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Contributions to the distribution, biology, and conservation of *Euchloe bazae* Fabiano, 1993 (Lepidoptera: Pieridae): discovery of a new population and new host plant in the province of Granada (Andalusia, Spain)

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Abstract: *Euchloe bazae* Fabiano, 1993 (Lepidoptera: Pieridae) is an endemic butterfly of the Iberian Peninsula with a highly restricted and disjunct distribution, classified as "Endangered" in the Spanish Catalogue of Threatened Species (CEEA). A comprehensive understanding of its distribution, biology, and ecology is crucial for conservation efforts. Records obtained from 2021 to 2024 have expanded the known range of the species, adding four new 10x10 km UTM squares. Additionally, its distribution has increased by 143%, from 58 to 141 1x1 km UTM squares. In 2024, the presence of *E. bazae* was confirmed in 54 1x1 km UTM squares in the province of Granada, with a total count of 198 adults, recording its presence for the first time in the municipalities of Castilléjar and Orce. In Orce, a previously unknown population was discovered, associated with the paleoendemic plant *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. This population displays unique ecological characteristics, and genetic analyses revealed that it shares a mitochondrial haplotype with the Hoya de Baza population, while also presenting a unique haplotype, indicating high genetic diversity despite its restricted range. The use of two species of the genus *Vella* L. (*Vella aspera* Pers. in Aragón y *V. pseudocytisus* L. in Granada) suggests an ancestral relationship between the butterfly and the plant. This study provides updated information on the species' distribution, phenology, biology, and conservation, with four management units identified: "iberae-Zaragoza", "iberae-Huesca", "bazae-Hoya de Baza", and "bazae-Orce". According to the IUCN criteria, the study reaffirms the "Endangered" status of *E. bazae* due to significant threats such as habitat fragmentation, intensive agriculture, extensive livestock farming, pine plantations, and energy infrastructure development. These threats highlight the urgency for conservation strategies.
Key words: Lepidoptera, Pieridae, *Euchloe bazae*, *Vella pseudocytisus*, distribution, biology, conservation, new population, Spain, Andalucía, Aragón.

Resumen: Contribuciones a la distribución, biología y conservación de *Euchloe bazae* Fabiano, 1993 (Lepidoptera: Pieridae): descubrimiento de una nueva población y de una nueva planta nutricia en la provincia de Granada (Andalucía, España). *Euchloe bazae* Fabiano, 1993 (Lepidoptera: Pieridae) es un endemismo ibérico catalogado como "En Peligro de Extinción" en el Catálogo Español de Especies Amenazadas (CEEA). Su área de distribución es extremadamente reducida y fragmentada, lo que subraya la necesidad de profundizar en la mejora de su conocimiento. Entre 2021 y 2024 se amplió significativamente su rango conocido, con la detección de su presencia en cuatro nuevas cuadrículas UTM de 10x10 km de lado. Su distribución pasó de 58 a 141 cuadrículas de 1x1 km, lo que representa un incremento del 143%. Durante 2024, en Granada se contabilizaron 198 ejemplares adultos en 54 cuadrículas de 1x1 km, incluyendo los primeros registros en los municipios de Castilléjar y Orce. En esta última localidad se halló una población asociada al paleoendemismo *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Esta población presenta características ecológicas singulares y el análisis genético reveló que comparte un haplotipo mitocondrial con la de la

Hoya de Baza, pero también exhibe un haplotipo exclusivo, reflejando una alta diversidad genética en un entorno de extensión muy limitada. La utilización de dos especies del género *Vella* L. (*Vella aspera* Pers. en Aragón y *V. pseudocytisus* L. en Granada) refuerza la hipótesis de una relación ancestral entre ambos organismos. Se actualiza la información conocida sobre su distribución, fenología, biología y conservación. Se identifican cuatro unidades de gestión diferenciadas: "iberae-Zaragoza", "iberae-Huesca", "bazae-Hoya de Baza" y "bazae-Orce". Según los criterios de la UICN, se confirma su catalogación como "En peligro", debido a amenazas como la fragmentación del hábitat, la agricultura intensiva, la ganadería extensiva, las plantaciones de pinos y las infraestructuras energéticas. Estas amenazas subrayan la urgencia de implementar medidas encaminadas a su conservación.

Palabras clave: Lepidoptera, Pieridae, *Euchloe bazae*, *Vella pseudocytisus*, distribución, biología, conservación, nueva población, España, Andalucía, Aragón.

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Introduction

Euchloe bazae Fabiano 1993 (Lepidoptera: Pieridae), the Spanish Greenish Black-tip, is a butterfly species characterised by its extremely restricted and fragmented distribution (Fig. 1), making it one of the most threatened species of the Papilionoidea group within Europe. Endemic to the Iberian Peninsula, it is the only member of the Pieridae family with this status. Historically, the first findings of *E. bazae* were attributed to the North African taxon *Euchloe (=Elphinstonia) charlonia* (Donzel, 1842), which also inhabits the Spanish territory, specifically Melilla and the islands of Lanzarote and Fuerteventura (Maes *et al.*, 2019). Additionally, the species' colonisation of Gran Canaria has been documented (Naranjo Morales & Suárez Ramos, 2019).

The first written record of *E. bazae* in mainland Spain came from Pérez De-Gregorio *et al.* (1992) which cited the species in the "Serreta Negra de Fraga", province of Huesca. However, the first specimen was captured in 1982, in Hoya de Baza, Granada. Fabiano (1993), who had discovered the Andalusian population, described the subspecies *bazae* of *Euchloe charlonia*. Later, Olivares & Jiménez (1996) reassigned the taxon, elevating it to species rank as *E. bazae*, a status supported by genetic studies (Back *et al.*, 2005, 2006; Wiemers *et al.*, 2020; Marabuto *et al.*, 2020; Escuer *et al.*, 2022). Subsequently, Back *et al.* (2005) described the subspecies *iberae*, found in the regions of Monegros, Bajo Cinca, and Bajo Aragón. Thus, the nominal subspecies *E. bazae bazae* Fabiano, 1993 corresponds to the population in Granada (Fig. 2), while the subspecies *E. bazae iberae* Back, Olivares & Leestmans, 2005 corresponds to populations in Aragón (Fig. 3). Until recently, two populations were known in Aragón and one in Granada. Its presence in Catalonia is limited to a specimen captured in the Ermita de St. Jaume near La Granja d'Escarp on 26 March 1992, which is still preserved in the collection of Agustí Moliné (unpublished data, Ramon Macià pers. comm.), along with another specimen from 1994 and a reported observation in 2017 (Pérez De-Gregorio, 1994; Pérez De-Gregorio & Romañá, 2021) (Fig. 3).

Euchloe bazae is part of the "*charlonia* group" (subgenus *Elphinstonia*) which also includes *Euchloe charlonia* (Donzel, 1842), *Euchloe penia* (Freyer, 1852), *Euchloe lucilla* Butler, 1886, and *Euchloe transcaspica* (Staudinger, 1892) (Back *et al.*, 2006). The divergence of *E. bazae* from other species, likely coinciding with its isolation within the Iberian Peninsula, occurred approximately 3 million years ago during the Late Pliocene (see Escuer *et al.*, 2022).

Ecologically, *E. bazae* exhibits significant differences between its northern and southern populations. In Hoya de Baza, Granada, larvae feed on *Eruca vesicaria* (L.) Cav., a species widely distributed across the Iberian Peninsula. In contrast, in Aragón, larvae feed on the paleoendemic *Vella aspera* Pers. (Redondo & Murria, 1994; Murria & Redondo, 1995). Both plant species belong to the family Cruciferae. Egg-laying have been anecdotally observed on the leaves of *Reseda phyteuma* L. in the Huesca population, Aragón (Murria & Redondo, 1995), though its successful use as a host plant has not been confirmed. The habitats the butterfly inhabits also differ between north and south. In Aragón,

the butterfly occupies Mediterranean scrubland communities with high floristic diversity, where *V. aspera* is a keystone species. Conversely, in Hoya de Baza, the species inhabits monotonous esparto grasslands (*Macrochloa tenacissima* (L.) Kunth) with low floristic diversity, adjacent to agricultural areas that favour the growth of *E. vesicaria* during fallow periods. Despite these differences, both regions share semiarid conditions and soils characterised by the presence of gypsum.

Due to its recent description, *E. bazae* is not included in the annexes of EU biodiversity policy (Habitats Directive) or in international treaties such as the Bern Convention or CITES. However, in Spain, it has recently received legal protection with the highest possible status at the national level. In 2015, the Spanish Association for the Protection of Butterflies and their Environment (ZERYNTHIA Association) and the Government of Aragón highlighted the various threats facing the species and submitted a formal request to the then Ministry of Agriculture, Food, and Environment (Burrel *et al.*, 2015). After a lengthy administrative process, in 2019, all its populations were included by the Ministry for the Ecological Transition in the Spanish Catalogue of Threatened Species (CEEA), under the category "Endangered" through the approval of Order TEC/596/2019, of 8 April, which amended the annex of Royal Decree 139/2011, of 4 February. As a result, it became the third lepidopteran species in this catalogue and the second in the highest threat category in Spain.

