Antlions (Myrmeleontidae) in the Doñana National Park

Hormigas león (Myrmeleontidae) en el Parque Nacional de Doñana

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Abstract

This study represents the first comprehensive survey of antlions (Myrmeleontidae) in Doñana National Park, conducted across 58 sampling locations during two field seasons (April–June 2023 and March–July 2024). A total of 12 species from 9 genera were identified, with 406 larval-stage specimens collected, of which 295 successfully emerged as adults (201 females and 94 males, including 28 imagos captured directly in the field). The altitudes of collection sites ranged from 2 to 38 meters above sea level, reflecting the diverse landscapes of the park. These findings enhance knowledge of the region's biodiversity. Notably, this research documents the first occurrences of *Distoleon tetragrammicus* and *Neuroleon ocreatus* in Huelva Province, expanding their known distribution ranges.

Our results highlight shrublands and grasslands as key habitats for antlion colonization, offering critical resources such as shelter and abundant prey. These biotopes provide optimal conditions for larval development due to fine soil textures and high prey availability. While most species occupied distinct ecological niches, *Myrmeleon hyalinus*, *M. almohadarum*, and *M. gerlindae* were observed coexisting in different biotopes, with spatial segregation driven by ecological requirements and competition.

This study establishes a foundational species inventory for Doñana National Park and underscores the importance of continued monitoring to assess ecological dynamics and species interactions. Future research should focus on resource competition, habitat preferences, and the impacts of environmental changes to further understand Myrmeleontidae adaptation and biodiversity within this protected area.

Keywords: Myrmeleontidae, antlions, Doñana National Park, Mediterranean, antlion larval development, antlion habitat, antlion diversity, shrublands, grasslands.

Resumen

Este estudio representa el primer relevamiento exhaustivo de las hormigas león (Myrmeleontidae) en el Parque Nacional de Doñana, realizado en 58 puntos de muestreo durante dos temporadas de campo (abril–junio de 2023 y marzo–julio de 2024). Se identificaron un total de 12 especies de 9 géneros, con 406 especímenes en fase larval recolectados, de los cuales 295 lograron emerger como adultos (201 hembras y 94 machos, incluyendo 28 imagos capturados directamente en el campo). Las altitudes de los puntos de recolección variaron entre 2 y 38 metros sobre el nivel del mar, reflejando los diversos paisajes del parque. Estos hallazgos mejoran significativamente el conocimiento sobre la biodiversidad de la región. Es destacable que esta investigación documenta las primeras ocurrencias de *Distoleon tetragrammicus* y *Neuroleon ocreatus* en la provincia de Huelva, ampliando sus rangos de distribución conocidos.

Los resultados destacan los matorrales y los pastizales como hábitats clave para la colonización de hormigas león, ofreciendo recursos críticos como refugio y abundante alimento. Estos biotopos proporcionan condiciones óptimas para el desarrollo larval debido a la textura fina del suelo y la alta disponibilidad de presas. Aunque la mayoría de las especies ocuparon nichos ecológicos distintos, se observó la coexistencia de *Myrmeleon hyalinus*, *M. almohadarum* y *M. gerlindae* en biotopos diferentes, con una segregación espacial impulsada por requerimientos ecológicos y competencia.

Este estudio establece un inventario fundamental de especies para el Parque Nacional de Doñana y subraya la importancia de un monitoreo continuo para evaluar las dinámicas ecológicas y las interacciones entre especies. Las investigaciones futuras deberían centrarse en la competencia por los recursos, las preferencias de hábitat y los impactos de los cambios ambientales para comprender mejor la adaptación de *Myrmeleontidae* y la biodiversidad dentro de esta área protegida.

Palabras clave: *Myrmeleontidae*, hormigas león, Parque Nacional de Doñana, Mediterráneo, desarrollo larval de hormigas león, hábitat de hormigas león, diversidad de hormigas león, matorrales, pastizales.

INTRODUCTION

Antlions (Myrmeleontidae) belong to the infraorder Neuropterida and constitute the most diverse family within Neuroptera. Over 2000 species of this family have been described worldwide (ASPÖCK et al., 2001; ACEVEDO et al., 2013). Antlions are distributed across all continents except Antarctica, with primary distribution centers in Asia and Africa. Additionally, they are found to a lesser extent in Australia and the Americas. In Europe, the Mediterranean region is the center of antlion distribution and exhibits the highest species diversity (ASPÖCK et al., 1980).

The life cycle of antlions comprises four stages: egg, larva, pupa, and adult. The majority of adult antlions lead an active nocturnal or crepuscular lifestyle, resting on vegetation during the daylight hours, though some species exhibit a more pronounced diurnal rhythm. Most adult antlions are predators; in some species, their diet includes plant pollen, and there are also non-feeding (afagous) species (ASPÖCK et al., 1980; STELZL & GEPP, 1990; MIRMOAYEDI, 2008). All antlion larvae are predators, primarily preying on ants and, to a lesser extent, other arthropods. They are well-known for their distinctive behavior, employing ambush hunting and constructing pitfall traps (MILLER & STANGE, 1985; STANGE, 2004; BADANO & PANTALEONI, 2014). The larvae of many antlion species construct conical pits in sand or fine soil. Typically, the larva settles at the bottom, burying itself in the soil, with only the jaws protruding above the surface, typically in a widely open position on both sides of the tip of the cone trap. The larvae go through three stages before burrowing into the ground and pupating. They are most commonly found in dry and sandy habitats, where larvae can easily dig their pits.

The Doñana Protected Area, including the National Park, is situated in the Mediterranean region, recognized as one of 34 global biodiversity hotspots (TABERLET et al., 1998; MYERS et al., 2000; DELIBES-MATEOS et al., 2008; ZACHOS & HABEL, 2011) (Fig.1). Despite its ecological importance, only a limited number of publications mention Myrmeleontidae species from the surrounding areas and the vicinity of the park (MONSERRAT & ACEVEDO, 2011, 2013; BARREDA et al., 2015; RAMOS, 2017; MONSERRAT, 2022). These studies provide valuable data;

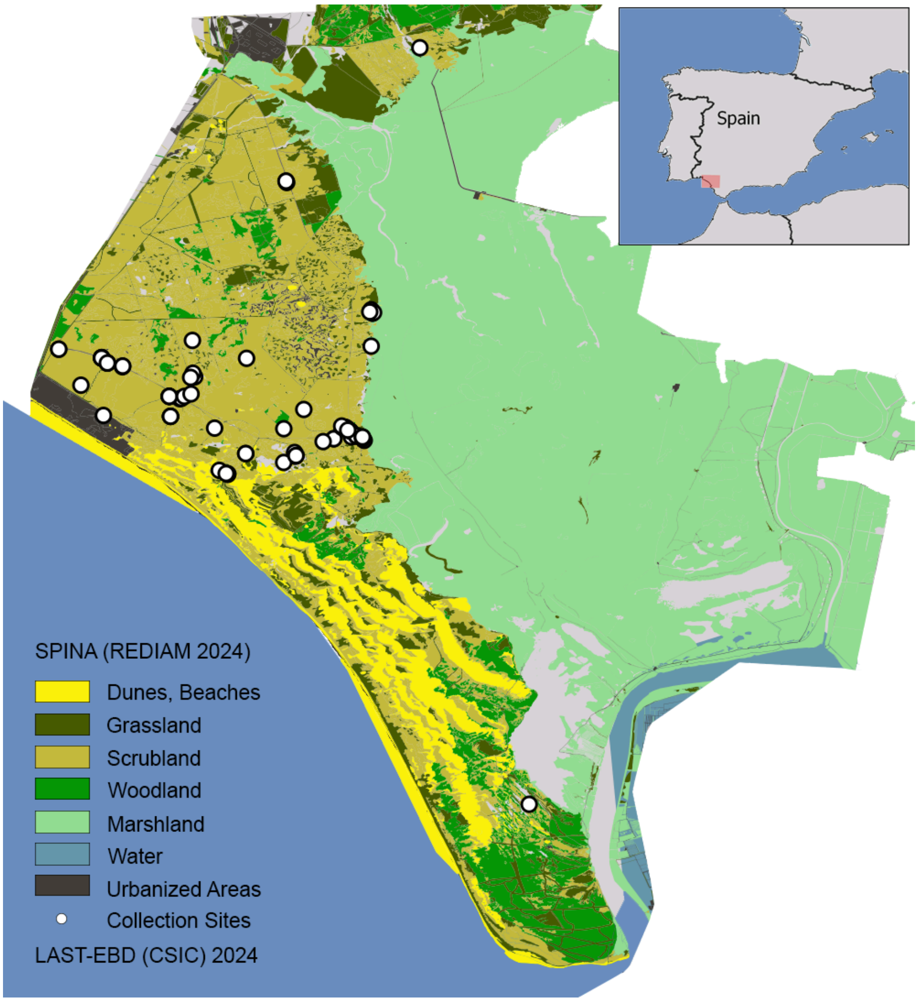

Figure 1. Map of habitat distribution and sampling locations for antlion larvae and adults in Doñana National Park, 2023–2024 (Figure by LAST-EBD/CSIC 2024 ©, with permission).
Figura 1. Mapa de la distribución de hábitats y los puntos de muestreo de larvas y adultos de hormigas león en el Parque Nacional de Doñana, 2023–2024 (Figura de LAST-EBD/CSIC 2024 ©, con permiso).

however, comprehensive investigations focused on antlions within the park itself have not been conducted until now.

