Rediscovering *Gortyna flavago* (Denis & Schiffermüller, 1775) (Noctuidae) in Portugal after six decades: host-plant fidelity at the Atlanto-Mediterranean interface

Paulo Lemos [1,2]

[1] *Independent Researcher, Caldas da Rainha, Portugal.*
[2] *Escola Superior de Turismo e Tecnologia do Mar; Politécnico de Leiria, Campus 4; Rua do Conhecimento 4; P-2520-614 Peniche; Portugal. email: paulolemos@live.com.pt;* https://orcid.org/0000-0002-3917-0520

Abstract

The noctuid moth *Gortyna flavago* ([Denis & Schiffermüller], 1775) was recently rediscovered in Portugal, following a 63-year absence of collection and observation records. Surveys conducted between 2023 and 2026 in central-western Portugal identified localised core populations strongly associated with humid riparian ecotones supporting *Eupatorium cannabinum.* In contrast to its broader ecological plasticity elsewhere in Europe, the species appears to exhibit host-plant specialization in the study area, and the local distribution suggests a metapopulation structure linked to fragmented microhabitats. This report documents aspects of the regional ecology and reproductive behaviour of *G. flavago* and provides preliminary insights into its population structure. These findings suggest that riparian megaforb communities may function as bioclimatic refugia for moisture-dependent taxa in Mediterranean landscapes, underscoring the need for targeted habitat management to support the long-term persistence of *G. flavago* in central-western Portugal.
Keywords: Insecta; Lepidoptera; Noctuidae; Apameina; host-plants; riparian habitats; conservation; Portugal.

Resumo

O noctuídeo *Gortyna flavago* ([Denis & Schiffermüller], 1775) foi recentemente redescoberto em Portugal, depois de 63 anos sem observações nem registos de coleção no país. Prospecções realizadas entre 2023 e 2026 no Litoral Oeste identificaram populações localizadas, fortemente associadas a ecótonos ripícolas húmidos com *Eupatorium cannabinum* na sua composição. Ao contrário da plasticidade ecológica registada noutras regiões da Europa, parece aqui ocorrer uma especialização relativamente a esta planta hospedeira, enquanto a distribuição local sugere uma estrutura metapopulacional associada a microhabitats fragmentados. O presente trabalho descreve a ecologia desta borboleta, o seu comportamento reprodutivo e, preliminarmente, a estrutura populacional da espécie a nível regional. Os resultados sugerem que as comunidades de megafórbias ripícolas poderão funcionar como refúgios bioclimáticos para taxa dependentes de humidade em paisagens mediterrânicas. A persistência de *G. flavago* salienta o valor de conservação das formações higrófilas de ervas altas, fundamentando a necessidade de uma gestão de habitat mais direcionada em Portugal.
Palavras-chave: Insecta; Lepidoptera; Noctuidae; Apameina; plantas hospedeiras; habitats ribeirinhos; conservação; Portugal.

Introduction

Gortyna flavago is a Palearctic noctuid with scattered and localized occurrences across Eurasia. Although widespread in Europe, the ecology of this moth remains poorly understood in the Iberian Peninsula.

A single historical Portuguese specimen was collected in Vouzela, by Timoteo Gonçalves in September 1960 (Silva Cruz & Gonçalves, 1961), deposited at Museu de História Natural e da Ciência da Universidade do Porto, with no subsequent records for over six decades (Corley, 2015). The locality lies within the Lafões Mountain Range, a transitional zone towards the north of the country.

The rediscovery of *G. flavago* in Portugal took place within small patches of relict riparian systems, in the central-western region, amidst a degraded ecological matrix. Through targeted Lepidoptera surveys, over two hundred observations were made between 2023 and 2026, with ninety-two selected observations documented photographically on iNaturalist (plemos, 2026), all in the presence of *Eupatorium cannabinum* subsp. *cannabinum* L., a tall hygrophilous herb whose national distribution becomes scarce towards the southern half. Monitoring followed a key network of host-plant locations, optimized by the author's contributions to the predictive vegetation mapping from the Red List of Mainland Portugal's Vascular Flora (Carapeto et al., 2020).



