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An interactive key (Lucid) for identification of the Western Palearctic butterflies in the genus *Pseudochazara* (Lepidoptera: Nymphalidae: Satyrinae)

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Abstract

This study presents a digital taxonomic monograph of the genus *Pseudochazara* de Lesse, 1951, focusing on 23 species occurring in the western part of the Palaearctic region, from North Africa and the Iberian Peninsula to the Caucasus and the Kopet Dagh Mountains. The system integrates an interactive multi-entry identification key developed using the Lucid platform, extensive comparative photographic material, and taxonomic pages for each species, including nomenclatural history, distribution data, and taxonomic notes. Identification within *Pseudochazara* is often challenging due to considerable intraspecific variation, overlap among external morphological characters, and pronounced sexual dimorphism. The multi-entry structure allows flexible selection of characters and supports identification based on photographic material. While primarily designed for species-level identification, the system also provides a framework for exploring morphological variability within taxa. The tool is intended as a practical resource for identification and comparative study, rather than as a formal taxonomic revision.

Key words: Brush-footed butterflies, electronic key, digital identification

Introduction

The genus *Pseudochazara* de Lesse, 1951 comprises a group of Satyrinae butterflies primarily distributed in dry mountainous habitats across the Palaearctic region, ranging from North Africa to the Himalayas, including China and Mongolia (Gross 1978; Verovnik & Wiemers 2016). Identification within the genus is often challenging, as several species show similar wing patterns and considerable intraspecific variation. In addition, pronounced sexual dimorphism further complicates identification, particularly when both sexes are considered together.

Major taxonomic treatments and classification-oriented studies of *Pseudochazara* exist (e.g. Gross 1978; Bogdanov 2004, 2007), yet practical identification within the genus remains difficult, particularly when based on photographic material. Previous studies have also noted that male genitalia often show limited interspecific differentiation within *Pseudochazara*, while androconial structures have been explored as potentially informative taxonomic characters for grouping species and assessing affinities (Brown 1976; Wakeham-Dawson 1996, 1997).

Traditional identification keys for the genus are scarce and often rely on static dichotomous keys, which may be difficult to apply to photographic material. Interactive identification systems have previously been developed for Lepidoptera, particularly for broader taxonomic or applied purposes. However, comparable species-level tools integrating extensive comparative photographic documentation for taxonomically difficult butterfly groups remain uncommon. To facilitate identification and comparative study of the genus, a novel digital taxonomic monograph has been developed, combining an interactive identification key with extensive photographic documentation and taxonomic information for each species. Unlike traditional printed keys, this system allows flexible selection of characters and can evolve over time as new data and species become available. The interactive nature of the tool allows users to navigate and identify taxa based on photographic evidence, providing a more flexible and accessible approach to species identification.

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While the present system provides a robust framework for morphological identification, it is acknowledged that the taxonomic complexity of the genus cannot be fully resolved without integrative approaches, including molecular data. The tool is therefore not intended to replace genetic analyses, but rather to complement them by facilitating consistent morphological interpretation and comparative assessment of taxa.