Our primary objective was to study the species composition of antlions in Doñana National Park. Specifically, we aimed to identify which species are present in the park's most representative habitats and to explore the coexistence of antlion species that construct conical sand traps across different environments. By addressing these objectives, we sought to contribute to a deeper understanding of the ecological dynamics of antlion populations in this protected area.

To achieve this, we employed an integrated approach, combining field and laboratory methodologies. Our methodology included deploying Malaise traps over two consecutive seasons, from April to August in 2023 and 2024. Additionally, we periodically used a butterfly net to collect imagos and manually gathered larvae from their characteristic conical traps in the field. The collected larvae were reared to the adult stage in laboratory conditions to confirm species identification. These methods allowed us to systematically document the antlion fauna and, for the first time, compile a detailed species list for Doñana National Park. This contributes significantly to the understanding of biodiversity in this globally important region.

MATERIALS AND METHODS

Study area

Doñana National Park, located in southwestern Spain (Fig. 1), is one of the largest nature reserves in Europe. The ecological importance of this region led to its initial protection in 1963, with its establishment as a national park in 1969. In 1994, it was designated a UNESCO World Heritage Site due to its unique environmental value (PÉREZ-RAMOS et al., 2017). The region is characterized by a Mediterranean climate, with variable rainy seasons in autumn, winter, and spring, and hot and dry summers. These seasonal changes play a key role in shaping the park's diverse ecosystems. Doñana National Park is characterized by a rich array of terrestrial and aquatic ecosystems, ranging from pine and cork forests to shrublands, grasslands, dunes, and marshes with varying levels of salinity (PÉREZ-RAMOS et al., 2017).

Key zones of the park

Doñana National Park encompasses a variety of ecosystems that can be categorized into several key zones. Along the coastline lies a sandy beach area and an active dune system, which forms part of the largest mobile dune formation in Europe. Further inland, stabilized dunes host diverse shrublands. Beyond this lies the Vera, a transitional zone between dunes and marshes, characterized by unique soil types and vegetation that are crucial for maintaining biodiversity. The Vera creates a contour-like belt throughout the park, varying in width from a few meters to several kilometres. Finally, extensive marshlands, covering approximately 34,000 hectares, represent one of the largest wetland habitats in Europe and serve as critical stopover sites for migratory birds travelling between Africa and Europe (DOMINGO et al., 2020; RODRÍGUEZ-VIDAL et al., 2014; DÍAZ-PANIAGUA et al., 2016; SERRANO et al., 2006; LIONELLO et al., 2006; FERNÁNDEZ et al., 2010).Together, these habitats form a mosaic of environments, each playing a role in supporting the complex life cycles of the diverse antlion populations in Doñana.

Habitats within these zones

Within these primary zones, more specific habitats can be identified, such as beaches and dunes, grasslands, shrublands, forests, and areas influenced by urbanization (Fig. 1). All zones, except the marshes, provide unique conditions that support antlions at both larval and adult stages. The sandy, easily excavated soils of dunes and beaches allow antlions to construct their characteristic pit traps for hunting. Grasslands provide open landscapes rich in food resources for ants, which serve as the primary prey for antlions. Shrublands and forests feature diverse vegetation, creating a wide range of microclimatic niches that ensure stable population dynamics. Habitats such as roadsides and zones near human settlements offer unexpected yet favourable conditions for certain antlion species, mainly due to the high abundance of ants in these habitats (Tshiguvho et al., 1999; Amatta et al., 2023).

Sample collection

Larvae

Our habitat selection in Doñana National Park was guided by the ecological requirements of antlions, focusing on areas with suitable substrates rather than a random approach. We targeted habitats with sandy or loose soils that are conducive to antlion presence, ensuring that our sampling areas aligned with the species' specific habitat preferences within the park's diverse landscape (Fig. 2) (Supporting Material S1).

Figure 2. Typical habitats where antlions were collected in Doñana National Park: **a-d**: Roadside habitats with sandy soil, sparse vegetation, and low shrubs, typical of open and dry

roadside environments; **e-h**: Dune habitats with sandy soil and scattered low shrubs, adapted to arid and exposed conditions; **i-l**: Semi-natural areas near human habitation with scattered trees and open ground, providing shaded and moderately vegetated environments; **m-p**: Grassland areas with a mix of low grasses, shrubs, and occasional trees, offering open, sun-exposed habitats; **q-t**: Shrubland with scattered trees and low shrubs, creating a semi-wooded and structurally diverse environment; **u-x**: Dense shrubland with sandy soil and compact low shrubs.

Figura 2. Hábitats típicos donde se recolectaron hormigas león en el Parque Nacional de Doñana: **a-d**: Hábitats de bordes de caminos con suelo arenoso, vegetación escasa y arbustos bajos, típicos de entornos abiertos y secos; **e-h**: Hábitats de dunas con suelo arenoso y arbustos bajos dispersos, adaptados a condiciones áridas y expuestas; **i-l**: Áreas semi-naturales cerca de asentamientos humanos con árboles dispersos y suelo abierto, que proporcionan entornos sombreados y moderadamente vegetados; **m-p**: Áreas de pastizales con una mezcla de hierbas bajas, arbustos y árboles ocasionales, ofreciendo hábitats abiertos y expuestos al sol; **q-t**: Matorral con árboles dispersos y arbustos bajos, creando un entorno semi-boscoso y estructuralmente diverso; **u-x**: Matorral denso con suelo arenoso y arbustos bajos compactos.

Imago

During the field seasons of 2023 and 2024, from March to August, adult Myrmeleontidae were collected in Doñana National Park using a combination of butterfly nets and Malaise traps (Fig. 3).

Figure 3. Malaise trap set up in a pine forest near the dunes of Doñana National Park during the 2023–2024 field seasons.

Figura 3. Trampa Malaise instalada en un bosque de pinos cerca de las dunas del Parque Nacional de Doñana durante las temporadas de campo 2023–2024.

Malaise traps were deployed from April to August in both 2023 and 2024. We deployed the Malaise traps in four different habitats within the park to ensure a representative sample of the species present. The traps remained open continuously throughout the study period, while butterfly nets were used whenever conditions allowed, providing comprehensive data on adult emergence and activity. The combination of active (butterfly net) and passive (Malaise trap) methods enabled the capture of individuals from different species, increasing the robustness of the dataset. All captured specimens were preserved in 96% ethanol and are stored in the collections of the Doñana Biological Station (EBD-CSIC).

RESULT

A total of 58 locations (Fig. 1) across Doñana National Park were surveyed for antlions (Myrmeleontidae) during two collection periods: from April 25, 2023, to June 22, 2023, and from March 28, 2024, to July 27, 2024. Larval-stage collections yielded 406 specimens, of which 295 successfully emerged as adults in the laboratory, including 201 females and 94 males. Additionally, 28 imago-stage individuals were directly captured in the field using butterfly nets and Malaise traps, comprising 15 males and 13 females. The total number of adult individuals, therefore, was 323. The altitudes of the collection sites ranged from 2 to 38 meters above sea level. Following the identification and processing of the collected material, a total of 12 species representing 9 genera of antlions were documented.

We surveyed areas with loose soil to identify antlion species and assess whether multiple species could share the same habitat. During the study, we recorded four species that construct conical pit traps, along with *Synclisis baetica*, which was observed both with and without traps, suggesting flexibility in its hunting strategies.
Co-occurrence of species within the same habitat was observed. For example, *Myrmeleon hyalinus* and *Myrmeleon almohadarum* were frequently found along dirt road edges but displayed spatial segregation. *M. hyalinus* preferred areas near vegetation, constructing traps at plant bases, while *M. almohadarum* inhabited open sandy patches closer to the road. In one location, M. *hyalinus, M. almohadarum,* and *Myrmeleon gerlindae* were found coexisting. In contrast, *Myrmecaelurus trigrammus* was never observed near other species, indicating a preference for solitary habitats.