Among the three autonomous communities with documented presence of this butterfly (Catalonia, Aragón, and Andalusia) recent regulations have been established for the first two. In Catalonia, *E. bazae* has been declared "regionally extinct" in the *Catàleg de la fauna salvatge autòctona amenaçada* under the category "Espècies i subespècies extintes com a reproductores a Catalunya" (Decree 172/2022, September 20), a status supported by technical publications categorising it as "regionally extinct" (see Vila *et al.*, 2018). The autonomous community of Aragón continues to manage the remaining populations of *E. bazae iberae*, listed as "Endangered" in the Aragonese Catalogue of Threatened Species (Decree 129/2022). In contrast, Andalusia remains the only region that has yet to

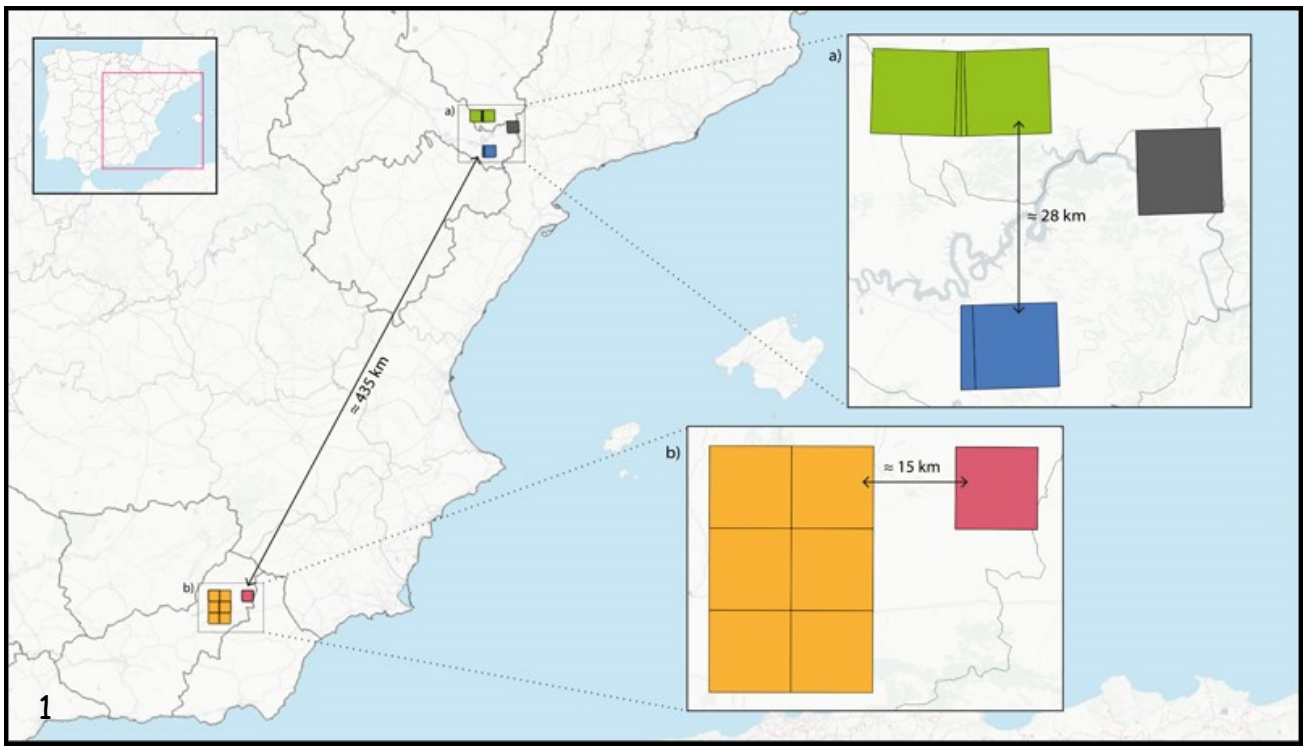

Fig. 1.- Updated distribution of *Euchloe bazae* Fabiano, 1993 represented by a 10x10 km UTM grid. Each of the four currently known populations is displayed in a different colour. Two of them are in Aragón, referred to as "iberae-Zaragoza" and "iberae-Huesca", as well as the presumed extinct population in Catalonia (a), and the other two are in the province of Granada, Andalusia, identified as "bazae-Hoya de Baza" and "bazae-Orce" (b). Arrows indicate the distances in km separating the different populations, preventing connectivity between them.

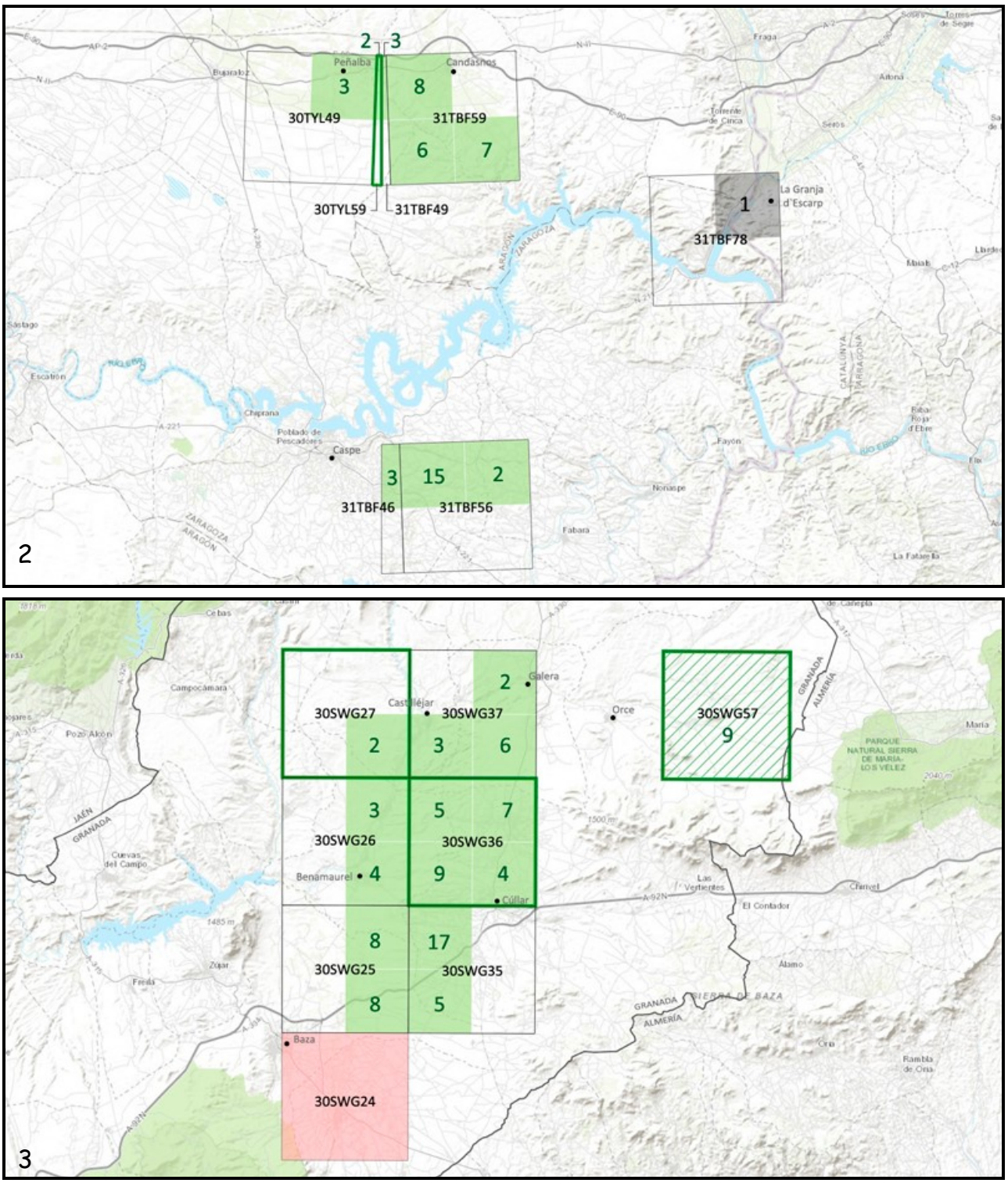

Fig. 2.- Distribution of *Euchloe bazae* Fabiano, 1993 in Granada, Andalusia. The 10x10 km UTM grid shows the names of each square. Squares not previously reported in the literature (30SWG27, 30SWG36, and 30SWG57) are outlined in green. Green shading of the 5x5 km UTM grid is used to indicate the squares where the butterfly is present and the number of 1x1 km UTM squares where the species has been observed. Square 30SWG24 (in red), previously mentioned in the literature, is removed due to the absence of records to justify its inclusion. The locations of the main municipalities are included as spatial references.