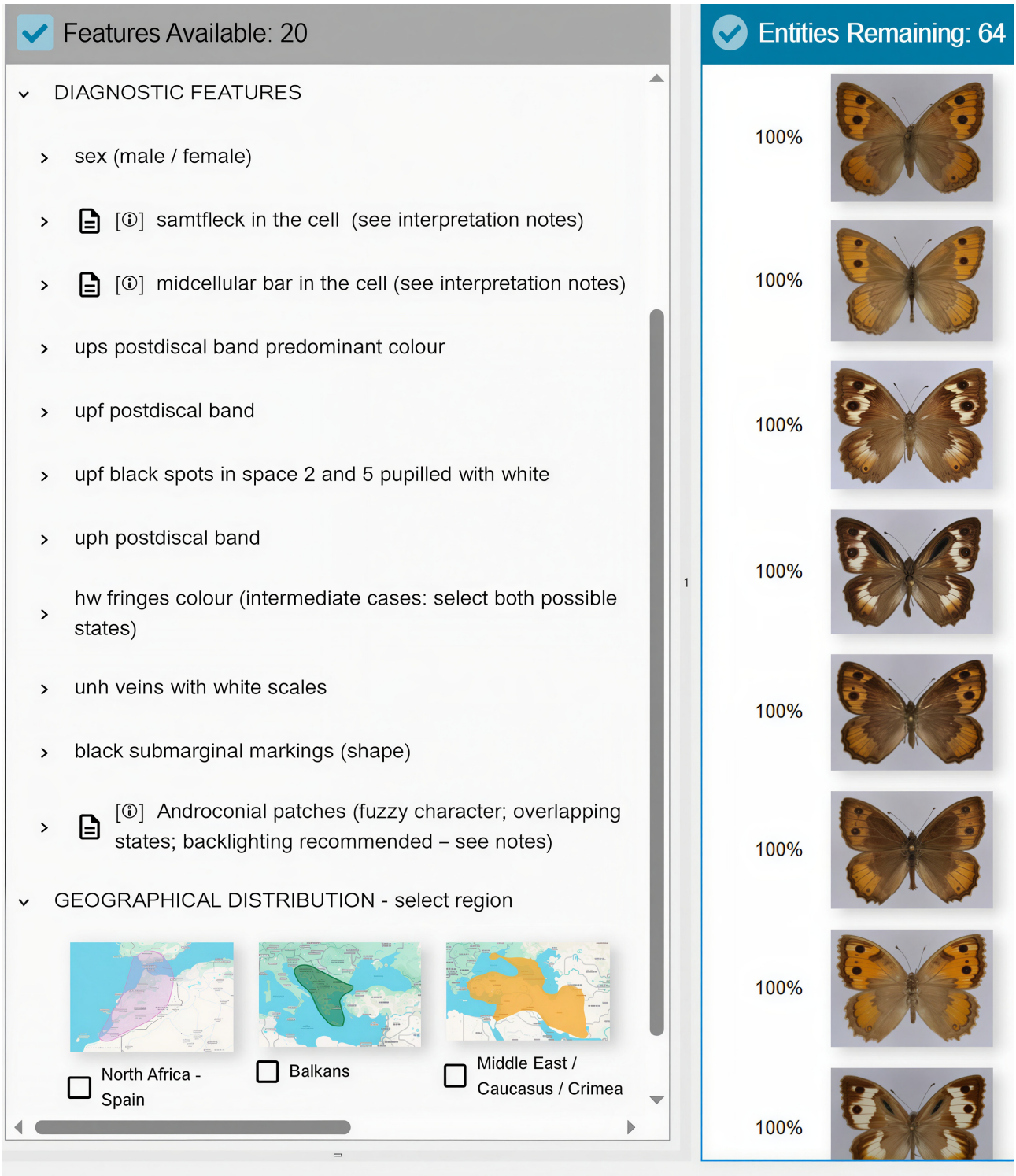

FIGURE 1. Screenshot of the interactive identification player interface showing the selection of characters and photographic comparisons.

Structure of the digital monograph

The digital monograph integrates three main components:

1. an interactive identification key developed using *Lucid Builder v4* (Lucidcentral, Australia);
2. extensive photographic galleries organised for comparative examination of taxa, including species-specific and comparative galleries;
3. taxonomic pages for each species, including nomenclatural history, distribution maps, and taxonomic notes.

The identification system, implemented using *Lucid Builder v4*, allows users to select morphological characters in any order and progressively reduce the list of possible taxa. This matrix-based approach, as implemented in the Lucid framework, is particularly suitable for groups such as *Pseudochazara*, where identification often relies on combinations of characters rather than single diagnostic traits. The photographic galleries enable direct visual comparison among species, subspecies, and sexes.