Our research findings indicate that shrub-dominated biotopes are the most attractive for ant colonization. We recorded ten species within this biotope (Fig. 4). Open grassland biotopes are also favourable for settlement, with six species collected in these areas. Other suitable biotopes exhibited relatively low species diversity; specifically, three species were observed in dune and urbanized areas, while only two species were found in coniferous forests.

In the following section, we provide detailed information for each Myrmeleontidae species recorded in Doñana National Park. Each entry includes data on the species' broader distribution, the specific habitat characteristics at the collection sites, geographical coordinates, and relevant details of the collected specimens.

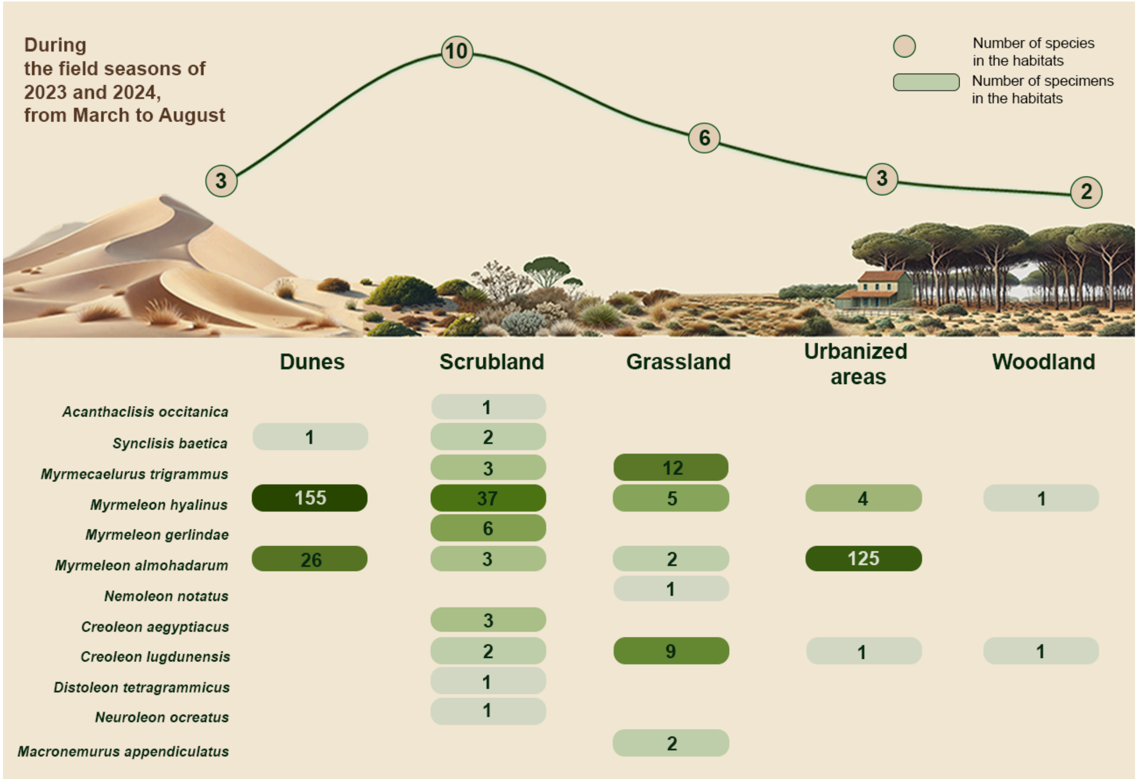

Figure 4. Habitat preferences of antelope species recorded in Doñana National Park during the 2023-2024 field seasons, based on collection data from March to August.

Figura 4. Preferencias de hábitat de las especies de hormigas león registradas en el Parque Nacional de Doñana durante las temporadas de campo 2023–2024, basadas en datos de recolección de marzo a agosto.

List of Myrmeleontidae species of the Doñana National Park:

MYRMEMELONTIDAE Latreille, 1802

Acanthaclisinae Navás, 1912

Acanthaclisini Navás, 1912

***Acanthaclisis occitanica* (Villers, 1789)** (Fig. 5)

A Holomediterranean species, distributed in the Western Palearctic, including the Caucasus, Armenia, Iran, Afghanistan, Pakistan, India, and Kazakhstan. It is also known from the Iberian Peninsula and Mallorca in Mediterranean-influenced regions (MONSERRAT & ACEVEDO, 2013; BADANO & PANTALEONI, 2014; MONSERRAT, 2022).

In Andalusia, records of this species have been reported from the provinces of Almería (MONSERRAT & ACEVEDO, 2011; BADANO & PANTALEONI, 2014), Huelva (RAMOS, 2017), Sevilla (BARREDA et al., 2015; RAMOS, 2017), Cádiz (RAMOS, 2017), Málaga (RAMOS, 2017) and Jaén (RAMOS, 2017).

New examined material: 27.07.2024, 1 2nd instar larva (7 m a.s.l., 36°58'59.2"N 6°28'04.5"W).

We found one second instar larva in sandy soil; the surrounding vegetation included shrubs *Halimium halimifolium* (L.) Willk. and *Juniperus macrocarpa* Sibth. & Sm., along with herbaceous plants, primarily from the Poaceae family, and scattered bushes of *Lavandula pedunculata* (Mill.) Cav. The larva was identified, and its instar determined using the keys provided by BADANO & PANTALEONI (2014).

***Synclisis baetica* (Rambur, 1842)** (Fig. 5)

A Holomediterranean species, distributed from Macaronesia and Senegal to Anatolia and Iran. It is known across the entire Iberian Peninsula and Mallorca, particularly in coastal regions. The species has been recorded throughout the Iberian Peninsula, especially in the coastal areas of both the Atlantic Ocean and the Mediterranean Sea, as well as on the Balearic Islands (MONSERRAT & ACEVEDO, 2013; BARREDA et al., 2015; MONSERRAT, 2022).

In Andalusia, records of this species come from the provinces of Almería (MONSERRAT & ACEVEDO, 2013, 2011; BARREDA et al., 2015; RAMOS, 2017; MONSERRAT, 2022) Huelva (RAMOS, 2017), Cádiz (BARREDA et al., 2015), Córdoba (BARREDA et al., 2015), Málaga (BARREDA et al., 2015; RAMOS, 2017) and Sevilla (RAMOS, 2017).

Figure 5. Larvae of two antlion species collected in Doñana National Park: a) *Acanthaclisis occitanica*; **b)** *Synclisis baetica*.

Figura 5. Larvas de dos especies de hormigas león recolectadas en el Parque Nacional de Doñana: a) *Acanthaclisis occitanica*; **b)** *Synclisis baetica*.

New examined material: Three larvae at different instar stages were found at three separate locations: 1 3rd instar larva → 1♀ on 28.03.2024 (20 m a.s.l., 36°58'36.3"N 6°29'36.0"W); 1 1st instar larva on 10.06.2024 (13 m a.s.l., 36°59'35.5"N 6°28'19.7"W); 1 2nd instar larva on 11.07.2024 (11 m a.s.l., 36°59'36.3"N 6°29'51.3"W).

We collected the first larva, in the third instar stage, from dune sand within a conical pit trap with a diameter of 7.34 mm, located at the base of *Corema album* (L.) D.Don in a shaded area. Under laboratory conditions, the adult emerged on August 17. We collected the second larva, in the first instar stage, from sand on a wide dirt road, 70 cm from the roadside and 10 m from shrubs and continuous herb cover. Nearby vegetation included scattered plants of *Malcolmia littorea* (L.) W.T. Aiton and species from the Poaceae family. Although no pit trap was present, a small depression was visible in the sand. We found the third larva accidentally in the sand without any visible conical pit trap or markings. Nearby vegetation included scattered herbaceous plants and *Halimium halimifolium* shurbs. We identified the larval instars and determined their stages using the keys provided by BADANO & PANTALEONI (2014).

Myrmecaelurinae Esben-Petersen, 1919
Myrmecaelurini Esben-Petersen, 1919
***Myrmecaelurus trigrammus* (Pallas, 1771)** (Fig.7)

A Holomediterranean species, distributed across the Caucasus, Armenia, Iran, Kyrgyzstan, Tajikistan, Afghanistan, and Kazakhstan. It is known from the Iberian Peninsula and the Balearic Islands (Mallorca, Formentera) in Mediterranean-influenced regions (MONSERRAT & ACEVEDO, 2013, 2011; BARREDA et al., 2015; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Almería (MONSERRAT & ACEVEDO, 2013, 2011; RAMOS, 2017), Cádiz (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017), Córdoba (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017), Granada (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Jaén (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017), Huelva (Doñana, La Rocina, Matalascañas) (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017), Málaga (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017) and Sevilla (RAMOS, 2017).