Fig. 3.- Distribution of *Euchloe bazae* Fabiano, 1993 in Aragón and Catalonia. The grid square not previously reported in the literature (30TYL57) is outlined in green. The 5x5 km UTM grid is used to indicate, in green and gray, the squares where the butterfly is present and the number of 1x1 km UTM squares where the species has been observed. The locations of the main municipalities are included as spatial references.

legislatively addressed this matter. *Euchloe bazae* was assessed as "Least Concern" on the IUCN Red List (van Swaay *et al.*, 2015), a status that has remained unchanged. However, a recent review of available data applying IUCN criteria confirmed a reclassification to "Endangered" [EN B1ab(i,ii,iii,iv); B2ab(i,ii, iii,iv)] (Escuer *et al.*, 2022), although this status has not been officially adopted.

The legal protection of its primary host plant in Aragón, *V. aspera*, is equally important. This plant is included in the List of Wild Species under Special Protection, according to Royal Decree 139/2011, dated 4 February. It is also classified as "of special interest" in the Aragonese Catalogue of Threatened Species (Order of 4 March 2004, from the Department of Environment). At the European level, the species is protected under its inclusion in Annexes II and IV of the Habitats Directive 92/43/EEC and its transposition in Law 42/2007. It is also covered by Annex I of the Bern Convention (1992). Regarding habitat protection, nearly the entire area occupied by *E. bazae* in Aragón is included within the Natura 2000 Network. Conversely, in Andalusia, the habitat lacks any formal or legal protection, despite the main habitat type being classified under Annex I of the Habitats Directive as "Mediterranean gypsicolous vegetation (Gypsophiletalia)" with code 1520.

Materials and methods

Fieldwork was conducted to better understand the distribution of *E. bazae*, aiming to provide finer spatial resolution for improved species and habitat management, thus contributing to its conservation. The study also sought to find new populations.

A comprehensive review of the existing literature on *E. bazae* was undertaken to gather both bibliographic and field data. This review included records from scientific databases, private and public collections (such as the National Museum of Natural Sciences in Madrid), as well as direct observations from specialists. Additionally, records from previous research conducted by the authors in Aragón and Granada from 2021 to 2023 were included, along with data collected in Granada during 2024.

To select study areas, a methodology using a 1x1 km UTM grid system was developed. Habitat characteristics were used to identify areas likely to host the species, within which the most prominent relief points in each square were selected *a priori*. This approach was designed to leverage the hilltopping behaviour of *E. bazae* males, facilitating the detection of imagoes. The method proved highly efficient, allowing multiple UTM squares to be surveyed in a single day. Spatial data analysis was conducted using the open software QGIS, with UTM grids at 10x10 km, 5x5 km, and 1x1 km scales, all in WGS84 format. These grids were retrieved from the Nature Data Bank (BDN) of the Ministry for Ecological Transition and the Demographic Challenge of the Government of Spain (https://www.miteco.gob.es/es/biodiversidad/servicios/banco-datos-naturaleza/informacion-disponible/bdn-cart-aux-descargas-ccaa.html). QGIS was also used to calculate the Minimum Convex Polygon (MCP), or Convex Hull, a geometric technique that defines the smallest area encompassing all recorded locations, forming the minimal polygon that connects the peripheral points.

During fieldwork, the exact position of each specimen was recorded using a GPS device. Specimen counts were conducted over 15-minute intervals, and climatic variables such as cloud cover, wind speed, and temperature were noted. When present, pressures and threats in the environment were also recorded.

Based on prior knowledge of the biology and ecology of *E. bazae*, the study aimed to test the potential existence of unknown populations associated with other *Vella* L. species beyond *Vella aspera* (Figs. 6 and 7). Populations of *Vella pseudocytisus* L. in the autonomous community of Madrid and in the provinces of Teruel and Granada were examined (Figs. 8 and 9), while *Vella lucentina* M.B. Crespo populations were surveyed in Alicante (Figs. 10 and 11). The same methodology, focusing on prominent topological features, was applied to evaluate the presence of the butterfly in these environments. To confirm the use of *V. pseudocytisus* as a host plant, direct observations and tracking during the oviposition behaviour of females were employed.

Captive breeding was conducted using eggs to obtain detailed observational and graphical documentation of the life cycle of *E. bazae bazae* and its use of *V. pseudocytisus* as a nutritional plant. The breeding process occurred under controlled conditions on live plants of *V. pseudocytisus* subsp. *pseudocytisus* sourced from a nursery garden.

To characterise vegetation, the Vegetation Series Map of Spain by Rivas Martínez (1987) was used. This map integrates bioclimatic zones, biogeography, ombroclimate (precipitation values), soil affinities, dominant species, and potential vegetation. To define the geology of the habitats, the Geological Map of Spain at a scale of 1:50000 was utilised. Botanical nomenclature follows *Flora Ibérica* (Castroviejo, 1986-2021) and the programme Plants of the World Online (POWO, 2024).

A total of five samples of *E. bazae* were collected and deposited at the Instituto de Biología Evolutiva (CSIC-UPF) in Barcelona. Genetic analysis focused on the mitochondrial gene cytochrome c oxidase I (COI), specifically targeting the 658 bp fragment of the genetic barcode. DNA extraction, PCR amplification, and sequencing were performed following the protocol outlined by de Freina *et al.* (2015). The sequences were visualised, edited, and aligned using Geneious Prime 2019.0.3 (https://www.geneious.com). A haplotype network was constructed using available GenBank sequences for the complete fragment (658 bp) and those obtained in this study, using TCS 1.21 (Clement *et al.*, 2000), and graphically edited with tcsBU (Múrias dos Santos *et al.*, 2016) and Adobe Illustrator CC. All sequences generated in the study have been deposited in GenBank (codes PQ423095-PQ423098).

Fieldwork and sample collection was conducted with the necessary administrative authorizations issued by the respective autonomous communities.

Results

The compiled database included 185 records obtained from bibliographic sources, scientific collections, and observations provided by other specialists. In addition, 189 unpublished observations were gathered between 2021 and 2023 from various research projects mainly conducted in Aragón (Monasterio León, 2020; Monasterio León & Escobés Jiménez, 2021, 2022; Monasterio León & Iglesias Baquero, 2022). Fieldwork conducted by the authors in 2024 contributed additional 437 observations, derived from both positive and negative samplings. In total, the compilation included 811 records, making it the most comprehensive and updated dataset on *E. bazae*.

Between February and May 2024, a total of 85 fieldwork days were dedicated to studying *E. bazae* in Granada, sampling 179 1x1 km UTM squares. The species was detected in 54 of these squares, resulting in 198 individual observations.

The fourth population: a different habitat and host plant in Orce, Granada

In 2022, promising results were obtained in Granada with the observation of two *E. bazae* specimens within the municipality of Orce, a location outside their typical habitat where *V. pseudocytisus* was present. This location was revisited in 2023, but extreme drought conditions resulted in a very short flight period and low adult density, limiting further observation that year.

In 2024, a large field effort confirmed a hypothesis that initially seemed unlikely. The team (Figs. 46 and 47) successfully identified what can be considered the original habitat of *E. bazae* in Andalusia, an ecosystem which shares notable similarities to the habitat used by the butterfly in Aragón (Figs. 7 and 12). This habitat features rich and diverse Mediterranean scrubland vegetation, with a floristic structure comparable to that observed in the northern populations, although different species occupy equivalent ecological niches. Within this location, *V. pseudocytisus* (Fig. 13) was confirmed as the exclusive host plant, playing a similar role to that of *V. aspera* in the northern populations.

The study also explored the potential existence of populations associated with other *Vella* species. To this end, in addition to the area in Granada, populations of this plant genus were surveyed in

Madrid, Teruel, and Alicante, the latter specifically due to the presence of *V. lucentina*. However, no isolated populations of the butterfly were found in these locations. Notably, the areas surveyed in Alicante were extremely dry in 2024 (Fig. 11), conditions considered unsuitable for the presence of *E. bazae* due to the lack of flowering plants and the degree of leaf dryness. In contrast, the flowering of *V. pseudocytisus* in Teruel peaked in 2024 (Fig. 8), likely due to spring rains, which prompted survey repetition; however, these efforts were ultimately unsuccessful.

Until recently, three populations of *E. bazae* were known. Two populations in Aragón: one in Huesca, around the municipalities of Peñalba and Candasnos (regions of Monegros and Bajo Cinca) and another in Zaragoza, at the municipality of Caspe (region of Bajo Aragón). A third population was known in Granada, spread across much of Hoya de Baza, a high plain encompassing several municipalities in the administrative regions of Baza and Huéscar. The newly discovered location in Orce represents a fourth population, with distinct ecological characteristics and showing apparent geographic isolation from the Hoya de Baza population. Despite being separated by less than 15 linear kilometres, no records of the butterfly were obtained in the intermediate area, even after intensive searching. The Orce population is both the northernmost and easternmost known in Andalusia and located at the highest elevation among all four populations, reaching 1020 meters above sea level. In contrast, the Huesca population is found at the lowest elevation, 150 m, defining an altitudinal range of 870 m.