Taxonomic coverage

The present digital monograph covers 23 species of *Pseudochazara* occurring primarily in the western part of the genus range, extending from North Africa (Morocco) and southern Spain through the Balkans, Turkey, the Levant, Iran, and the Caucasus, up to the Kopet Dagh Mountains. Taxa occurring further east are not included, as their taxonomy remains controversial and in several cases insufficiently resolved, and their inclusion would require a dedicated and comprehensive revision that is beyond the scope of the present work. Future developments of the project may incorporate these eastern taxa as new data become available.

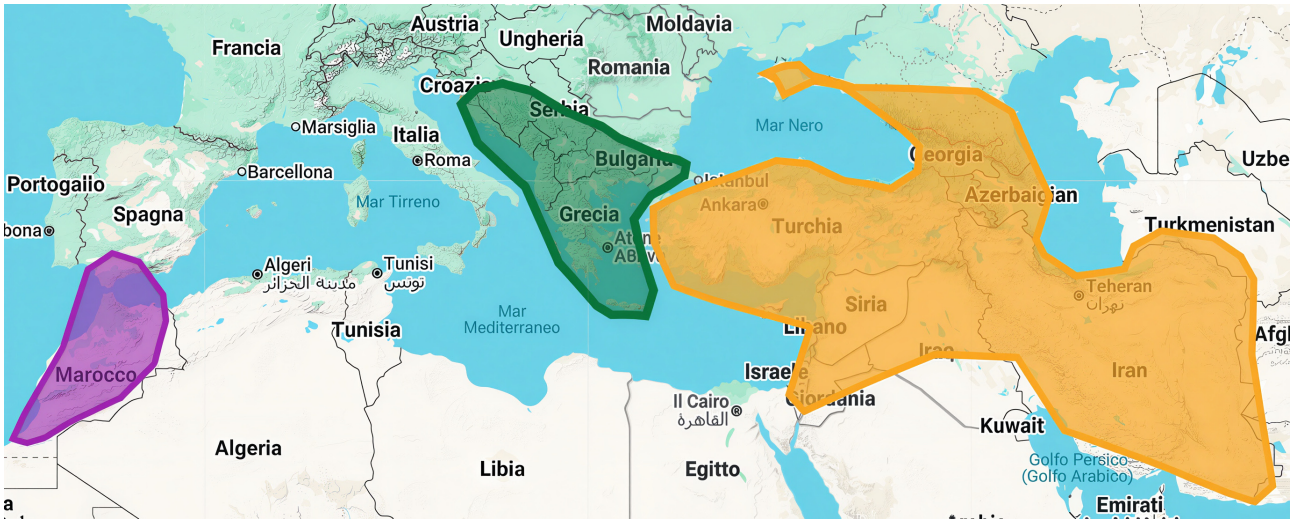

FIGURE 2. Map of the covered range (base map © Google. Map shading by authors).

In total, 64 taxa (including species and subspecies) are treated in the identification system, as males and females are considered separately due to the significant sexual dimorphism typical of the genus. Subspecies are also included when stable external characters, such as wing pattern, allow for reliable identification.

The species included in the key, in alphabetic order, include:

1. Pseudochazara alpina (Staudinger, 1878)
2. Pseudochazara amalthea (Frivaldszky, 1845)
3. Pseudochazara amymone Brown J., 1976
4. Pseudochazara anthelea (Hübner, 1824)
5. Pseudochazara atlantis (Austaut, 1905)
6. Pseudochazara beroe (Herrich-Schäffer, 1843)
7. Pseudochazara caucasica (Lederer, 1864)
8. Pseudochazara cingovskii (Gross, 1973)
9. Pseudochazara daghestana (Holik, 1955)

