(iii)

Date Assessed: November, 2024

Justification:

Tachycixius chaoensis is an endemic planthopper confined to Ponta de São Lourenço, the easternmost peninsula of Madeira Island (Portugal), including its adjacent islet (Ilhéu da Cevada) and Ilhéu Chão in the Desertas Islands. It inhabits xerophytic habitats associated with its host plant, Suaeda vera. The species has a restricted distribution, with an Area of Occupancy (AOO) between 16 and 56 km² and an Extent of Occurrence (EOO) ranging from 23 to 179 km². The main threat to this species is the increasing tourism pressure in Ponta de São Lourenço, along with stochastic events affecting coastal areas. Additionally, while climate change could eventually push its suitable habitat to higher altitudes, this is unlikely to pose an immediate risk. To aid conservation, regular monitoring of stable populations is recommended, along with adaptive habitat management to mitigate tourism impact.

Geographic Range

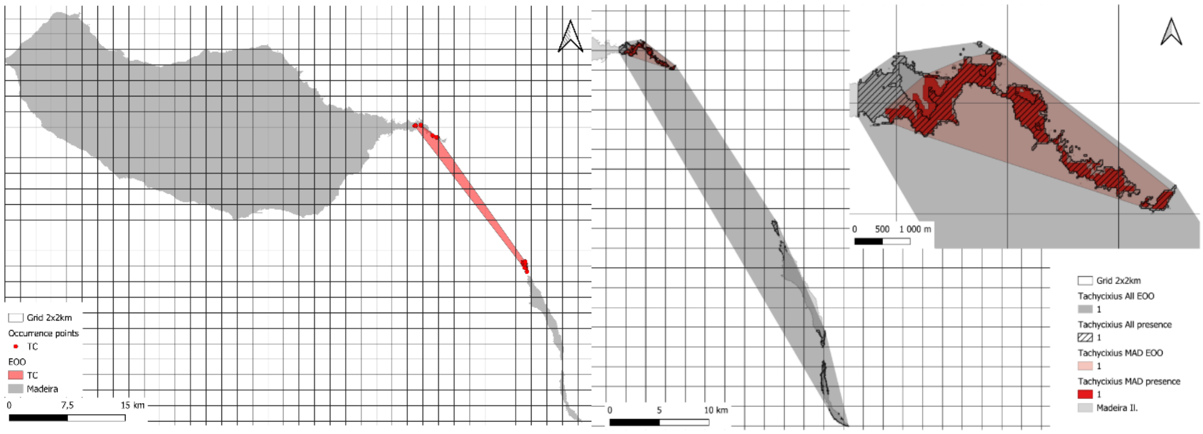
Range Description:

Tachycixius chaoensis is found in four distinct locations: two within Ponta de São Lourenço, one on the nearby islet Ilhéu da Cevada, and another on Ilhéu Chão in the Desertas Islands.

Country Occurrence:

Native Extant (resident): Portugal (Madeira)

Distribution Map



Population

The species occurs in four locations. Due to limited historical records, population trends remain uncertain. However, the largest population is found on Ilhéu Chão, while the other three have only a few recorded individuals. According to records from the Insect Collection of Madeira Island (UMACI), adults exhibit two distinct activity periods: the first from early April to June and the second from late September to early December.

Current Population Trend: Unknown

Habitat and Ecology

The species inhabits xerophytic coastal habitats closely associated with its host plant, *Suaeda vera*.

Systems: Terrestrial

Use and Trade

The species is not utilised.

Threats

The primary threat to *Tachycixius chaoensis* is the impact of tourism, particularly in Ponta de São Lourenço, where trampling damages its host plant, *Suaeda vera*, and degrades its habitat. Additionally, livestock grazing, particularly by goats in the Desertas Islands, further reduces the availability of its host plant. The species is also vulnerable to stochastic events such as landslides, which can lead to sudden habitat loss. Climate change poses a long-term risk, potentially shifting suitable habitat to conditions the species cannot adapt to, while prolonged droughts may negatively affect *Suaeda vera*. Although invasive plants like *Cenchrus ciliaris* are present, they currently pose a minor threat. Historically, agriculture in Ponta de São Lourenço and the Desertas Islands may have influenced the species' current distribution, further restricting its range.