Figure 1 - Mating pair of *G. flavago* on *E. cannabinum*. Observation under red-spectrum light to minimize phototactic stress and ensure minimal light disturbance to the environment. Nadadouro; 10.ix.2026.

The principal study area comprises the Caldas da Rainha typhonic valley, the adjacent coastline, and the western part of the synclinal structures between the Caldas da Rainha diapiric anticline and Serra dos Candeeiros, extending northwards to the Alcobaça River basin. These formations offer a high degree of topographic sheltering, in a region characterized by a Mediterranean climate with strong Atlantic influence, mild temperatures, frequent fog, and relatively cool summers.

The territory's remarkable geological diversity provides the foundation for its renowned floristic importance (Farminhão, 2021), particularly within its riparian corridors and relict forest remnants. Such habitats serve as refugia (Keppel et al., 2012; Zhang et al., 2023), combining topography, hydrography and vegetation with proximity to the Atlantic to shield against the Mediterranean influence.

Notably, this region hosts the southernmost known disjunct populations with Eurosiberian affinities, encompassing both flora and microfauna at low elevations. This pattern is exemplified by species such as the oak bush-cricket *Meconema thalassinum* (De Geer, 1773), the locally abundant moth *Epione repandaria* (Hufnagel, 1767), the leaf beetle *Hydrothassa glabra* (Herbst, 1783), and others (GBIF.org, 2025).

This study aims to document the rediscovery of *Gortyna flavago* in Portugal, characterize its ecological niche in the central-western region, and assess the role of riparian habitats as bioclimatic refugia to better inform conservation strategies.

Materials and Methods

A direct visual census was applied in areas with varying accessibility to provide immediate taxonomic identification and an approximate quantification of population densities, phenological traits, and behavioural and reproductive aspects, thereby minimizing disturbance while maximizing the monitoring of nocturnal activity.



Figure 2 - Surveys extended simultaneously across several locations, with considerable effort devoted to monitoring adults and observing their behaviour, allowing less-known aspects of their ecology, such as adult feeding, to be documented. In the photograph, an adult male was observed hovering around a bramble thicket onto which aphid honeydew was dripping from an infested willow above. Nadadouro; 27.viii.2024.

Due to high environmental stochasticity and the structured yet adaptive survey design, the resulting data were inherently heterogeneous, reflecting an approach intended to maximize the quality and range of observations obtained during each field session rather than conform to a rigid quantitative protocol. Although concrete data were collected, their numerical representation did not always adequately reflect population abundance, relative density, spatial structure, and ecological patterns evident through direct observation, particularly at sites where numerous individuals made exact tracking impractical. Quantitative analysis was therefore avoided where it could be misleading. Instead, interpretation relied on ecological contextualization, integrating empirical observations with regional knowledge of habitat structure, host-plant distribution, analogous species, and historical trends. Maps use only a minimum selection of available data to represent distribution, and density on a relative basis.

In 2026, no additional localities were surveyed; fieldwork instead focused on the species' behaviour and on its responses to extreme climatic events and environmental degradation. In previous years, phenology and behavioural monitoring of the adults was conducted every other day at two selected sampling sites (Nadadouro and Quinta dos Bugalhos neighbourhood), complemented on alternate days by targeted surveys in additional locations. Effort was concentrated in September to capture the full flying period, with particular attention to its onset and termination (August-October).

Surveys targeted late-instar larvae and pupae across all *E. cannabinum* occurrence sites known, and were also intensively surveyed on other potential host-plant taxa, searching for characteristic signs of occurrence of this species. Monitoring and documentation impact was minimized, particularly of first instars to avoid host-plant alterations and vulnerability to predators.