10. Pseudochazara euxina (Kusnezov, 1909)
11. Pseudochazara geyeri (Herrich-Schäffer, 1846)
12. Pseudochazara graeca (Staudinger, 1870)
13. Pseudochazara herrichi (Staudinger, 1901)
14. Pseudochazara lydia (Staudinger, 1878)
15. Pseudochazara mamurra (Herrich-Schäffer, 1846)
16. Pseudochazara mniszechii (Herrich-Schäffer, 1851)
17. Pseudochazara nukatli Bogdanov, 2000
18. Pseudochazara orestes de Prins & van Poorten, 1981
19. Pseudochazara pelopea (Klug, 1832)
20. Pseudochazara schakuhensis (Staudinger, 1881)
21. Pseudochazara telephassa (Geyer, 1827)
22. Pseudochazara tisiphone Brown J., 1980
23. Pseudochazara williamsi (Romei, 1927)

The taxonomic treatment adopted here follows a pragmatic approach aimed at facilitating identification at the species level. The status of several taxa included in the present list remains debated in the literature, with alternative taxonomic interpretations proposed by various authors.

The present work does not attempt to resolve these issues, and the identification system is not intended as a formal taxonomic revision of the genus.

Identification characters

The identification system is based on a set of characters derived from external morphology and wing pattern. Sex is treated as a primary variable, as males and females differ in several diagnostic features. Characters of the forewing include wing cell structure, such as the presence and structure of the androconial patch, including its distinctly pigmented component (samtfleck), and the midcellular bar, as well as the colour, structure, and continuity of the postdiscal band on the upperside. Additional forewing characters include the presence of ocelli with white pupils. The hindwing upperside provides further diagnostic information through variation in the postdiscal band, including its width, prominence, internal spots, and proximal shading. Additional characters include hindwing fringe colour, the presence of white scaling along the veins on the hindwing underside, and the shape of the submarginal markings. Characters specific to males include the structure and extent of androconial patches, which may vary from diffuse to well-defined and extensive. Geographic distribution is also included as an auxiliary variable, allowing the user to restrict the set of possible taxa based on broad regional occurrence. The characters used in the identification system are summarised in Table 1. Together, these characters provide a flexible framework for identification, allowing reliable discrimination among taxa despite the considerable morphological variability observed within the genus.

TABLE 1. Characters used in the identification system.

Feature category	Description
Sex	males and females treated separately
Forewing	Includes presence and structure of the androconial patch, including its distinctly pigmented component (samtfleck), midcellular bar, and variation in the postdiscal band (colour, prominence, internal shading, light spots, extension towards the costa, interruption in spaces 3–4)
Forewing ocelli (upperside)	Presence of black spots pupilled with white, particularly in spaces 2 and 5
Hindwing	Variation in postdiscal band (width, prominence, internal spots, proximal shading) and hindwing fringes (colour variation from light (white or cream) to dark)
Hindwing underside pattern	Presence or absence of white scaling along the veins
Submarginal markings	Shape of black markings, ranging from straight to strongly arched
Androconial patches (males)	Variation in structure, extent, and contrast, from diffuse to well-defined patches
Geographic distribution	Broad regional occurrence used as an auxiliary filtering variable

Photographic dataset

The digital monograph is supported by an extensive photographic dataset illustrating both dorsal and ventral wing patterns across taxa and geographic populations.

Images are organised into two types of galleries:

1. Species-specific galleries: each species and subspecies is represented by a dedicated image gallery illustrating dorsal and ventral wing patterns across taxa and geographic populations. .

2. Comparative galleries: these allow direct visual comparison among species, subspecies, and sexes. Additionally, they illustrate non-diagnostic morphological variation and assist users in interpreting morphological characters used in the identification key.

An example of non-diagnostic morphological variation illustrated in the photographic dataset is shown below.