The habitat characteristics in Orce are unique for *E. bazae*, mainly due to the presence of the endemic botanical element *V. pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán, which serves as the host plant. The surrounding floristic composition is notable, consisting of a Mediterranean scrubland environment with *Macrochloa tenacissima* (L.) Kunth and *Quercus ilex* subsp. *ballota* (Desf.) Samp. as the dominant tree species (Figs. 14-17). Other species present include *Ononis tridentata* L. and *Ononis fruticose* L., *Genista* L. sp., and *Thymus vulgaris* L. The absence of *Salvia rosmarinus* Spenn. which is found in nearby areas, is particularly striking. Additionally, sections of the habitat are occupied by *Pinus halepensis* Mill. plantations, which negatively impact both the quantity and quality of the habitat. The flora in these plantations is extremely poor, with remnants of dead *V. pseudocytisus* individuals observed.

According to the Vegetation Series Map of Spain by Rivas Martínez (1987), the habitat in Orce belongs to series 22b, defined as the "mesomediterranean Manchegan and Aragonese basophilous series of *Quercus rotundifolia* (=*Q. ilex* subsp. *ballota*) (Bupleuro rigidi-*Querceto rotundifoliae*)" typical of the Manchegan sector. The oak grove represents the potential vegetation; however, modern agricultural practices involving cereal and stone fruit cultivation have significantly altered the landscape. This vegetation series is highly distinctive compared to those occupied by the other three known populations. The northern populations are found in series 29c (thermophilic Aragonese facies with *Pistacia lentiscus* L.), while the population in Hoya de Baza is found in series 29a (Betic facies with *Ephedra fragilis* Desf.) (Figs. 18-20). Both series are defined as "mesomediterranean Murcian-Almerian, Guadix-Baza, Setabense, Valencian-Tarraconense, and Aragonese semi-arid series of *Quercus coccifera* L. or kermes oak (*Rhamno lycioidis-Querceto cocciferae* sigmetum)". The kermes oak represents the potential vegetation in both previously known habitats of the butterfly. Thus, the newly discovered Orce population occupies a well-differentiated ecological niche compared to all previously known populations.

Following the advent of modern agriculture, the habitat in Orce became highly restricted, now consisting of a fragmented habitat for *E. bazae* that has been preserved due to the region's orography (Figs. 14-17). Despite the presence of hilltops that appear suitable for *V. pseudocytisus*, its distribution abruptly ends, with no known individuals or populations of the plant outside of the 10x10 km UTM grid square 30SWG57. *Euchloe bazae* has been found on several hills where this plant grows; however, it has not been observed on nearby prominences where *V. pseudocytisus* is absent. Given the wide availability of *E. vesicaria* across the entire area, it appears that the Orce population, like those in Aragón, relies solely on *Vella* species as host plant, unlike the behaviour observed in Hoya de Baza.

According to the Geological Map of Spain at a scale of 1:50000, the population in Orce occupies three types of sedimentary layers belonging to the paleolake of Baza: "clays and conglomerates of

immature pebbles" from the late Tertiary period, as well as slightly more recent materials from the late Tertiary and early Quaternary composed of "sandy and micritic silts" and "clay silts with conglomerates, sometimes with gypsum". In contrast, the population in Hoya de Baza primarily occupies soils composed of materials from the Baza basin, characterised by "fine sands with gypsum and levels of marls and limestones" formed at the beginning of the Quaternary. Notably, *V. pseudocytisus* grows abundantly on other substrates classified as "micritic limestones, oolitic limestones with silicifications, and somewhat nodular red limestones" from the Jurassic as well. However, *E. bazae* was not observed in habitats with this soil type. In comparison, in Huesca, *E. bazae* is based in regions with soils described as "Limestones, gray marls, and reddish clays", "Layers of gray limestones and marls, occasionally with gypsum nodules", "Limestones and marls. Occasionally gypsum nodules", and "Reddish clays, sometimes with gypsum nodules, sandstones in paleochannels, and limestone levels", all having originated in the Tertiary period. The population of Zaragoza is situated on a unit referred to as "Clays, sandstone paleochannels, and limestones", which also originated in the Tertiary.

Biology of the species in the new population

The primary novelty of this study is the confirmation of *V. pseudocytisus* as the exclusive host plant for the new butterfly population in Orce, Granada. Despite the widespread presence of *E. vesicaria*, all observed specimens of both sexes exhibited a preference for *V. pseudocytisus*. Females laid eggs exclusively on this plant, with a 100% occurrence rate (n > 50) (Fig. 22). Eggs were consistently laid on smaller plants that had not yet developed the capacity to flower or had a very small number of incipient flowers. Furthermore, *V. pseudocytisus* serves as the primary resting substrate for imagoes, both during brief pauses in daytime activity and for nocturnal resting (Figs. 21 and 23).

The close relationship between the plant and the butterfly is evident in photographs, including the first recorded images of copulation (Fig. 24) in the scientific literature, as well as images of eggs and larvae feeding on the leaves. The larvae not only share the green hue of the host plant (Fig. 39), but also present whitish hairiness that mimics the hairiness of the leaves and stems of *V. pseudocytisus* (Figs. 35 and 36), achieving excellent camouflage. Successful captive breeding was conducted using live *V. pseudocytisus* plants sourced from the Madrid population, which helped facilitate larval feeding, given the challenges of maintaining the plant in good condition throughout the extended developmental period of the larvae. This enabled the documentation of immature stages and confirmed the viability of this crucifer as host plant to complete the biological cycle of the butterfly (Figs. 25-41).

Regarding the feeding habits of the imagoes, *E. bazae* consumes nectar from various plant species. In Aragón, they primarily visit the flowers from *S. rosmarinus* and *V. aspera*, suggesting that the butterfly may act as a pollinator for these species. In Granada, *S. rosmarinus* and *E. vesicaria* have been observed as nectar sources in Hoya de Baza, while for the Orce population, the only confirmed nectar source is *V. pseudocytisus* subsp. *orcensis* (Fig. 42). This further indicates the ecological relationship between the butterfly and *V. pseudocytisus* in Orce, suggesting its role as a significant pollinator of this scarce plant.

Distribution update

The results obtained in this study, the most comprehensive to date for *E. bazae*, allow for a more precise estimation of its distribution. The primary objective was to achieve a greater resolution by using a 1x1 km UTM grid, which is better suited for studying such a rare and localised species compared to the previously used 10x10 km UTM grid. This refined approach, also used by Escuer *et al.* (2022), helps avoid the excessively optimistic distribution that may arise from a larger grid size.

Fieldwork conducted in Aragón between 2021 and 2022 (Monasterio León & Escobés Jiménez, 2021, 2022; Monasterio León & Iglesias Baquero, 2022) revealed that *E. bazae* occupies 49 of the 1x1 km UTM squares in this region, with 29 in Huesca, and 20 in Zaragoza (Fig. 3). This assessment is based on the number of 1x1 km UTM squares identified from both historical observations and recent

fieldwork by the authors. A previous study had reported the presence of the butterfly in only 15 squares across Aragón (Escuer *et al.*, 2022), resulting in a remarkable distribution increase of 226.6%. Specifically, the knowledge of the species' distribution in Huesca has increased by 150%, where seven squares were previously known, while in Zaragoza it has increased by 314.2%, where only eight squares were known (Escuer *et al.*, 2022).

In the whole province of Granada, the understanding of the *E. bazae* range has more than doubled based on records obtained in 2024 alone (Fig. 2). The known distribution expanded from 43 1x1 km UTM squares (Escuer *et al.*, 2022) to a total of 92, representing a 113.9% increase. Specifically, the population in Hoya de Baza increased from 43 to 83 known 1x1 km UTM squares, a 93% increase. Meanwhile, the previously unknown Orce population was documented in nine 1x1 km UTM squares.

Overall, the distribution has increased from 58 known 1x1 km UTM squares to 141, representing a 143.1% increase (Escuer *et al.*, 2022). As it stands, the global distribution of *E. bazae* is 141 km^2, fragmented into four core populations, covering an area equivalent to less than 1.5 hypothetical 10x10 km UTM squares (Fig. 4). This fragmentation, along with habitat scarcity and generally low population sizes, constitute the primary threats faced by the species.