Two distinct approaches were employed for detection and monitoring, based on *E. cannabinum* occurrence sites:

a) On-site trapping:

LepiLED Maxi Switch (customized LED configuration; Fig. 3), and a tripod-mounted 3x 10 W 365 nm (UVA) mini-projectors, with an additional vertical blue light LED strip, powered by small portable powerbanks, and UVA protection glasses.

b) Surveys with flashlights:

High-powered handheld LED flashlights were used for adult stage monitoring. Specifically, a deep red (660 nm) light was used to detect, track and observe the species with minimal disturbance; a 6500 K white light for general purposes; and a high-power UVA light (365 nm) to facilitate the occasional capture and identification of dispersing individuals, relying on temporary optical stunning rather than long-range attraction.



Figure 3 - Factory-customized LepiLED Maxi Switch. The device is equipped with high-efficiency Nichia LEDs, configured with four UVA LEDs, two blue LEDs, and two green LEDs. Additionally, a user-made upgrade: polished aluminium “mirrors” on the upper and lower inner faces.

Overcoming negative phototaxis:

Gortyna flavago adults frequently exhibited negative phototaxis toward white-light flashlights, slight sensitivity to red light at close distance, and a stunned response to direct strong UV light. Behavioural response to 630-660 nm illumination is not manifested through violent reactions, but still sufficient to interrupt activities such as oviposition or pheromone release. The species' weak affinity for illumination had already been reported as sporadic and occurring under intense light, making it easier to find during earlier stages (South, 1907). These traits made some observations difficult, necessitating attention under extremely low red-light intensity or brief, intermittent periods in total darkness.

Fixed light trapping was only effective near the host-plant stands with LepiLED, although moths were often observed keeping their distance from the lamp. Consequently, and also to minimize disturbance too close to the core populations, this method was used only occasionally. High-powered handheld LED flashlights provided the best results for adult monitoring.

Documentary photography:

Macro photography was performed using a Canon EOS 6D with a 100 mm macro lens, and photographs were edited to approximate natural perception. Imaging was essential for precise georeferencing and temporal data, as well as for the analysis and identification of specific individuals across distinct dates or localities.

Mapping:

The distribution maps for *G. flavago* were based on selected photographic records of the adult stage, only supplemented by larval records in locations where adults were absent or remained undetected.

Spatial analysis and mapping were conducted using QGIS (v3.36.3; QGIS Development Team, 2026). Topographic contextualization for the central-western Region (Oeste, Portugal) was established using the Esri World Hillshade three-dimensional terrain model. Urban settlement centroids (cities and towns) were extracted from OpenStreetMap (OpenStreetMap Contributors, 2026).

Night-time light (NTL) spatial distribution was evaluated using high-resolution multispectral observations from the SDGSAT-1 satellite via its Glimmer imager (GMI) night-light sensor. Orthorectified high-resolution product (10m/40m) with sensor noise removal. Final imagery was generated from the complete overlay of four GeoTIFF (TIF) provided by the SDGSAT-1 Team (CBAS/CAS, 2026).

National distribution maps for *E. cannabinum* are available on the Flora-On portal (Flora-On, 2005–2025), which aggregates reliable data from the author and multiple sources. The author's mapping contribution is currently being updated and prepared for a forthcoming independent publication.

Municipalities covered by surveys:

Alcobaça, Bombarral, Caldas da Rainha, Leiria*, Marinha Grande*, Nazaré, Óbidos, Pombal* (altitude ranged from 0 to 150 m).

Greater monitoring efforts were conducted along the Typhonic Valley and the western sector of the A-dos-Francos syncline, as opposed to the eastern strip, where visits were scaled back following the first negative results and a lower density of mapped host-plant locations.

Field surveys beyond this territory (*) were occasional, especially further north, in the coastal regions of Marinha Grande, Leiria, and Pombal, where extensive stands of *E. cannabinum* were previously known to the author at varying distances from the coastline. These lands were severely impacted by extreme wildfires in 2017, in several cases followed by inadequate habitat management.