Conservation Actions

The species is not currently protected by national or regional legislation; however, its habitat falls within the regionally protected areas of Madeira Natural Park and the nature reserves of Ponta de São Lourenço and the Desertas Islands. Due to the limited knowledge of its population size and ecological requirements, further research is necessary to understand its population dynamics, ecological role, and the extent of existing threats. For effective conservation, long-term monitoring is recommended, especially in stable and peripheral populations, to track trends and detect early signs of decline. Adaptive habitat management should be implemented, including increased awareness efforts to educate tourists on the impact of their activities. Additionally, aligning tourism with the ecosystem’s carrying capacity and ensuring the protection of high-quality habitat are essential for the species’ long-term survival.

Tables

Habitat	**Season**	**Suitability**	**Major importance?**
6. Rocky Areas (Sea Cliffs and Rocky Offshore Islands)	Resident	Suitable	Yes
7. Caves & Subterranean Habitats (non-aquatic) -> 7.2. Caves and Subterranean Habitats (non-aquatic) – Other subterranean habitats (roots)	Resident	Suitable	Yes

Threat	**Timing**	**Scope**	**Severity**

1 Residential & commercial development -> 1.3 Tourism & recreation areas	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
2 Agriculture & aquaculture -> 2.1 Annual & perennial non-timber crops -> 2.1.2 Small-holder farming, 2.1.3 Agro-industry farming	Only in the past and unlikely to return	Majority (50-90%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
2 Agriculture & aquaculture -> 2.3 Livestock farming & ranching -> 2.3.2 Small-holder grazing, ranching or farming	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1. Ecosystem conversion		
8 Invasive & other problematic species, genes & diseases -> 8.1 Invasive non-native/alien species/diseases -> 8.1.2 *Cenchrus ciliaris*	Ongoing	Minority (50%)	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
10 Geological events -> 10.3 Avalanches/landslides	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
11 Climate change & severe weather -> 11.1 Habitat shifting & alteration	Future	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		
11 Climate change & severe weather -> 11.2 Droughts	Ongoing	Unknown	Unknown
	Stresses: 1. Ecosystem stresses -> 1.1 Ecosystem conversion		

Conservation Actions in Place
Monitoring & Planning
Action Recovery plan: No
Systematic monitoring scheme: No
Land/Water Protection and Management
Conservation sites identified: Yes, over part of range
Occur in at least one PA: Yes
Percentage of population protected by PAs (0-100): 100
Area based regional management plan: Yes
Invasive species control/prevention: Yes
Species Management
Harvest management plan: No

Successful reintroduced: No
Ex-situ conservation: No
Education & Legislation
Subject of any recent education/awareness programmes: No
Included in international legislation: No
Included in international management/trade controls: No

Conservation Actions Needed
2. Land/water management -> 2.1. Site/area management
4. Education & awareness -> 4.1. Formal education
4. Education & awareness -> 4.2. Training
4. Education & awareness -> 4.3. Awareness & communications
5. Law & policy -> 5.1. Legislation -> 5.1.3. Sub-national level

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology
1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
2. Conservation Planning -> 2.1. Species Action/Recovery Plan
2. Conservation Planning -> 2.2. Area-based Management Plan
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.4. Habitat trends
4. Research -> Philogenetics

Additional Data Fields

Distribution
Estimated area of occupancy (AOO) (km^2): 16-56
Continuing decline in area of occupancy (AOO): Unknown
Extreme fluctuations in area of occupancy (AOO): Unknown
Estimated extent of occurrence (EOO) (km^2): 23-179
Continuing decline in extent of occurrence (EOO): Unknown
Extreme fluctuations in extent of occurrence (EOO): Unknown
Number of Locations: 4
Continuing decline in number of locations: Unknown
Extreme fluctuations in the number of locations: Unknown
Lower elevation limit (m): 13
Upper elevation limit (m): 92

Population
Number of mature individuals: Unknown
Continuing decline of mature individuals: Unknown
Extreme fluctuations: Unknown
Population severely fragmented: Unknown
No. of individuals in largest subpopulation: Unknown
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): half an year
Movement patterns: Not a Migrant
Congregatory: Congregatory (year-round)