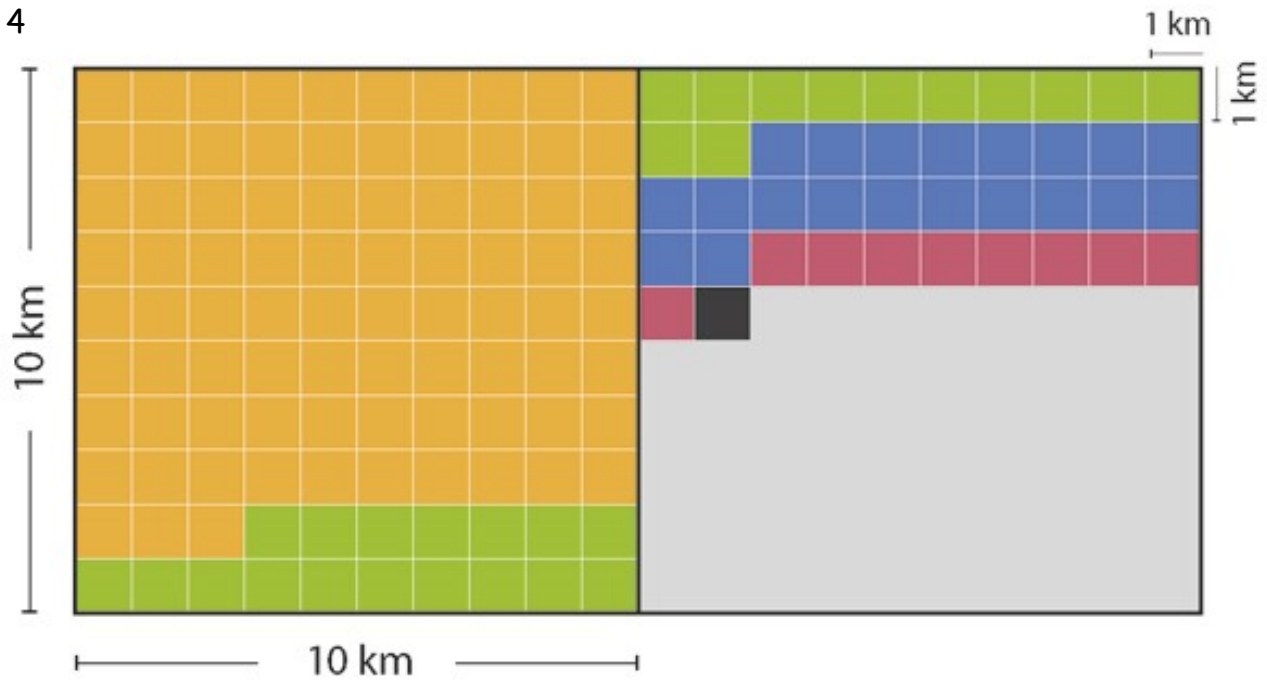

Fig. 4.- *Euchloe bazae* Fabiano, 1993 is present in 14 10x10 km UTM squares throughout its distribution, a scale inappropriate for studying this species due to its uneven distribution within these squares and its disjunct range. The diagram represents two hypothetical 10x10 UTM squares, with the total known 1x1 km UTM squares of the four populations. The species has been recorded in 141 1x1 UTM squares, which corresponds to an area smaller than what would fit into 1.5 10x10 km UTM squares across its distribution. The 1x1 UTM squares occupied in Hoya de Baza are highlighted in orange, those in Huesca in green, those in Zaragoza in blue, those in Orce in pink, and the only one with bibliographic records in Catalonia in black, where the species is presumably extinct.

Currently, the species is confirmed in 13 10x10 km UTM squares (Fig. 1). In Aragón, it occupies six of these squares on both sides of the Greenwich meridian (30TYL49, 30TYL59, 31TBF49, 31TBF59, 31TBF46, and 31TBF56). Squares YL59, BF49, and BF46 are reduced due to the correction applied by the passage of the Prime Meridian. Square YL59 is recorded for the first time in this study (Fig. 3). In Granada, it is found in seven squares from zone 30 and zone S (WG27, WG37, WG57, WG26, WG36, WG25, WG35). Squares WG27, WG36, and WG57 are novel in this work (Fig. 2). In total, these findings expand the knowledge of the species' distribution across four additional 10x10 km UTM squares.

However, square 30SWG24, cited for the first time by García Barros et al. (2004) and located at the southernmost point of its distribution, is considered erroneous due to the complete absence of specific records of *E. bazae* after thorough bibliographic search. During the study, sampling areas with esparto grass within this square did not yield any observations of the butterfly. It is understood that this square was marked based on citations from older publications that merely labelled "Baza" as a location, as the city is located within this square. For these reasons, it is considered unjustified to retain this square, and it has been removed from the cartographic study to avoid a significant (100 km^2) overestimation of its distribution (Fig. 2).

The presence of *E. bazae* in Catalonia is based solely on three isolated observations within grid square 31TBF78: a specimen captured in 1992 (Agustí Moliné leg., unpublished data, Ramon Macià comm. pers.), a female captured in 1994, and another apparently observed in 2017 (Pérez De-Gregorio, 1994; Pérez De-Gregorio & Romañá, 2021). Despite multiple visits by the authors and other researchers over several years, including during spring 2024, the species has not been observed in this area, which has a very scarce presence of *V. aspera*.

Applying IUCN methodology for criteria B, which refers to the geographical distribution of species (IUCN, 2012), we obtained the following values: the area of occupancy (*AOO*) is 141 km^2 (*E. b. bazae* = 92 km^2 and *E. b. iberae* = 49 km^2), and the extent of occurrence (*EOO*) is 795 km^2 (*E. b. bazae* = 520 km^2 and *E. b. iberae* = 275 km^2). However, these values likely represent an overestimation as they include areas between the two populations of each subspecies, where the butterfly has not been detected despite being surveyed.

To estimate the range of populations beyond the area defined by the UTM grid squares, we calculated the Minimum Convex Polygon (MCP) based on recent georeferenced observations of *E. bazae*. In the Zaragoza population, the species is found in 29 1x1 km UTM squares, with the MCP calculation yielding an area of 21 km^2. In Huesca, observations span across 20 squares, and the derived polygon results in 9 km^2. For Orce, observations cover 9 1x1 km UTM squares, distributed across three relatively separate areas, leading to three distinct MCPs. The combined area of these polygons is only 2 km^2, highlighting their limited extent. Although substantial progress has been made in understanding its distribution in Hoya de Baza, the area remains under-studied, suggesting that the number of 1x1 km UTM squares with *E. bazae* presence could increase in future studies. This is supported by the MCP calculation for this population, which results in a polygon of 215 km^2, potentially reflecting the area the species could occupy in this region. The cumulative area derived from MCP calculations for all four populations suggests a species range of 247 km^2. However, this estimate may be overly optimistic; therefore, for conservation status assessments of this butterfly, we have chosen the more conservative measurement derived from the 1x1 km UTM grid.

The study conducted in Granada has confirmed the presence of *E. bazae* in the municipalities of Baza, Cúllar, Galera, Benamaurel, Castilléjar, and Orce, marking its presence as novel in the latter two. The Orce population is considered a distinct management unit due to its isolation from the others and its unique ecological characteristics. In Aragón, the species is found in the municipalities of Peñalba and Candasnos in Huesca, as well as in an area around the municipality of Caspe, Zaragoza.

Genetic results and conservation implications

Genetic analyses of the mitochondrial gene COI reveal that the new Orce population is related to the Hoya de Baza population, sharing a common haplotype (Fig. 5). However, the Orce population also exhibits a well-differentiated haplotype characterised by two nucleotide substitutions, which appears to be absent in the other populations. This suggests a high level of genetic diversity relative to the small geographic distribution of the new population. The presence of a unique haplotype in Orce, coupled with its current geographical and reproductive isolation, justifies its consideration as a distinct population under IUCN (2012) criteria.

Based on these genetic results, the Orce population would still be included under the subspecies *E. b. bazae*. However, from a conservation perspective, four distinct management units can be

identified. For better differentiation, these units are named as follows: "iberae-Zaragoza," "iberae-Huesca," "bazae-Hoya de Baza," and "bazae-Orce," referring to their respective subspecies and their geographical locations. Each unit is represented by different colours in Fig. 1. Complementary management strategies are required for these four units, as their ecological characteristics and conservation strategies differ significantly.