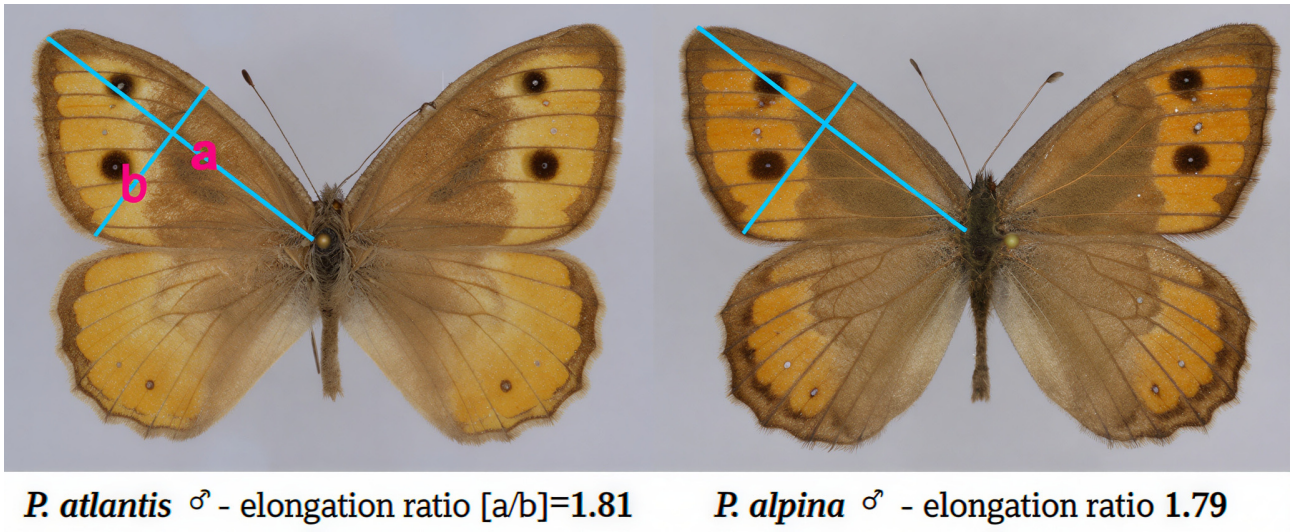

FIGURE 3. Example of non-diagnostic morphological variation (wing elongation) illustrated in the photographic dataset and not included in the identification key.

Taxonomic pages

Each taxon included in the system is accompanied by a dedicated page providing nomenclatural history, distribution maps, and taxonomic notes. These pages summarise the current taxonomic interpretation of each species and highlight cases where further study may be required to clarify relationships within species complexes.

Availability

The digital monograph and interactive identification key are archived on Zenodo with a persistent DOI, ensuring long-term accessibility:

https://doi.org/10.5281/zenodo.19034929.

The current version of the application can be accessed at:

https://pseudochazara-player.pages.dev, which is actively maintained and managed by the author.

Discussion

The digital format adopted for this project enables the integration of identification tools, photographic documentation, and taxonomic information within a single system. Compared with traditional printed keys, the interactive structure allows flexible selection of characters and facilitates identification based on photographic material.

To our knowledge, comparable species-level systems integrating an interactive identification key with extensive

photographic documentation and taxonomic information for a taxonomically challenging butterfly genus remain uncommon in Lepidoptera. The present system is intended not only as an identification tool, but also as a practical framework for comparative morphological studies.

The system is designed to be expandable and can be updated as new taxonomic or distributional data become available. While primarily intended for species-level identification, it also supports exploration of morphological variability within taxa through comparative photographic material and may assist in recognising geographically structured variation.

Future directions

A key objective of this project is to ensure that the identification key remains adaptable and can evolve over time. To this end, both the key and the underlying digital monograph are intended to be updated as new taxonomic or distributional data become available.

The system is publicly accessible, allowing researchers and entomologists to explore the identification key and submit suggestions for improvement. Proposed changes are subject to review and, if accepted, are incorporated into subsequent updates of the system.

This approach facilitates ongoing refinement of the tool and supports its use as a resource for the study and identification of *Pseudochazara* species.

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The development of the interactive identification key benefited from the invaluable guidance of G. C. Bozano, who introduced a rigorous and structured approach to the study of *Pseudochazara*.

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