Entomological collection:

A couple of wild specimens are kept in the author's private collection, and one male is deposited in the José Luis Yela collection (Spain).

Rearing trials:

To avoid damaging sensitive damp areas and maximize the probability of tracking adults from emergence onwards, a small number of larvae were collected at selected sites and meticulously relocated to nearby, more accessible plant stands. A few captive specimens were used in an attempt to compare behavioural aspects and biotic interactions with those observed in the field.

Results and Discussion

The rediscovery of *G. flavago* and known spatial distribution:

Extant populations of *G. flavago* were discovered in the Central West of Portugal (Fig. 4), occurring in several scattered and highly localized sites within the municipalities of Óbidos, Caldas da Rainha, and Alcobaça. Since the intensive monitoring efforts were conducted along the Typhonic Valley and the western sector of the A-dos-Francos syncline, the current regional distribution map (Fig. 4) may expand as future research progresses.

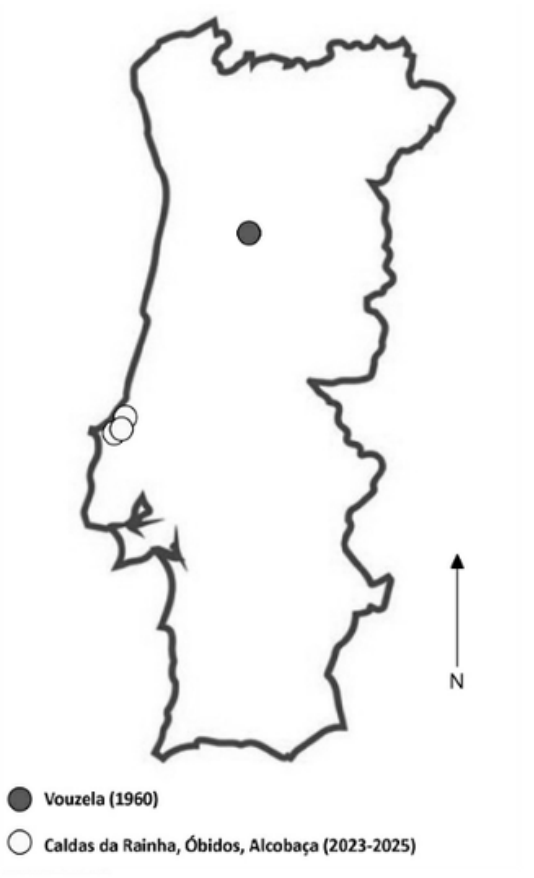

Figure 4 - Known distribution of *Gortyna flavago* in Portugal. The solid circle indicates the historical record from Vouzela (1960), while open circles indicate the recently documented populations in Caldas da Rainha, Óbidos and Alcobaça municipalities (2023–2025).

The *G. flavago* occurrence sites central to this study are the following:

- **Ribeira do Nadadouro** (upstream section) - The site features a water spring at Casais da Fonte and is part of the Lagoa de Óbidos catchment. The partially hydromorphic system extends across arenosols on broad, gently sloping terrain comprising smallholder agriculture and a marshy alder woodland upstream (*Alnus lusitanica* Vít, Douda & Mandák), shaped by highly diverse hydrological inputs that create a particularly favourable setting for megaforb vegetation. The first record for this location is a male, collected on 27.ix.2023 at UTM 29S MD3864 (Caldas da Rainha Municipality).

- **Vicinity of Águas Santas** - A former alder grove on hydromorphic arenosols still hosts *E. cannabinum* in catenal areas, presently consisting of a strip of mature willow woodland (*Salix atrocinerea* Brot.), in the alternation between slopes with *Quercus pseudococcifera* Desf. or *Quercus lusitanica* Lam., on a lentic section of a Rio da Cal tributary, within the Óbidos Lagoon catchment. The first record for this location is a male, recorded on 27.ix.2023 at UTM 29S MD4161 (Óbidos Municipality).