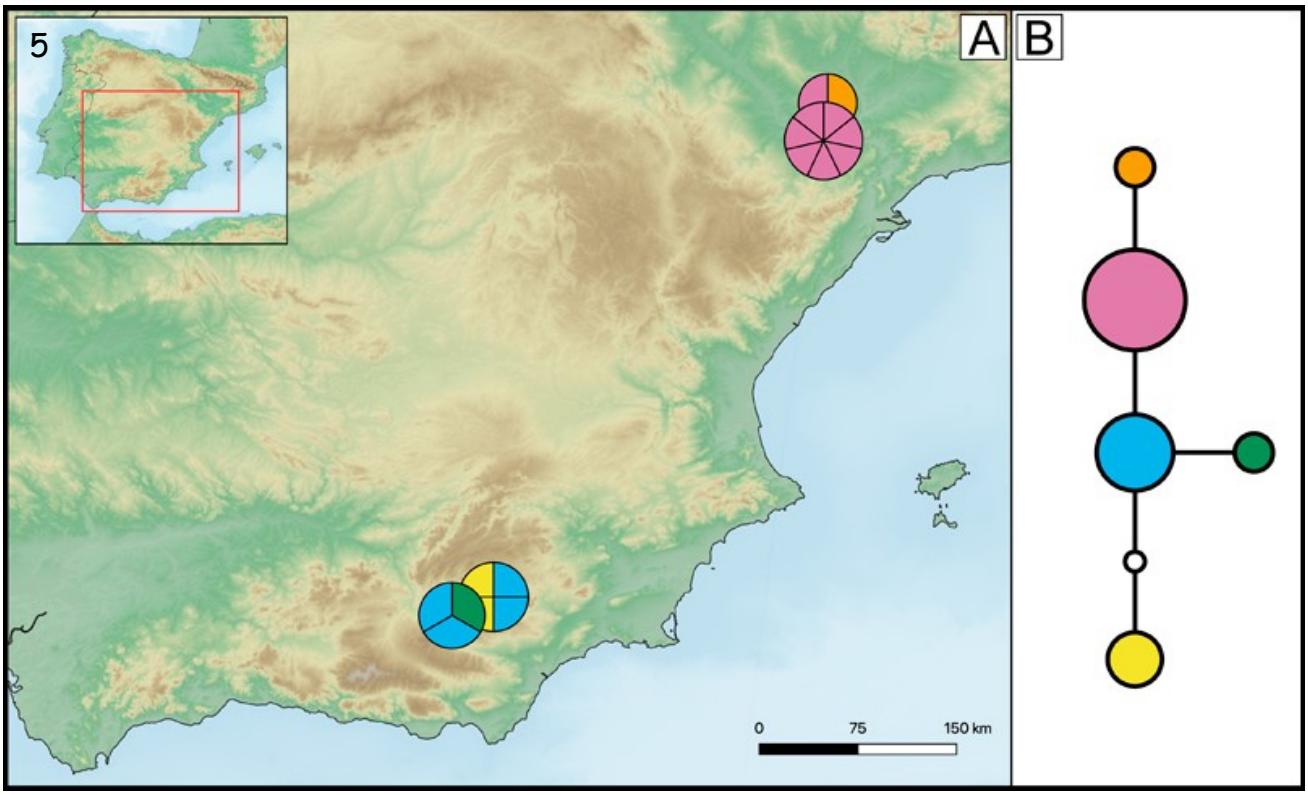

Fig. 5.- Haplotype network of *Euchloe bazae* Fabiano, 1993 based on the barcode fragment of the mitochondrial gene cytochrome *c* oxidase I (COI, 658 bp). The area of the circles is proportional to the number of sequences they represent. Colours represent the different haplotypes obtained.

New data on phenology

Between 2021 and 2024, atypical climatic conditions had a noticeable impact on the phenology of *E. bazae*. In 2021, an exceptionally low abundance of individuals was observed in Aragón, with only a single individual being observed per locality. This phenomenon may be associated with "Storm Filomena", which severely affected large parts of the Iberian Peninsula in January, marking the largest snowstorm in Spain since 1971.

In 2022, an extremely rainy spring affected uninterruptedly the entire Peninsula, preventing the appearance of imagoes in March. These rains delayed the emergence of adults until the beginning of April, postponing the end of the flight period until the first week of June in Granada as well, marking the latest records for this butterfly. In Aragón, the peak abundance was observed on 16 April, with females not seen in any significant numbers until 26 April. The presence of late individuals in Granada, corresponding to a second generation, raised the possibility of a similar occurrence in Aragón. However, surveys conducted on 29 May in known areas of Candasnos, where *E. bazae* typically exhibits the highest densities in the northern populations, found no specimens. It is likely that the high temperatures during this period, classified as a heatwave, inhibited the emergence of a second generation; alternatively, it may be that a second generation does not occur in Aragón.

In 2023, the spring was extremely dry, resulting in very low observed abundance in both Aragón and Andalusia, and as a result, the second generation typical of the southern population did not occur.

In 2024, high temperatures persisted throughout much of February, prompting earlier field visits that resulted in the earliest records for this butterfly. The first specimens were observed in Granada on 18 February, although favourable conditions had existed for several days prior, suggesting that their activity may have begun even earlier. In Aragón, the first known observation was recorded on 29 February of the same year.

Estimation of abundances

The methodology for estimating the population abundance of *E. bazae* has changed significantly over the years, due to the species' peculiar behavioural characteristics. Initially, a standardised approach calculated density per linear kilometre using 1-kilometre transects (Munguira *et al.*, 2015; Monasterio León, 2020). However, this method proved ineffective due to the tendency of adults to aggregate on hilltops or elevations (a phenomenon known as hilltopping) which leads to a heterogeneous distribution of individuals, with few sightings in lower areas and high concentrations in elevated zones. Recognizing this limitation, the methodology was refined to a more representative approach involving direct counts of individuals over a fixed 15-minute period at aggregation points. This method is efficient, allowing for multiple sites to be visited in a single day, given the low time investment required.

Comparisons with previous data are challenging due to the differing methodologies used to estimate abundance. For the Hoya de Baza population, abundance observations collected by Javier Olivares (unpublished data) between 1994 and 2003, although not standardised and lacking spatio-temporal reference, offer a valuable series for understanding the species' abundance variations. The highest observed abundances for each year and single-day counts are as follows: 1994: 8 individuals, 1996: 17 individuals, 1997: 31 individuals, 1998: 23 individuals, 1999: 15 individuals, 2000: 8 individuals, 2001: 27 individuals, 2002: 22 individuals, and 2003: 5 individuals. After over a decade without any abundance data, Munguira *et al.* (2015) estimated an average abundance of 1.9 imagoes per kilometre in Hoya de Baza for 2013 and 2014. Later, Monasterio León & Iglesias Baquero (2022) studied the Hoya de Baza population in 2022, obtaining an average of 3.8 individuals per kilometre from data collected across five surveys over 19 days of fieldwork. In the three days with the highest number of observations, abundance values were recorded at 7.9, 7.1, and 3.1 imagoes per kilometre. The abundance observed in 15-minute counts ranged from 1 to 5 individuals, peaking on 10 May. Finally, in 2023, an extremely dry spring resulted in very low population density, with only 2 specimens observed during a 15-minute count on 5 April in Benamaurel.

Between February and May of 2024, the authors conducted 72 positive 15-minute counts across 50 different 1x1 km UTM squares in the province of Granada. These counts yielded abundances ranging from 1 to 5 individuals, with a single individual being the most common sighting and an average of 1.5 individuals. When differentiating these estimates between the two populations, 55 counts were conducted in Hoya de Baza across 43 1x1 km UTM squares, with an average abundance of 1.3 individuals. In Orce, 17 counts resulted in an average of 2.6 individuals. In total, 185 individual observations of *E. bazae* were recorded in 2024, consisting of 175 males and 10 females.

In Aragón, Munguira *et al.* (2015) estimated an average abundance of 8.3 imagoes per kilometre for 2013 and 2014, a result that contrasts significantly with later studies. For example, in 2018, Monasterio León (2020) documented a much higher density in the Huesca population, approximately 30 individuals per kilometre, indicating notably higher abundance compared to previous records. However, in 2021, the Zaragoza population experienced a dramatic decline, with counts of just one individual per locality per visit, resulting in a density of less than 1 adult per linear kilometre and an average of 1 individual per 15 minutes, with only males recorded (Monasterio León & Escobés Jiménez, 2021). In 2022, variations in abundance in Huesca were influenced by sampling dates and habitat conditions at different sites. While only a single individual was observed in many locations, the highest recorded density was 10 adults per kilometre on 16 April (Monasterio León & Escobés Jiménez, 2022). During 15-minute counts, between 1 and 7 individuals were recorded, with the highest densities observed on 26 April and 10 May. The sex ratio in 2022 showed a total proportion of 42 males to 6 females, with

females primarily observed towards the end of the phenological period. Finally, in 2023, surveys were conducted in both Zaragoza and Huesca. The 15-minute counts reflected abundances of 3 to 5 individuals, with notable observations of 5 on 27 March and 4 on 17 April in Huesca, and 3 in Zaragoza on 28 March, with no sightings on 18 April. These observations confirm that, generally, the abundance of *E. bazae* tends to be higher in the Huesca population than in the Zaragoza population.

Discussion

Importance of the new population

The differences in habitat types and feeding strategies between the northern and southern populations of *E. bazae* have puzzled researchers for decades. It appears inconsistent that northern populations feed on a paleoendemic species such as *V. aspera*, which is ancient, endemic, and threatened, while southern populations feed on a more ubiquitous plant such as *E. vesicaria*. The taxonomic reclassification of *Boleum asperum* to *V. aspera* (Simón-Porcar *et al.*, 2015) prompted an investigation in 2022 to explore whether butterfly populations utilise a different species of *Vella* aside from *V. aspera*. However, the discovery of new populations associated with *V. aspera* is considered unlikely, as the authors have studied all known populations of this plant in various research efforts over the last decade.

This study confirms that *E. bazae* utilises a previously unknown host plant, *V. pseudocytisus*, a very rare species similar to its associated plant in Aragón. This Iberian-Maghreb endemic occurs only in Madrid and Toledo (*V. pseudocytisus pseudocytisus*), Teruel (*V. pseudocytisus paui*), and Granada (*V. pseudocytisus orcensis*) (Domínguez Lozano *et al.*, 2011). The subspecies *V. p. orcensis* serves as the host for *E. bazae*, with adults of both sexes showing a strong preference for this plant. Observations show that females consistently oviposit on *V. pseudocytisus*. Interestingly, in this environment, the species does not appear to utilise *E. vesicaria* despite its presence, a pattern also observed in Aragón. Although the distribution of *V. pseudocytisus* in Granada is very limited, *E. bazae* specimens were observed in many of the hills where it grows, excluding those likely affected by pesticides. In contrast, the butterfly is always absent from nearby areas where the plant is not found.