<u>New examined material:</u> 09.05.2024, 3rd instar → 2♀ (7 m a.s.l., 36°59'20.11992"N 6°26'33.17208"W), 3rd instar → 1♀ (8 m a.s.l., 36°58'59.94408"N 6°28'3.5436"W), 3rd instar → 1♀ (4 m a.s.l., 37°2'9.13776"N 6°26'20.79456"W); 14.05.2024, 3rd instar → 1♀ (7 m a.s.l., 36°59'36.3"N 6°29'51.3"W); 31.05.2024, 3rd instar → 1♀ (8 m a.s.l., 36°58'59.94408"N 6°28'3.5436"W); 26.06.2024, 1♀ 1♂ (2 m a.s.l., 37°02'08.4"N 6°26'22.3"W); 01.07.2024, 1♂ (9 m a.s.l., 36°59'37.34412"N 6°27'2.60388"W), 1♂ (8 m a.s.l., 36°59'36.3"N 6°29'51.3"W), 1♂ (9 m a.s.l., 36°59'35.70432"N 6°26'55.35852"W), 2♂ (5 m a.s.l., 36°59'32.2609"N 6°26'51.43848"W); 11.07.2024, 1♀ 1♂ (2 m a.s.l., 37°02'12.8"N 6°26'24.1"W).

Adults of this species prefer open, sunlit environments, particularly grassy meadows (MONSERRAT & ACEVEDO, 2013). In Doñana National Park, although relatively common, this species tends to localize in specific areas with favorable conditions. It thrives in open habitats with dense grassy vegetation, primarily composed of species from the Poaceae family. The larvae construct cone-shaped pit traps at the base of plants, which is typical of their behaviour. The adult flight period begins in early June and extends through the first week of August, with peak activity observed between mid-June and late July in 2024. We identified the larvae collected during the study and determined their developmental stages using the classification keys of BADANO & PANTALEONI (2014).

Myrmeleontinae Latreille, 1802
Myrmeleontini Latreille, 1802
***Myrmeleon hyalinus* Olivier, 1811**

Holomediterranean species. This species is widely distributed from Macaronesia and North Africa (Morocco, Algeria, Libya, Egypt, Ethiopia, Gambia, Mauritania, Senegal, Sudan) to Syria, Saudi Arabia, Oman, Yemen, Iran, Iraq, Uzbekistan, India, and Afghanistan. It is well-known across the Iberian Peninsula and the Balearic Islands (Mallorca, Menorca, Formentera, Ibiza), primarily in coastal areas influenced by the Mediterranean Sea (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, records of this species come from the provinces of Almería (MONSERRAT & ACEVEDO, 2011, 2013; RAMOS, 2017), Cádiz (MONSERRAT & ACEVEDO, 2011, 2013; RAMOS, 2017), Granada (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Huelva (Matalascañas, Punta Umbría, Doñana, La Rocina) (MONSERRAT & ACEVEDO, 2011, 2013; RAMOS, 2017) and Jaén (MONSERRAT & ACEVEDO, 2011).

<u>New examined material:</u> 17.05.2023, 3rd instar → 3♂ (3 m a.s.l., 36°59'24.5"N 6°26'35.5"W), 3rd instar → 7♀ 2♂ (22 m a.s.l., 36°59'51.9"N 6°30'49.7"W); 15.06.2023, 3rd instar → 1♀ (22 m a.s.l., 37°01'08.6"N 6°29'09.0"W); 02.04.2024, 3rd instar → 1♀ (38 m a.s.l., 37°01'20.7"N 6°33'17.7"W), 3rd instar → 1♀ (31 m a.s.l., 37°01'20.7"N 6°33'17.7"W); 08.04.2024, 3rd instar → 1♀ (34 m a.s.l., 37°0'58.31892"N 6°31'53.08212"W); 11.04.2024, 3rd instar → 1♀ (22 m a.s.l., 37°00'15.6"N 6°30'35.3"W); 15.04.2024, 3rd instar → 1♀ (24 m a.s.l., 37°0'48.942"N 6°30'20.01996"W); 09.05.2024, 3rd instar → 1♂ (5 m a.s.l., 37°2'10.0932"N 6°26'25.8774"W), 3rd instar → 1♀ (35 m a.s.l., 37°0'57.44448"N 6°31'53.35788"W), 3rd instar → 1♂ (6 m a.s.l., 36°59'39.06078"N 6°27'3.03408"W), 3rd instar → 1♀ (31 m a.s.l., 36°59'36.3"N 6°29'51.3"W), 3rd instar → 1♀ (37 m a.s.l., 37°01'32.3"N 6°30'20.7"W), 14.05.2024 3rd instar → 1♂ (29 m a.s.l., 37°0'15.24744"N 6°30'37.501304"W), 3rd instar → 1♀ (31 m a.s.l., 37°0'18.29484"N 6°30'51.37308"W), 3rd instar → 1♂ (12 m a.s.l., 36°58'36.003"N 6°29'33.88992"W), 3rd instar → 1♂ (10 m a.s.l., 36°59'2.69988"N 6°29'10.14576"W), 3rd instar → 2♂ (37 m a.s.l., 37°1'9.0768"N 6°32'20.96988"W), 3rd instar → 1♀ (31 m a.s.l., 37°0'18.29484"N 6°30'51.37308"W), 3rd instar → 1♂ (10 m a.s.l., 36°59'2.69988"N 6°29'10.14576"W), 3rd instar → 1♀ (35 m a.s.l., 36°59'36.3"N 6°29'51.3"W), 3rd instar → 1♀ (37 m a.s.l., 37°1'9.0768"N 6°32'20.96688"W), 3rd instar → 1♂ (34 m a.s.l., 37°1'2.43984"N 6°32'13.3242"W), 3rd instar → 1♀ (37 m a.s.l., 37°1'9.0768"N 6°32'20.96988"W), 3rd instar → 1♀ (37 m a.s.l., 37°1'9.0768"N 6°32'20.96988"W), 3rd instar → 1 (35 m a.s.l., 37°1'2.43984"N 6°32'13.3242W), 3rd instar → 2♀ (31 m a.s.l., 37°0'18.29484"N 6°30'51.37308"W), 3rd instar → 1♀ (7 m a.s.l., 36°59'36.3"N 6°29'51.3"W), 3rd instar → 1♀ (29 m a.s.l., 37°0'43.36668"N 6°30'23.03388"W), 3rd instar → 1♀ (37 m a.s.l., 37°1'9.59988"N 6°32'20.814"W), 3rd instar → 1♀ (12 m a.s.l., 37°58'35.1804"N 6°29'33.8334"W), 3rd instar → 2 (34 m a.s.l., 37°1'2.43984"N 6°32'13.3242"W), 3rd instar → 1♂ (37 m a.s.l., 37°1'9.0768"N 6°32'20.96988"W), 3rd instar → 1♀ (31 m a.s.l., 37°0'18.29484"N 6°30'31.37308"W), 3rd instar → 2♀ (12 m a.s.l., 36°58'35.1804"N 6°29'33.8344"W), 3rd instar → 1♂ (34 m a.s.l., 37°1'2.43984"N 6°32'13.3242"W), 01.07.2024 3rd instar → 1♀1♂ (9 m a.s.l., 36°59'37.34412"N 6°27'2.60388"W), 26.03.2024 larvae 58, 1–3 instars → 50♂43♀(7 m a.s.l., 36°58'36.1"N 6°29'36.5"W).

Myrmeleon hyalinus is one of the most characteristic species of Doñana National Park, frequently encountered across various habitats. The larvae construct cone-shaped pit traps in sandy soil and begin their activity in late February or early March, depending on weather conditions. Over the course of the year, two generations were observed. The first generation consists of overwintering larvae that emerge in early spring, with adults appearing from May to early June. The second generation of larvae starts to appear in early August.

Although larvae were found in a variety of habitats, they were most frequently encountered in specific environments, such as sandy dunes with sparse shrubs like

Corema album and *Juniperus macrocarpa*. Larvae are also commonly found in partially shaded sandy areas along dirt roads or in grassy habitats dominated by species from the Poaceae family. In addition, larvae have been observed near human dwellings, indicating their adaptability to different environments.