- **Vicinities of Formigal** (Salir de Matos Parish) - Several sections of hydromorphic arenosols with willow woodland (formerly Alder), including a larval record at Olhos de Água. A mating pair was recorded on 10.ix.2025 at UTM 29S MD9162 (Caldas da Rainha Municipality).

- **Vicinities of Quinta dos Bugalhos** (Vidais Parish) - This subpopulation thrives at a few sites along small upstream tributaries and catenal sequences of hydromorphic arenosols, as well as in interflow and runoff systems uphill, and along alluvial forest edges and ditches, forming a cluster of dispersed points. A significant core population occurs near Quinta dos Bugalhos that features scarce remnants of *Alnus lusitanica* marginal woodlands dominated by *Quercus* spp. The first regional finding and the second national record for the species was a female recorded on 23.ix.2023 at UTM 29S MC4663 (Caldas da Rainha Municipality).

- **Tornada - Barrantes** - Located on the eastern flank of the Caldas da Rainha Typhonic Valley, the habitat consists of runoff sections and micro-terrace borders associated with the Rio Tornada valley, overlooking forested slopes, hillside small permanent runoff or seepages and rural land. The first record for this location was a larva on *E. cannabinum*, recorded on 21.v.2024 at UTM 29S MD5168 (Caldas da Rainha Municipality).

- **Fonte Figueira** - Margin of an incised stream passing through a place named Fonte Figueira. Sloping banks dominated by *Quercus* spp.. The single record for this location was a larva on *E. cannabinum*, recorded on 14.vi.2025 at UTM 29S MD4623 (Alcobaça Municipality).

Upstream hydrographic sections of Ribeira do Nadadouro and the vicinities of Quinta dos Bugalhos are the most relevant core populations, possibly source populations (in a metapopulation context), exhibiting the highest recorded densities of larval traces and adult activity.