Genetic analysis of the Orce population reveals significant genetic diversity, suggesting that the Hoya de Baza population likely represents a recent divergence. However, due to geographic isolation, these two populations currently do not seem to maintain gene flow. Ecological conditions and genetic relationships suggest that the Orce population could be the origin of the current Hoya de Baza population, which has relatively recently adapted to using *E. vesicaria* as its host plant. Furthermore, it is plausible that the association between *E. bazae* and the genus *Vella*, crucifer plants bearing woody characters considered relict and primitive (Domínguez Lozano *et al.*, 2011), is ancestral, with both populations feeding on *Vella* species during their larval stage. This association provides strong evidence for a possible African origin of *E. bazae*, rather than a Palaearctic one, given that all species currently belonging to the genus *Vella* are restricted to Spain and the Maghreb (see GBIF Secretariat, 2023).

It is worth noting that a similar adaptive process has occurred in *Euchloe tagis* (Hübner, [1804]), whose larvae feed exclusively on plants of the genus *Iberis* L. across its entire distribution, except in Hoya de Baza, where that genus is absent. In this location, *E. tagis* has adapted to feed on *E. vesicaria* (Olivares Villegas & Back, 2004 and 2024 obs.). Nonetheless, *E. tagis* still feeds on *Iberis saxatilis* L. in the Orce area (authors pers. obs.).

Given its unique genetic and ecological characteristics, the risk posed to populations with reduced census numbers, the occupation of an extremely limited territory, the threats faced by its habitat and host plant, and its relatively higher population density compared to that recorded in the Hoya de Baza, the effective protection and active management of the Orce population are essential priorities for the conservation of *E. bazae*.

Threats and Conservation

Euchloe bazae, an endemic species of the Iberian Peninsula, faces significant threats that justify its

legal classification as "Endangered" in the Spanish Catalogue of Endangered Species. Comprehensive conservation efforts are required to protect *E. bazae* as this species exhibits a disjunct distribution characterised by very limited habitat availability and alarmingly low observed population sizes. Additionally, increasing aridity driven by global climate change may further challenge the persistence of certain populations.

Fragmentation is a consistent characteristic of *E. bazae* populations, which are distributed across four isolated areas. The linear distance between the two northern and two southern populations is about 435 km (Fig. 1). Specifically, the populations in Zaragoza and Huesca, Aragón, are separated by approximately 28 km, with various barriers hindering connectivity, especially the absence of the host plant, *V. aspera*, in the intervening region. The Ebro River, which traverses this region, widens significantly due to the Mequinenza reservoir, further complicating connections between these populations (Fig. 1). Additionally, extensive reforestation with *Pinus halepensis* has been identified as another significant obstacle to species dispersal.

Between the populations of Hoya de Baza and Orce there is a gap of approximately 15 km where *E. bazae* has been consistently absent despite numerous search efforts. The discovery of a fourth population in Orce is extremely positive for conservation efforts. However, fragmentation persists, even within this new population, leading to a lack of connectivity. Isolated subpopulations are likely the result of recent agricultural intensification, which has most likely eliminated large areas of the host plant, and thereby minimised or obstructed connectivity between these subpopulations. While larger communities of *V. pseudocytisus* have been observed, some numbering in the thousands, the butterfly remains absent from these areas. Geological differences could partially explain this absence, but the extensive use of synthetic chemicals (herbicides, fungicides, pesticides, etc.) in the surrounding cultivated areas likely affect *E. bazae* and other insect species. Indeed, the low diversity of insect species in these regions sharply contrasts with areas where *E. bazae* thrives. Furthermore, the species observed in these low-diversity locations tend to be migratory, such as *Vanessa cardui* (Linnaeus, 1758) (Lepidoptera: Nymphalidae), or exhibit high mobility, like *Iphiclides feisthamelii* (Duponchel, 1832) (Lepidoptera: Papilionidae).

Another threat facing the newly discovered population is the habitat reduction of *V. pseudocytisus* due to the planting of *P. halepensis*, a concern also highlighted by previous studies (Benito *et al.*, 2004). This endemic plant, which requires basic soils, competes for space with the pines, which lower the soil pH, leading to the demise of the plant. Numerous dead or dying *V. pseudocytisus* specimens have been observed at the base of pines (Fig. 43). In addition to modifying soil conditions, pine plantations reduce the solar radiation received by smaller plants, which also creates competition. This situation is notably impactful in Hoya de Baza and is especially concerning in the municipalities of Benamaurel and Orce, where it seems to correlate with the absence of the butterfly in areas dominated by pines, thereby decreasing habitat quality and extent. Similarly, in Aragón, pine plantations have been observed to act as barriers, hindering the dispersal of the species.

Extensive livestock farming is negatively impacting the new population found in Orce, where excessive browsing by sheep herds has been noted on *V. pseudocytisus* subsp. *orcensis* (Fig. 44). Protective measures for this plant are necessary to preserve the habitat of the butterfly (Hernández-Bermejo *et al.*, 1999). However, in Aragón, this threat is currently not considered significant, particularly since livestock farming has almost disappeared in a region that once had substantial livestock activity.

The legal protection of *V. pseudocytisus* is also essential. This species is protected in Madrid, Castilla-La Mancha, and Andalusia. In the latter, which encompasses the newly discovered population of *E. bazae*, *V. pseudocytisus* is included in the Andalusian Catalog of Threatened Species under the category "Endangered," identified as "*Vella pseudocytisus* L. subsp. *pseudocytisus*". However, this population is currently classified as subsp. *orcensis* (Simón-Porcar *et al.*, 2015), highlighting the need for legislative updates to improve accuracy. This protection is regulated by Law 8/2003, of 28 October, on the Flora and Fauna of the Autonomous Community of Andalusia. Benito *et al.* (2004) recommended

including *V. pseudocytisus* in the Spanish Catalog of Threatened Species, alongside effective protection measures such as the avoidance of harmful practices, monitoring, and public awareness campaigns. The threats facing both the butterfly and its host plant are interconnected. Previous botanical studies have identified similar threats, and Cabezudo *et al*. (2005) highlighted forestry, grazing, and agriculture as key risks. Given that these factors are common and well-identified for both taxa, urgent measures are necessary to work synergistically towards the conservation of this plant-butterfly association.

A significant and common risk to both population of *E. bazae* in the province of Granada is the lack of territorial protection, as the habitat occurs outside Andalusia's network of natural spaces and the Natura 2000 network. Much of this habitat is privately owned, which threatens the survival of the species due to potential habitat alterations. In contrast, much of the area occupied by *E. bazae* in Aragón is included in the Natura 2000 network. Therefore, prioritizing habitat protection in Granada is essential, alongside safeguarding it against threats from wind and solar energy production and transportation infrastructures, activities that are particularly relevant today in Spain. These activities currently represent the most significant threats to the species' populations in the province of Granada. The absence of territorial protection and the fact that the butterfly inhabits privately owned land may facilitate energy companies in establishing such infrastructures in critical habitats. Notably, there is a project for a 400 kilovolt power line that crosses the Baza-Antas area (Fig. 45), whose design and associated mitigation measures are currently under discussion to minimise the impact on the species.

The projected infrastructure has prompted a study assessing the potential impact of the constructions on *E. bazae* (Monasterio León & Iglesias Baquero, 2022), as well as the formulation of numerous objections and the organization of meetings with stakeholders. Support from the ZERYNTHIA Association alongside endorsements from numerous national and international specialists and over 6000 signatures backing the presented arguments, has been instrumental to these efforts. All of this allows us to affirm that, for the first time in Spain, the conservation of a butterfly species may influence decisions regarding the construction of large infrastructures. This achievement is linked to the species' inclusion in the Spanish List of Threatened Species in 2019 as "Endangered". As a result, new routing proposals will avoid areas with the highest occupancy of the species, minimizing potential impact. This represents a significant milestone in the conservation of lepidopterans in Spain.

Models developed by Escuer *et al*. (2022) suggest that the climatically suitable area for *E. bazae* was less fragmented in the past. These models also suggest a recent decline in habitat quality in the areas currently occupied by the butterfly. While the models also predict a resurgence of climatically appropriate habitats, the limited dispersal capacity of both the butterfly and its host plants of the genus *Vella* makes it unlikely that their populations can rapidly migrate to mitigate this impact. These factors suggest a future decrease in populations as well as a declining trend.

The distinct geographical, latitudinal and altitudinal locations of each population, along with their ecological differences, contribute to their complementary roles in the conservation of the species. For this reason, they must be considered as separate management units. In the context of current climate change, the populations in Aragón, specifically the "iberae-Huesca" and "iberae-Zaragoza" units, which are associated with *V. aspera*, may play a critical role for the species. Their northern latitude may provide greater resilience compared to the populations in Andalusia, especially for the "iberae-Huesca" unit which is in the northernmost point. The "bazae-Hoya de Baza" unit, located in Hoya de Baza and relying on *E. vesicaria*, would become increasingly important in a future scenario where the two *Vella* species continue to decline, as it represents the only population relying on a common and abundant host plant without conservation concerns. Meanwhile, the "bazae-Orce" unit, situated at the north-easternmost point of its distribution in Andalusia and at the highest altitude within its total distribution range, stands out for its limited range and dependence on *V. pseudocytisus*. This unit harbours considerable genetic diversity and could be crucial for the survival of the species if the Hoya de Baza population were to experience a significant decline. This population could serve as an important genetic reservoir, helping to mitigate inbreeding issues and increasing the likelihood of the species adapting to environmental changes.