Larval stages were identified and classified using the work of BADANO & PANTALEONI (2014).

Myrmeleon gerlindae **Hölzel, 1974** (Fig. 7)

This Western Mediterranean species is known from the Iberian Peninsula, southern France, northern and western Italy, Sardinia, and Morocco, primarily in areas influenced by the Mediterranean climate. (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, records of this species come from the provinces of Granada (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Huelva (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Jaén (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), and Málaga (RAMOS, 2017).

New examined material: 17.05.2023, 3rd instar → 1♂ (24 m a.s.l., 36°59'51.9"N 6°30'49.7"W); 08.04.2024, 3rd instar → 1♀ (22 m a.s.l., 36°59'58.31892"N 6°31'53.08212"W), 3rd instar → 1♂ (35 m a.s.l., 36°0'58.31892"N 6°31'53.08212"W); 14.05.2024, 3rd instar → 1♂ (8 m a.s.l., 36°59'14.1"N 6°27'50.8"W); 01.07.2024, 1♂ (6 m a.s.l., 36°59'21.1"N 6°27'20.4"W), 1♀ (9 m a.s.l., 36°59'18.5"N 6°27'27.6"W).

Adults of *Myrmeleon gerlindae* inhabit forested, open, and sunny areas, sometimes in coastal or mountainous regions. The larvae prefer sandy forested environments with abundant plant debris, where they construct their typical pit traps (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022). We collected one larva from a conical pit trap in sand along the edge of a dirt road and reared it under laboratory conditions. Other specimens were adults that we captured using an entomological net in their typical shrub-grass habitats with low vegetation density. We identified and classified the larval stages using the keys provided by BADANO & PANTALEONI (2014).

Myrmeleon almohadarum **Badano et al., 2016** (Fig.6)

This species was described in 2016 from specimens collected in Spain and North Africa, particularly Tunisia. It is known from the southern Iberian Peninsula, the Balearic Islands (Ibiza), and with new records from Sevilla and Tarragona (RAMOS, 2017; MONSERRAT, 2022).

In North Africa, it has been recorded in Tunisia, and it is likely distributed across the northwestern Mediterranean coast of Africa, excluding desert regions (RAMOS, 2017; MONSERRAT, 2022).

In Andalusia, records of this species come from the provinces of Cádiz (BADANO et al., 2016, RAMOS, 2017), Almería (BADANO et al., 2016, RAMOS, 2017), Huelva (Punta Umbría) (BADANO et al., 2016, RAMOS, 2017), Jaén

(BADANO et al., 2016, RAMOS, 2017), Málaga (BADANO et al., 2016, RAMOS, 2017) and Sevilla (RAMOS, 2017; MONSERRAT, 2022).

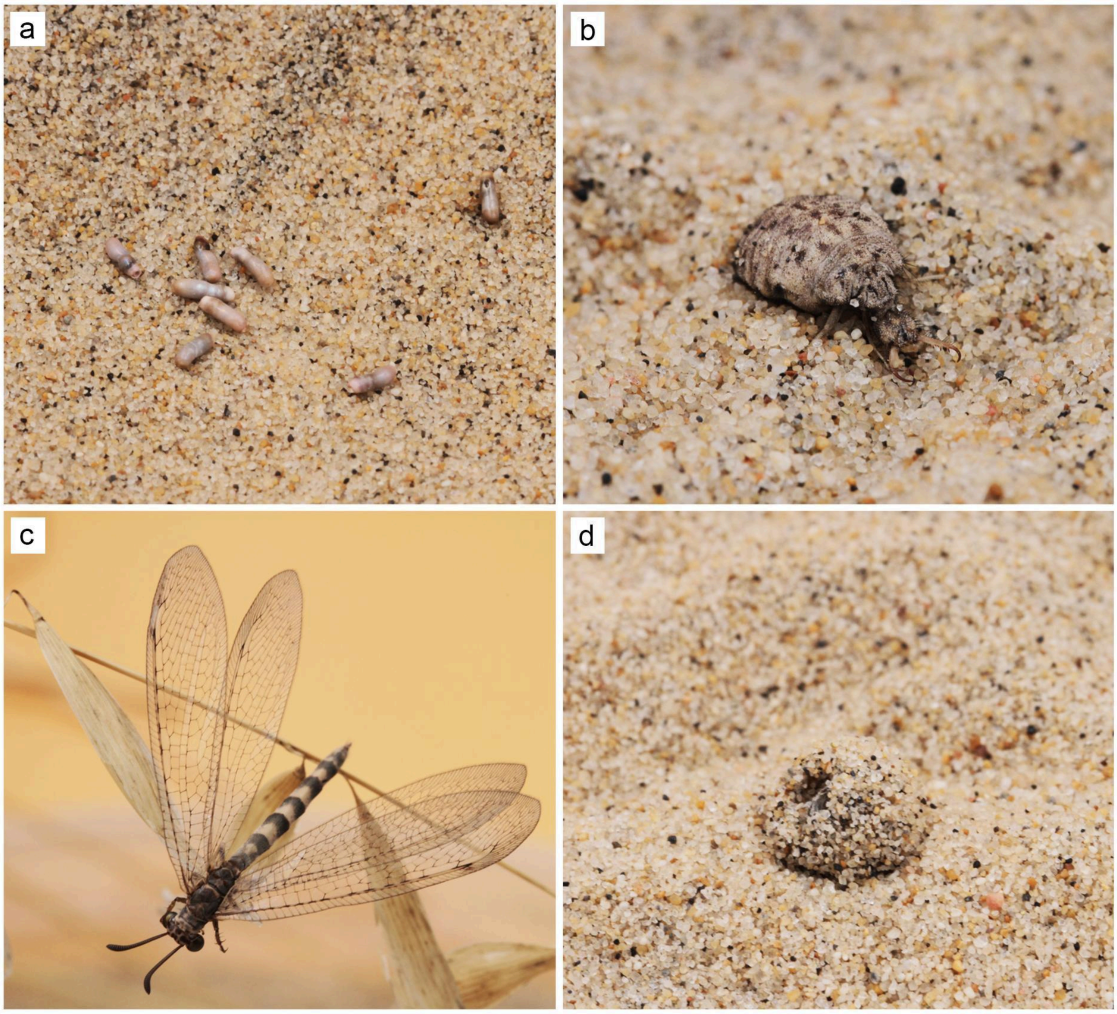

Figure 6. Life cycle stages of *Myrmeleon almohadarum*: a) eggs, **b)** 3rd instar larva, **c)** cocoon, **d)** adult.

Figura 6. Etapas del ciclo de vida de *Myrmeleon almohadarum*: a) huevos, **b)** larva de tercer estadio, **c)** capullo, **d)** adulto.

New examined material: 17.05.2023, 3rd instar → 11♀ 2♂ (3 m a.s.l., 36°59'24.5"N 6°26'35.5"W), 3rd instar → 2♀ 2♂ (21 m a.s.l., 36°59'51.9"N 6°30'49.7"W); 09.05.2024, 3rd instar → 3♀ 2♂ (3 m a.s.l., 36°59'22.5366"N 6°26'35.41812"W), 10.05.2024, 3rd instar → 2♀ 1♂ (3 m a.s.l., 36°59'25.9836"N 6°26'43.23012"W), 3rd instar → 1♂ (23 m a.s.l., 36°58'35.9"N 6°29'43.4"W), 29.05.2024, 3rd instar → 2♀ (21 m a.s.l., 37°00'44.3"N 6°30'14.7"W); 26.03.2024, larvae 7, 1–3 instars → 7♂11♀(3 m a.s.l., 36°58'36.1"N 6°29'36.5"W); 01.06.2024, larvae 15, 1–3 instars → 2♂87♀(11 m a.s.l., 36°59'23.5"N 6°26'35.2"W).

In Tunisia, *M. almohadarum* larvae, which construct pit traps, have been found in old coastal sandy dunes with woody vegetation, including pine plantations. In Spain, in addition to coastal dunes, the species has also been recorded along riverbanks and dry streambeds (MONSERRAT, 2022).

This species constructs cone-shaped pit traps in sandy dunes and along dirt roads near residential areas, similar to *Myrmeleon hyalinus*. Larval populations can number several hundred individuals in a single area. However, unlike *Myrmeleon hyalinus* and *Myrmecaelurus trigrammus*, we have not observed mass adult flights, nor have we captured adults in Malaise traps or with entomological nets. The cone-shaped pit traps of *M. almohadarum* are frequently found in the shade of shrubs and herbaceous plants, though about 5% of the traps are located in fully exposed sandy areas without shade. Laboratory studies indicate that this species is well-adapted to survive in high-temperature environments.