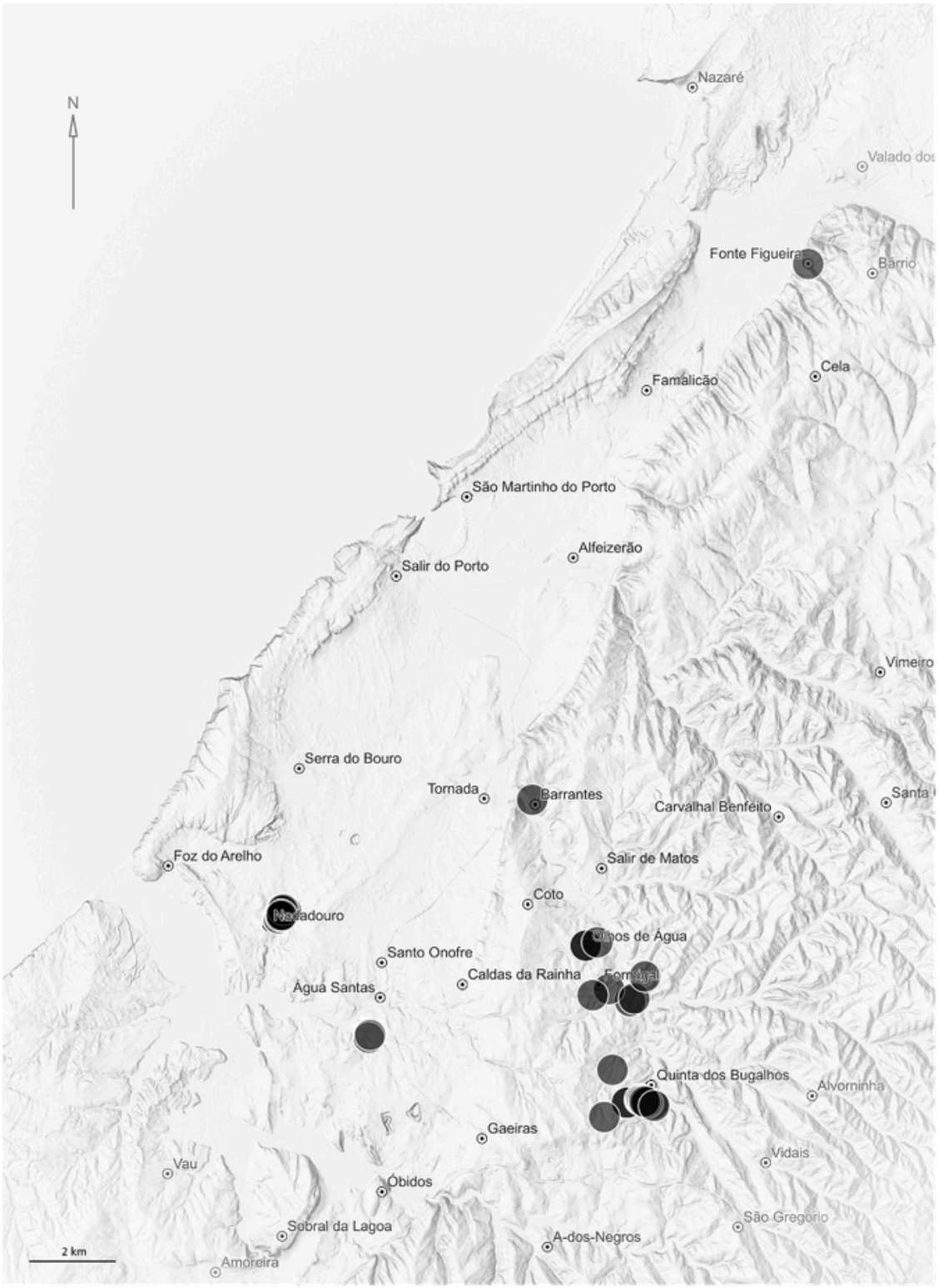

Figure 5 - Distribution of *Gortyna flavago* and urban settlements in the main study area of the Western Region (Oeste, Portugal), showing a low-precision density effect at coincident points by solid black circular markers representing documented occurrence. Light gray shading represents the topographic relief and three-dimensional terrain morphology (Esri World Hillshade; Esri, 2026). Settlement and geographic features derived from OpenStreetMap.

I. Habitat ecology

Southern range context:

At a broad scale across Europe, *Gortyna flavago* is described as an ecological generalist. According to Zilli et al. (2005), the species is widespread across most habitats in its western range, though populations are typically characterized by low density. This broad habitat tolerance is further supported by authors like Waring & Townsend (2017), Ebert (1997), and Skinner (2009), who note its presence in diverse environments ranging from gardens and woodland rides to waste ground. However, while assuming this generalist framework, Ebert (1997) and Skinner (2009) highlight a marked affinity for increased moisture, specifically pointing to ditch margins, riparian edges, and marshes as favoured sites.

The recent findings in Portugal align with these observations of moisture affinity but suggest a much narrower ecological breadth at the southern edge of the species' distribution. In the surveyed region, the moth has only been detected in two Portuguese biogeographic regions (Figs. 4 and 5), with Vouzela marked by mountain and continental influences, and the central-western region mainly representing a lowland region with a strong Atlantic influence.

Towards other southern parts of its European range, *Gortyna flavago* is very scarce and highly localized, with isolated and scattered records in the Iberian Peninsula and rare, localised occurrences in mountainous areas of southern Italy (Calle, 1982; Parenzan & Scalercio, 1996).

Host-plant specialization:

In north-western Europe *G. flavago* may show high ecological plasticity (Fibiger, 1990; Skinner, 2009) and utilizes a wide range of host-plants. Thistles (*Carduus*, *Cirsium*) and burdocks (*Arctium*) are frequently cited as primary hosts, while foxglove (*Digitalis*) is also mentioned. Other reported host-plants include *Jacobaea vulgaris* Gaertn., *Eupatorium, Verbascum* L., *Scrophularia* Tourn. ex L., *Artemisia vulgaris* L., *Pulicaria dysenterica* (L.) Bernh., *Achillea millefolium* L., *Angelica* L., *Aegopodium* L. and *Urtica* L. (Bretherton et al., 1983); *Petasites* Mill. and *Valeriana* L. (Zilli et al., 2005); and *Centaurea* L. (Henwood & Sterling, 2020).