Available observations indicate noteworthy interannual fluctuations in the population abundances of *E. bazae*, both in Aragón and Granada. These variations appear linked to interannual changes in rainfall and temperature during spring, which is the adult flight period. The steppe-like habitat occupied by *E. bazae* requires such an adaptation to ensure hatching during favourable springs with sufficient food resources. This interannual abundance variation currently makes the identification of clear trends difficult. However, despite observed peaks in abundance, such as 30 individuals per kilometre in Huesca in 2018 and 7.9 individuals per kilometre in Hoya de Baza in 2022, observations generally reveal low numbers. The accumulated dataset is insufficient to draw firm conclusions about population trends, underscoring the need for continued long-term monitoring, conducted by the ZERYNTHIA Association since 2021.

Consistent counts with low abundance results suggest that this species is extremely sensitive, indicating that its conservation status is not ideal. This highlights the urgent need for measures to conserve its habitat, making every effort to preserve or improve current conditions and avoiding any interventions that could reduce the area or quality of the habitat occupied by the butterfly.

The obtained values for area of occupancy (*AOO*) at 141 km^2 and extent of occurrence (*EOO*) at 795 km^2 clearly fall within the thresholds for being considered an endangered species (EN) by the IUCN (2012). Several additional factors warrant consideration: a) the species is severely fragmented and is not known to exist in more than four locations. Given its presumed extinction in Catalonia, the aforementioned impacts on habitats, and the assumption that the Orce population does not represent a recent expansion, it can be reasoned b) that there is a continuous decline, whether observed, inferred, or projected, in (i) extent of occurrence, (ii) area of occupancy, (iii) area, extent, and/or quality of habitat, and (iv) number of locations or subpopulations. Furthermore, c) extreme fluctuations have been noted in (iv) number of mature individuals. Consequently, it is concluded that *E. bazae* should be classified as "Endangered" [EN B1ab(i,ii,iii,iv)c(iv); B2ab(i,ii,iii,iv)c(iv)]. Therefore, the assessment of its conservation status as "Endangered", obtained by Escuer *et al.* (2022), is further supported by the evaluation conducted in this study, based on more extensive and recent data. It is imperative for the IUCN Red List to revise its current assessment, which still considers *E. bazae* as "Least concern" (van Swaay *et al.*, 2015).

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Fig. 6.- Detail of the leaves and flowers of *Vella aspera* Pers. in Candasnos, Huesca. Photo: Yeray Monasterio.

Fig. 7.- Habitat of *Euchloe bazae* Fabiano, 1993 in Candasnos, Huesca, with *Vella aspera* Pers. in the centre of the image. Photo: Yeray Monasterio.

Figs. 8-9.- Habitat of *Vella pseudocytisus* subsp. *paui* Gómez-Campo in Villel, Teruel. Photos: Yeray Monasterio.

Fig. 10.- Detail of the leaves and the flower of *Vella lucentina* M.B. Crespo in San Vicente del Raspeig, Alicante. Photo: Yeray Monasterio.

Fig. 11.- *Vella lucentina* M.B. Crespo in San Vicente del Raspeig, Alicante. Photo: Yeray Monasterio.

Fig. 12.- Habitat of *Euchloe bazae* Fabiano, 1993 in Orce, Granada, with *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán in the centre of the image. Photo: Yeray Monasterio.

Fig. 13.- Detail of the leaves and flowers of *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Figs. 14-15.- Habitat of *Euchloe bazae* Fabiano, 1993 habitat in Orce, Granada, with *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán in the blooming peak. The fragmentation of the habitat due to modern agriculture can be observed. Photos: Yeray Monasterio.

Fig. 16.- Habitat of *Euchloe bazae* Fabiano, 1993 in Orce, Granada, with *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán in the blooming peak. Photo: Yeray Monasterio.

Fig. 17.- Habitat of *Euchloe bazae* Fabiano, 1993 in Orce, Granada, with Sierra de María in the background. Photo: Yeray Monasterio.

Fig. 18.- Habitat of *Euchloe bazae* in Hoya de Baza, Granada. This area is an agricultural environment with livestock use, where the natural vegetation is characterised by esparto grasslands. Photo: Yeray Monasterio.

Figs. 19-20.- Habitat of *Euchloe bazae* in Hoya de Baza, Granada. This area is an agricultural environment with livestock use, where the natural vegetation is characterised by esparto grasslands. Photos: Yolanda Rodríguez.

Fig. 21.- Underside of a male of *Euchloe bazae bazae* Fabiano, 1993 resting on the flowers of *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Fig. 22.- *Euchloe bazae bazae* Fabiano, 1993 female laying eggs on *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Fig. 23.- *Euchloe bazae bazae* Fabiano, 1993 male surveying a *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán bush at dusk, searching for a place to rest. Photo: Yeray Monasterio.

Fig. 24.- Copulation of *Euchloe bazae bazae* Fabiano, 1993 on *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Arturo Iglesias.

Fig. 25-26.- *Euchloe bazae bazae* Fabiano, 1993 eggs on *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán moments after being laid by the female. Photos: Yeray Monasterio.

Fig. 27.- *Euchloe bazae bazae* Fabiano, 1993 egg on *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán moments after being laid by the female. Photo: Arturo Iglesias.

Fig. 28.- *Euchloe bazae bazae* Fabiano, 1993 caterpillar reared in captivity, in the first stage (L1) on *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Fig. 29.- *Euchloe bazae bazae* Fabiano, 1993 caterpillars reared in captivity, in the first (L1, bottom) and second stages (L2, top) on *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Fig. 30.- *Euchloe bazae bazae* Fabiano, 1993 caterpillar reared in captivity, in the third stage (L3) on cultivated *Vella pseudocytisus* subsp. *pseudocytisus*. Photo: Yeray Monasterio.

Figs. 31-32.- *Euchloe bazae bazae* Fabiano, 1993 caterpillars reared in captivity, in the fourth stage (L4) on cultivated *Vella pseudocytisus* subsp. *pseudocytisus*. Photos: Yeray Monasterio.

Figs. 33-34.- *Euchloe bazae bazae* Fabiano, 1993 caterpillars reared in captivity, in the fifth stage (L5) feeding on cultivated *Vella pseudocytisus* subsp. *pseudocytisus*. Photos: Yeray Monasterio.

Figs. 35-36.- *Euchloe bazae bazae* Fabiano, 1993 caterpillars reared in captivity, in the fifth stage (L5) on cultivated *Vella pseudocytisus* subsp. *pseudocytisus*. The camouflage of the caterpillars can be appreciated, resembling the white, elongated hairs of the plant stems and leaves. Photos: Yeray Monasterio.

Fig. 37.- *Euchloe bazae bazae* Fabiano, 1993 caterpillars reared in captivity, in the fifth stage (L5), feeding on wild *Vella pseudocytisus* subsp. *orcensis*. The integration of the larvaes with their host plant is evident, with excellent camouflage. Photo: Yeray Monasterio.

Figs. 38-39.- *Euchloe bazae bazae* Fabiano, 1993 caterpillars from the Orce population, reared in captivity, in the fifth stage (L5), feeding on wild *Vella pseudocytisus* subsp. *orcensis*. Two different colourations were observed: one intense green, previously known, and another dull, bluish, with a more evident white lateral line. Photos: Yeray Monasterio.

Figs. 40-41.- *Euchloe bazae bazae* Fabiano, 1993 chrysalides reared in captivity, on cultivated *Vella pseudocytisus* subsp. *pseudocytisus*. Photos: Yeray Monasterio.

Fig. 42.- *Euchloe bazae bazae* Fabiano, 1993 female feeding on the nectar of *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Fig. 43.- *Pinus halepensis* Mill. plantations contributing to the habitat degradation of *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán in Orce, Granada. The image shows dead mature specimens of the plant at the edge of a pine plantation. Apparently, the pH soil reduction caused by pine needles makes these alkaline soil-associated plants unable to tolerate acidification. Photo: Yeray Monasterio.

Fig. 44.- Flock of Segureña sheep in extensive grazing feeding on bushes of *Vella pseudocytisus* subsp. *orcensis* Vivero, Simón-Porcar, Pérez-Coll. & Catalán. Photo: Yeray Monasterio.

Fig. 45.- 400 kV electrical substation in Baza, Granada, part of the power line that is expected to cut across the provinces of Granada and Almería, with potential impacts on the habitat of *Euchloe bazae* Fabiano, 1993. The ZERYNTHIA Association has been working intensively to highlight the need to avoid any impact on this butterfly species and its habitat. Photo: Yolanda Rodríguez.

Figs. 46-47.- Part of the research team during fieldwork for the study of *Euchloe bazae* Fabiano, 1993 in the province of Granada, 2024. Photos: Ruth Escobés.