We identified the larval stages following the work of BADANO et al. (2016).

***Nemoleon notatus* (Rambur, 1842)**

This is a Circum-Saharan species, it is known from the Iberian Peninsula and Mallorca, with reports from Spain, Italy (Sardinia), Morocco, Algeria, Ethiopia, Chad, Uganda, Angola, and Madagascar. In Europe, it has been found on the Iberian Peninsula and the Balearic Islands (Mallorca), with a focus on Mediterranean coastal areas (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Almería (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Granada (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Huelva (Matalascañas) (BARREDA et al., 2015; RAMOS, 2017) and Jaén (RAMOS, 2017).

New examined material: 15.06.2023, 1♀ (29 m a.s.l., 37°00'22.5"N 6°30'20.0"W).

N. notatus is a little-known species, typically reported in the literature as being associated with open, arid environments such as savannas. In Europe, it has primarily been recorded in dry coastal areas, where adults are found in very hot, sub-desert, open, xeric, rocky, and sunny habitats (MONSERRAT, 2022).

In our study, we captured one specimen using an entomological net in an open area with dense grass cover, predominantly Poaceae, interspersed with scattered shrubs, characteristic of a typical xeric landscape.

***Creoleon aegyptiacus* (Rambur, 1842)**

This expansive Holomediterranean species is known from Egypt, Algeria, Tunisia, Morocco, Spain, Italy (Sicily and adjacent islands), Israel, Iraq, Iran, and Afghanistan. In the Iberian Peninsula, it has been recorded from both continental and Mediterranean regions, including the Balearic Islands (Mallorca, Menorca, Ibiza).(BARREDA et al., 2015; MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022) (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Almería (MONSERRAT & ACEVEDO, 2011, 2013; RAMOS, 2017), Cádiz (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Granada (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Huelva (Matalascañas), (MONSERRAT, 1986; MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Málaga (MONSERRAT & ACEVEDO, 2011;

RAMOS, 2017), Jaén (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017), and Sevilla (RAMOS, 2017).

New examined material: 01.07.2024, 1♂ (10 m a.s.l., 36°59'17.5"N 6°27'19.6"W), 1♀ (10 m a.s.l., 36°59'04.1"N 6°28'05.4"W), 3rd instar → 1♀ (8 m a.s.l., 36°58'50.9264"N 6°28'19.82388"W).
Literature sources indicate that the adults of *Creoleon aegyptiacus* inhabit hot, dry, arid, open, and sunny environments, often in dried-out meadows.

We collected three adults using a butterfly net, sweeping insects off various shrubs and herbaceous plants, such as *Halimium halimifolium*, *Salvia rosmarinus* Spenn., *Lavandula pedunculata*, *Linaria viscosa* (L.) Dum.Cours, *Thymus mastichina* (L.) L., and *Armeria gaditana* Boiss.

The habitats where we collected *Creoleon aegyptiacus* were quite similar — dry, sandy areas with scattered vegetation consisting of shrubs and herbaceous plants.

***Creoleon lugdunensis* (Villers, 1789)** (Fig. 7)

This Western Mediterranean species is known from Croatia, Switzerland, Italy, Malta, France, Spain, Portugal, Morocco, and Tunisia. It is found in Mediterranean-influenced areas of the Iberian Peninsula and the Balearic Islands (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Almería (MONSERRAT & ACEVEDO, 2011, 2013; RAMOS, 2017), Cádiz (MONSERRAT & ACEVEDO, 2013; BARREDA et al., 2015; RAMOS, 2017), Córdoba (BARREDA et al., 2015; RAMOS, 2017), Granada (BARREDA et al., 2015; RAMOS, 2017), Málaga (BARREDA et al., 2015; RAMOS, 2017), Jaén (MONSERRAT & ACEVEDO, 2011, 2013; RAMOS, 2017), Huelva (El Rocío, Niebla) (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017) and Sevilla (BARREDA et al., 2015; RAMOS, 2017).

New examined material: 25.04.2023, 3rd instar → 3♂2♀ (10 m a.s.l., 37°05'01.1"N 6°28'15.8"W), 1♀ (5 m a.s.l., 37°07'59.3"N 6°25'19.5"W), 04.05.2023, 1♂ (5 m a.s.l., 36°51'18.9"N 6°22'54.8"W); 01.06.2023, 1♀ (3 m a.s.l., 36°59'24.8"N 6°26'50.2"W); 06.05.2024, 3rd instar → 1♂ (6 m a.s.l., 37°01'24.7"N 6°26'24.0"W); 26.06.2024, 1♀ (2 m a.s.l., 37°02'08.4"N 6°26'22.3"W); 01.07.2024, 1♂ (9 m a.s.l., 36°59'37.34412"N 6°27'2.60388"W); 01.07.2024, 1♀1♂ (5 m a.s.l., 36°59'32.2609"N 6°26'51.43848"W).

According to the literature, adults of *Creoleon lugdunensis* are frequently found in dry, open, sunny environments without woody vegetation, such as steppes, dried-out meadows, forest clearings, as well as in thermal and arid coastal areas (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In our study, we collected adults of this species using two methods: Malaise traps and a butterfly net. The Malaise trap was set among shrubs like *Juniperus macrocarpa*, *Halimium halimifolium*, juvenile trees *Pinus pinea* L. and other species. Using the butterfly net, we collected specimens from dry vegetation in a dried-up lagoon near dunes with dense cover of dry plants from the genus *Juncus*. Additionally, we found this species in habitats characterized by sandy soil with shrubs and herbaceous plants, such as *Halimium halimifolium*, *H. calycinum* (L.) K.Koch, *Salvia rosmarinus*

Spenn., *Lavandula pedunculata*, *Linaria viscosa* (L.) Dum.Cours, *Thymus mastichina* (L.) L., *Armeria gaditana* Boiss., and other species.

***Distoleon tetragrammicus* (Fabricius, 1798)** (Fig.7)

This Holomediterranean species extends into Central and Northern Europe, the Caucasus, Armenia, Georgia, Syria, Azerbaijan, Kazakhstan, Iraq, and Iran (possibly Korea). It is widespread across the Iberian Peninsula (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Cádiz (MONSERRAT & ACEVEDO, 2013), Granada (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Jaén (MONSERRAT & ACEVEDO, 2011; RAMOS, 2017), Sevilla (RAMOS, 2017), Málaga (RAMOS, 2017) and Córdoba (RAMOS, 2017).

New examined material: 01.07.2024, 1♂ (4 m a.s.l., 36°59'33.7"N 6°26'55.0"W).

According to the literature, adults of *Distoleon tetragrammicus* are found in forested and humid environments. The larvae, being highly adaptable, can colonize microhabitats with dry, fine-grained substrates, especially in Mediterranean forests rich in humus. In Southern Europe, the species inhabits various biotopes, from coastal dunes to mountain forests, preferring sheltered areas at the base of trees, shrubs, or rocky ledges, and can also be found in artificial structures like stone walls (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In our study, we collected only one specimen of this species from *Juniperus macrocarpa* using a butterfly net. The habitat where we caught this specimen featured dense shrub cover, mainly *J. macrocarpa*, bordering a large open area with a dense cover of grasses. It is also noteworthy that a residential area was located about 300 meters from the collection site.

Neuroleontini Navás, 1912

***Neuroleon ocreatus* (Navás, 1904)**

This Atlantic-Mediterranean species is known from Spain, France, Italy, and Portugal. It has been recorded on the Iberian Peninsula, Mallorca, and Ibiza, primarily in areas under Mediterranean influence (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Almería (MONSERRAT & ACEVEDO, 2013), Málaga (MONSERRAT & ACEVEDO, 2013), Cádiz (RAMOS, 2017) and Jaén (RAMOS, 2017).

New examined material: 22.06.2023, 1♀ (8 m a.s.l., 36°58'40.5"N 6°29'45.2"W).

According to the literature, adults of *Neuroleon ocreatus* inhabit open, sunny areas, often near dry riverbeds (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022). In our study, we collected one specimen of this species from *Halimium halimifolium* using a butterfly net. The habitat where we found this specimen is a site near a dried lagoon, bordered on one side by a forest strip of *Pinus pinea* and on the other by tall sand dunes.