The published accounts differ in the number and selection of host-plants listed. Henwood & Sterling (2020) distinguish six main host-plants, including *Eupatorium*, and seven others used less commonly. Ebert (1998), mentions *Eupatorium* in a list of four. Leraut (2019) lists eleven plant genera but does not include *Eupatorium*. Additional host-plant records for *G. flavago* are available in the HOSTS database (Robinson et al., 2023).



Figure 6 - Well-developed, flowering stands of *Eupatorium cannabinum* subsp. *cannabinum*, the host plant of studied populations of *Gortyna flavago*.

Thus, although *Eupatorium* appears in several accounts, none of these descriptions identifies it as the most frequently used host plant.

In contrast, the recently studied Portuguese populations appear to rely exclusively on *E. cannabinum* (Figs. 6 and 7), despite intensive surveys of other plants. No evidence of *G. flavago* was found on *Cirsium palustre* (L.) Scop., a close associate of *Eupatorium* in central-western Portugal, nor on *Cirsium arvense* (L.) Scop., a long-established agricultural weed that is common near three of the recorded occurrence sites, and also not in *Cirsium vulgare* (Savi) Ten., a common plant in forest edges. No signs of larvae or adult activity were detected on other thistles, nor on *Digitalis purpurea* L., *Arctium minus* (Hill) Bernh., *Jacobaea vulgaris* Gaertn., *Pulicaria dysenterica*, *Cheirolophus uliginosus* (Brot.) Dostál or the regional endemic *Leucanthemum lacustre* Brot., even when they occur together with *Eupatorium* stands affected by *G. flavago*.

Host-plant specialization at regional scales is well documented in Lepidoptera (Bernays & Graham, 1988). This marked contrast between Portuguese and north-western European populations may be related to the peripheral position of western Portugal populations within the species' range. Host-plant use may become more restricted toward species' range margins, as observed in *Lycaena dispar* (Haworth,1802), whose northern marginal populations show greater host-plant specialization than populations closer to the core of its European distribution (Martin & Pullin, 2004).

Hydrological niche:

The habitat of *G. flavago* regionally depends on the hydrological niche of its host plant, which requires a regular seasonal hydrological regime despite topohydrological variations. The fundamental baseline consists of constant, well drained soil moisture levels throughout the seasons combined with stable margins during flood events. At specific sites within the study area, a stable soil-moisture profile was maintained even during the severe flooding after Storm Kristin in early 2026. This stability is critical for the host-plant, which, under the regional mild winter temperatures, does not tolerate prolonged flooding or stagnant water containing suspended and decomposing debris. Concurrently, these precise soil moisture tolerances and drainage dynamics are possibly equally vital for the vulnerable life stages of the moth.

Long-term studies of northern European fen vegetation have likewise demonstrated the importance of hydrological integrity for the persistence of hygrophilous plant communities, including tall-herb formations associated with *Eupatorium cannabinum* (Fojt & Harding, 1995).



Figure 7 - Stands of *Eupatorium cannabinum* still erect in a herbaceous meadow in the height of autumn. The associated *C. palustre* usually exhibits senescence after fruiting well before that of *E. cannabinum*, with many plants presenting dry stems by September; furthermore, they collapse, and their structures degrade more rapidly and completely over the following months, contrasting with *E. cannabinum*.

Vegetation Framework:

E. cannabinum depends on a narrow window of ecological conditions to thrive under a Mediterranean climate. In central-western Portugal, it can be found across a range of riverine and humid habitats, including runoff areas on coastal cliffs, where it may occur among rush communities. It also occurs in hygrophilous scrublands within semi-open woodland, in runoff or interflow sections, sometimes associated with pioneer mire formations and catenal boggy habitats, where it may be constrained by local chemical conditions. Even when occurring in dune slacks and intersection zones between drier and hygrophilous scrub, the vegetation always exhibits an Atlantic affinity, including Ericaceae, and generally features some nearby canopy cover.