Figure 7. Imagines of antlion species found in Doñana National Park:
a) *Myrmecaelurus trigrammus*; **b)** *Myrmeleon gerlindae*; **c)** *Distoleon tetragrammicus*; **d)** *Creoleon lugdunensis*.
Figura 7. Imagos de especies de hormigas león encontradas en el Parque Nacional de Doñana: a) *Myrmecaelurus trigrammus*; **b)** *Myrmeleon gerlindae*; **c)** *Distoleon tetragrammicus*; **d)** *Creoleon lugdunensis*.

Macronemurini Esben-Petersen, 1919
***Macronemurus appendiculatus* (Latreille, 1807)**

This Holomediterranean species is distributed across the Iberian Peninsula and the Balearic Islands, primarily in areas influenced by the Mediterranean climate. It is found in continental, Atlantic, and Mediterranean zones, with confirmed records from

Mallorca, Menorca, Ibiza, and Formentera (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In Andalusia, this species has been recorded in the provinces of Almería (MONSERRAT & ACEVEDO, 2013), Cádiz (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Córdoba, (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Málaga (MONSERRAT & ACEVEDO, 2013; RAMOS, 2017), Huelva (Matalascañas, Marismas del Odiel, Isla de Saltes) (MONSERRAT & ACEVEDO, 2013; BARREDA et al., 2015; RAMOS, 2017), Sevilla (RAMOS, 2017), Jaén (RAMOS, 2017) and Granada (RAMOS, 2017).

New examined material: 01.07.2024, 1♀ 1♂ (5 m a.s.l., 36°59'37.5"N 6°26'59.1"W).

According to the literature, adults of *Macronemurus appendiculatus* inhabit open, sunny areas, particularly grassy spaces with little to no woody vegetation. They are often found in steppe regions, rocky areas, and on dried-out or abandoned cereal fields (MONSERRAT & ACEVEDO, 2013; MONSERRAT, 2022).

In our study, *Macronemurus appendiculatus* was collected from dense grassy vegetation using a butterfly net. The habitat was an open area dominated by various grass species, particularly Poaceae, and bordered by shrubland, providing a suitable environment for this species.

DISCUSSION AND CONCLUSIONS

This study provides the first comprehensive investigation of Neuroptera, particularly Myrmeleontidae, in Doñana National Park. We recorded a total of 12 species from 9 genera, significantly enhancing knowledge of the region's biodiversity. Notably, this study includes the first records of *Distoleon tetragrammicus* and *Neuroleon ocreatus* in the province of Huelva, thereby expanding the known distribution of these species.

Previous research predominantly documented the coexistence of only two antlion species within the same habitat (DEVETAK, 2020; GRIFFITHS, 1991; KLOKOČOVNIK et al., 2019; MILER et al., 2017), with few reports indicating three. Among the most thoroughly studied cases are *Myrmeleon hyalinus* and *Cueta lineosa*, two species often found in shared habitats across the Eastern Mediterranean, where they avoid spatial overlap through territorial segregation (BARKAE et al., 2012; OVADIA et al., 2020; ROTKOPF et al., 2013; SCHARF et al., 2008). Our findings confirmed the coexistence of three antlion species (*Myrmeleon almohadarum*, *M. hyalinus*, and *M. gerlindae*) within a single habitat in Doñana, with species abundance influenced by varying levels of anthropogenic disturbance. *M. almohadarum* was more frequently observed at sites characterized by higher human impact, while *M. hyalinus* demonstrated specific ecological requirements for successful development. The presence of *M. almohadarum* populations near residential areas suggests a high tolerance for human-induced changes (Fig. 7). Future research investigating resource competition, including prey availability and optimal trap-building conditions, would further clarify the adaptive strategies of these species.

Our data also propose that shrub-dominated biotopes and grasslands are the most suitable habitats for antlion colonization within Doñana National Park. While we do not generalize this distribution pattern to other regions, it reflects the specific spatial distribution observed in our study area. Key factors for the successful reproduction of Myrmeleontidae populations include climatic conditions (e.g., temperature, humidity, light levels, soil type), availability of food resources, protection from predators, and manageable levels of inter- and intraspecific competition (ASPÖCK et al., 1980; MORRISON, 2004; SCHARF et al., 2011).

Shrub and grassland environments provide natural shelter, mitigating the effects of extreme heat, cold, and heavy rainfall. Additionally, these biotopes supply abundant food resources, attracting ants and caterpillars — primary prey for antlions — through diverse food sources such as small insects, nectar, carrion, and fruits. This rich food supply makes these habitats particularly favorable for ants (TSHIGUVHO et al., 1999; AMATTA et al., 2023), the primary food source for antlion larvae. Moreover, shrub and grassland biotopes offer various microhabitats for constructing pitfall traps. Antlions can establish traps under shrubs, around roots, or within decaying vegetation. Within these biotopes, we observed that the edges of unpaved roads are particularly attractive habitats for Myrmeleontidae. The fine soil texture facilitates trap construction and increases food accessibility, supporting antlion development (ITZHAK, 2008). Reduced vegetation and altered substrates along road edges promote higher ant abundance, further enriched by additional food sources such as herbivore droppings (AMATTA et al., 2023). Ant nests are denser along road edges than in natural areas (ITZHAK, 2008), attracting antlion species that benefit from high prey densities. Since 1956, the density of roads within Doñana National Park has doubled, with unpaved roads now covering approximately 4% of the protected area (ROMÁN et al., 2010).

In conclusion, our findings indicate that shrub and grassland biotopes, especially those along unpaved road edges, offer ideal conditions for antlion settlement in Doñana National Park. This habitat preference underscores the importance of food availability, microhabitat diversity, and favorable microclimatic conditions essential for sustaining robust Myrmeleontidae populations.

Overall, this study establishes a baseline species list for Doñana National Park. Further research is needed to fully assess the ecological dynamics and distribution patterns of these species. Expanding sample coverage and enhancing temporal resolution in future studies will be essential to add to the species list and to understand antlion population dynamics and species interactions within natural ecosystems.

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REFERENCES

Acevedo, R. F., V. J. Monserrat, and D. Badano. 2013. Comparative Description of Larvae of the European Species of *Distoleon* Banks: *D. annulatus* (Klug, 1834) and *D. tetragrammicus* (Fabricius, 1798) (Neuroptera, Myrmeleontidae). *Zootaxa* 3721(5): 488. https://doi.org/10.11646/zootaxa.3721.5.4.

Amatta, E., Andino, N., Calcaterra, L. A., & Giannoni, S. M., 2023. Effect of road disturbance on ant diversity in the Monte desert of Argentina. *Journal of Insect Conservation*, 27: 533–545. https://doi.org/10.1007/s10841-023-00477-9

Aspöck, H., U. Aspöck, and H. Hölzel. 1980. *Die Neuropteren Europas. Eine Zusammenfassende Darstellung der Systematic, Ökologie und Chorologie der Neuropteridae (Megaloptera, Raphidioptera, Planipennia) Europas.* Vols. 1 and 2. Krefeld: Goecke & Evers.

Aspöck, H., H. Hölzel, and U. Aspöck. 2001. *Kommentierter Katalog der Neuropterida (Insecta: Raphidioptera, Megaloptera, Neuroptera) der Westpaläarktis. Denisia* 2: 1–606.

Badano, D., F. Acevedo, R. A. Pantaleoni, and V. J. Monserrat. 2016. Myrmeleon almohadarum sp. nov., from Spain and North Africa, with Description of the Larva (Neuroptera Myrmeleontidae). *Zootaxa* 4196(2): 210. https://doi.org/10.11646/zootaxa.4196.2.2.

Badano, D., and R. A. Pantaleoni. 2014. The Larvae of European Myrmeleontidae (Neuroptera). *Zootaxa* 3762(1): 1. https://doi.org/10.11646/zootaxa.3762.1.1.

Barreda, J., J. L. Morell, C. Pérez-Hernando, and A. Nieto. 2015. Nuevos Datos de Hormigas-León del Sur de la Península Ibérica (Neuroptera, Myrmeleontidae). *Boletín de la SAE* 25: 18–22.

Barkae, E. D., I. Scharf, Z. Abramsky, and O. Ovadia. 2012. Jack of All Trades, Master of All: A Positive Association between Habitat Niche Breadth and Foraging Performance in Pit-Building Antlion Larvae. *PLoS ONE* 7(3): e33506. https://doi.org/10.1371/journal.pone.0033506.

Delibes-Mateos, M., M. Delibes, P. Ferreras, and R. Villafuerte. 2008. Key Role of European Rabbits in the Conservation of the Western Mediterranean Basin Hotspot. *Conservation Biology* 22(5): 1106–1117. https://doi.org/10.1111/j.1523-1739.2008.00993.x.

Devetak, D. 2020. Competition in Larvae of Two European Ant-Lion Species (Neuroptera: Myrmeleontidae). *Journal of Neuropterology* 3: 51–60.

Díaz-Paniagua, C., Fernández-Zamudio, R., Serrano, L., Florencio, M., Sousa, A., García-Murillo, P., et al. 2016. El sistema de lagunas temporales del Parque Nacional de Doñana: Aplicación a la gestión y conservación de hábitats acuáticos singulares. *Proyectos de Investigación en Parques Nacionales*, 2011–2014.

Domingo, M. S., Martín-Perea, D. M., Badgley, C., Cantero, E., López-Guerrero, P., Oliver, A., & Negro, J. J. 2020. Taphonomic information from the modern vertebrate death assemblage of Doñana National Park, Spain. *PLOS ONE, 15*(11), e0242082. https://doi.org/10.1371/journal.pone.0242082

Fernández, N., Paruelo, J. M., & Delibes, M. 2010. Ecosystem functioning of protected and altered Mediterranean environments: A remote sensing classification in Doñana, Spain. *Remote Sensing of Environment, 114*(2), 211–220. https://doi.org/10.1016/j.rse.2009.09.001

Griffiths, D. 1991. Intraspecific Competition in Larvae of the Ant-Lion Morter sp. and Interspecific Interactions with *Macroleon quinquemaculatus*. *Ecological Entomology* 16(2): 193–201. https://doi.org/10.1111/j.1365-2311.1991.tb00209.x.

Klokočovnik, V., E. Veler, and D. Devetak. 2019. Antlions in Interaction: Confrontation of Two Competitors in Limited Space. *Israel Journal of Ecology and Evolution* 66(1–2): 73–81. https://doi.org/10.1163/22244662-20191058.

Itzhak, M. J.-J., 2008. Seed harvester and scavenger ants along roadsides in Northern Israel. *Zoology in the Middle East,* 44(1): 75–82. https://doi.org/10.1080/09397140.2008.10638291

Lionello, P., Malanotte-Rizzoli, P., Boscolo, R., Alpert, P., Artale, V., Li, L., et al. 2006. The Mediterranean climate: An overview of the main characteristics and issues. In P. Lionello, P. Malanotte-Rizzoli, & R. Boscolo (Eds.), *Mediterranean Climate Variability. Developments in Earth and Environmental Sciences* (pp. 1–26). Amsterdam: Elsevier.

Miler, K., B. E. Yahya, and M. Czarnoleski. 2017. "Different Predation Efficiencies of Trap-Building Larvae of Sympatric Antlions and Wormlions from the Rainforest of Borneo." *Ecological Entomology* 43(2): 255–262. https://doi.org/10.1111/een.12495.

Miller, R. B., and L. A. Stange. 1985. "Description of the Antlion Larva *Navasoleon boliviana* Banks with Biological Notes (Neuroptera; Myrmeleontidae)." *Neuroptera International* III(3): 119–126.

Mirmoayedi, A. 2008. Morphological Characteristics of Larvae and Imago of *Myrmecaelurus trigrammus* (Pallas, 1771) (Neuroptera, Myrmeleontidae) Reared in Laboratory Condition. *Iranian Journal of Animal Biosystematics* 4: 1–6.

Monserrat, V. J. 1986. Sobre los Neurópteros ibéricos (IV) (Neuroptera). *Boletín de la Asociación Española de Entomología* 10: 95–105.

Monserrat, V. J. 2022. *Los Neuropterida de la Península Ibérica y Baleares.* Zaragoza: Sociedad Entomológica Aragonesa (S.E.A.).

Monserrat, V. J., and F. Acevedo. 2013. Los Mirmeleónidos (Hormigas-León) de la Península Ibérica e Islas Baleares (Insecta, Neuropterida, Neuroptera, Myrmeleontidae). *Graellsia* 69(2): 283–321. https://doi.org/10.3989/graellsia.2013.v69.098.

Monserrat, V. J., and F. Acevedo. 2011. Nuevos Datos Sobre las Hormigas León de la Península Ibérica (Insecta: Neuroptera: Myrmeleontidae). *Heteropterus Revista de Entomología* 11(1): 123–136.

Morrison, L. W. 2004. Spatiotemporal variation in antlion (Neuroptera: Myrmeleontidae) density and impacts on ant (Hymenoptera: Formicidae) and generalized arthropod foraging. *Annals of the Entomological Society of America, 97*(5), 913–922. https://doi.org/10.1603/0013-8746(2004)097[0913:SVIANM]2.0.CO;2

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. Biodiversity Hotspots for Conservation Priorities. *Nature* 403(6772): 853–858. https://doi.org/10.1038/35002501.

Ovadia, O., I. Scharf, E. D. Barkae, T. Levi, and Y. Alcalay. 2020. Asymmetrical Intra-Guild Predation and Niche Differentiation in Two Pit-Building Antlions. *Israel Journal of Ecology and Evolution* 66(1–2): 82–90. https://doi.org/10.1163/22244662-20191067.

Pérez-Ramos, I. M., R. Díaz-Delgado, E. G. de la Riva, R. Villar, F. Lloret, and T. Marañón. 2017. Climate Variability and Community Stability in Mediterranean Shrublands: The Role of Functional Diversity and Soil Environment. *Journal of Ecology* 105(5): 1335–1346. https://doi.org/10.1111/1365-2745.12747.

Ramos, F. A. 2017. *Avances en el Conocimiento de la Familia Myrmeleontidae (Insecta, Neuroptera) de la Península Ibérica y Baleares: Estadios Larvarios, Filogenia y Modelos de Distribución*. Doctoral dissertation, Universidad Complutense de Madrid.

Rodríguez-Vidal, J., Bardají, T., Zazo, C., Goy, J. L., Borja, F., Dabrio, C. J., & Others. 2014. Coastal dunes and marshes in Doñana National Park. In F. Gutiérrez & M. Gutiérrez (Eds.), *Landscapes and Landforms of Spain* (pp. 229–238).

Román, J., Barón, A. y Revilla, E. 2010. Evaluación de los efectos del tránsito a motor sobre especies y comunidades de interés en el Espacio Natural de Doñana. Consejería de Medio Ambiente, Junta de Andalucía. Estación Biológica de Doñana, CSIC. 236 pp.

Rotkopf, R., Y. Alcalay, E. Bar-Hanin, E. D. Barkae, and O. Ovadia. 2013. Slow Growth Improves Compensation Ability: Examining Growth Rate and Starvation Endurance in Pit-Building Antlions from Semi-Arid and Hyper-Arid Regions. *Evolutionary Ecology* 27(6): 1129–1144. https://doi.org/10.1007/s10682-013-9644-0.

Scharf, I., Y. Hollender, A. Subach, and O. Ovadia. 2008. Effect of Spatial Pattern and Microhabitat on Pit Construction and Relocation in *Myrmeleon hyalinus* (Neuroptera: Myrmeleontidae) Larvae. *Ecological Entomology* 33(3): 337–345. https://doi.org/10.1111/j.1365-2311.2007.00967.x.

Scharf, I., Lubin, Y., & Ovadia, O. 2011. Foraging decisions and behavioural flexibility in trap-building predators: A review. *Biological Reviews, 86*(3), 626–639. https://doi.org/10.1111/j.1469-185X.2010.00163.x

Stange, L. A. 2004. *A Systematic Catalog Bibliography and Classification of the World Antlions (Insecta: Neuroptera: Myrmeleontidae).* American Entomological Institute. February 7, 2024.

Stelzl, M., and J. Gepp. 1990. Food-Analysis of Imagines of Central European Myrmeleontidae (Insecta: Neuroptera). In *Advances in Neuropterology: Proceedings of the Third International Symposium on Neuropterology*, edited by M. W. Mansell and H. Aspöck, 205–201. Berg en Dal, Kruger National Park, South Africa.

Taberlet, P., L. Fumagalli, A. Wust-Saucy, and J. Cosson. 1998. Comparative Phylogeography and Postglacial Colonization Routes in Europe. *Molecular Ecology* 7(4): 453–464. https://doi.org/10.1046/j.1365-294x.1998.00289.x.

Tshiguvho, T., Dean, W. & Robertson, H. 1999. Conservation value of road verges in the semi-arid Karoo, South Africa: ants (Hymenoptera: Formicidae) as bio-indicators. *Biodiversity and Conservation 8*, 1683–1695 . https://doi.org/10.1023/A:1008911805007

Zachos, F. E., and J. C. Habel. 2011. *Biodiversity Hotspots.* Berlin: Springer. https://doi.org/10.1007/978-3-642-20992-5.