G. flavago occurs in abundance mainly corresponding to the priority habitat 91E0* (*Alluvial forests with Alnus glutinosa and Fraxinus excelsior*, Annex I of Directive 92/43/EEC; European Commission, 1992), which is locally represented by subtypes 91E0pt1, 91E0pt2 and 91E0pt3 according to the Portuguese Sectoral Plan (ALFA, 2004). While these subtypes vary in hydrological stability, in the studied region 91E0pt3 is usually structurally more stable and less prone to disruptive flooding. Highly resilient humid perennial megaforb communities (6430pt2), particularly those featuring *E. cannabinum*, are regionally closely associated with these habitats. Structurally similar hygrophilus vegetation is described in Northern Europe as riparian tall-herb communities, tall-herb fens, alder carr margins, or tall helophyte fringes.

Microclimatic Constraints:

Beyond the soil and water parameters, the dense, tall megaforb stands and the structural canopy of riparian woodland may provide microclimatic protection. The moth's flying period does not differ greatly across Europe, being concentrated in September, a month that can be remarkably warm under the Atlantic–Mediterranean climate of central-western Portugal. Areas lacking a minimum amount of tree-canopy cover and humid air may therefore be unfavourable. On the other hand, shading cannot be extensive as to preclude woodland edges and clearings in edaphically suitable positions, where *E. cannabinum* can develop under minimum adequate light conditions.

This localized microclimatic buffering is crucial in the Mediterranean-Atlantic bioclimatic transition, where structured riparian fringes decouple the understory from regional thermal extremes (Rivas-Martínez et al., 2011; De Frenne et al., 2019).

Main topohydrological settings:

The Caldas da Rainha typhonic valley is a unique diapiric depression characterized by differential erosion and Holocene alluvial plains (Zêzere, 2005). According to Zêzere, this geomorphological structure promotes significant water retention and creates a network of humid floodplains, surrounded by limestone ridges. Consequently, these dynamics create a microclimatic matrix and a microhabitat network.

The survey results indicate that the ecological niche of *G. flavago* is not confined to a single humid habitat type or ecotone, but emerges from the convergence of persistent moisture, adequate drainage, sufficient illumination, presence of arboreal cover, hydrological stability, and vigorous *E. cannabinum* growth. The different configurations described below represent distinct topographic and hydrological expressions of its ecological niche, ranging from marshy alder systems and larger riverine landscapes to narrow incised valleys and catenal hillslope runoff systems (surface runoff or subsurface flow).

a) Marshy woodland ecotones

The most favourable ecological setting identified for *G. flavago* is associated with marshy forests of *Alnus lusitanica* (Habitat 91E0pt3), particularly their riparian forest-edge ecotones and clearings. This habitat is currently very rare, confined and highly isolated regionally, with many sites retaining only secondary regeneration dominated by *Salix atrocinerea* Brot. (Fig. 8), which more readily colonizes transformed humid soils through wind-dispersed seeds, and sometimes with remnant *Frangula alnus* Mill..

The preferred habitat typically develops along a catenary sequence transitioning into hydromorphic arenosols (also argillaceous sands), often associated with deep, stable baseflow or shallow, gently sloping aquicludes. Hardwater flow, multi-directional lateral infiltration and lateral runoff extend suitable hydrological conditions across the system, particularly upstream of the Nadadouro stream, which stands out as an ecological hotspot for megaforb communities and *G. flavago*. Despite its limited spatial extent and being highly threatened, the Nadadouro site is a reference point also for other riparian Lepidoptera, revealing poorly known species towards their southern range limits, especially *A. lusitanica*-associated such as *Caloptilia elongella* (Linnaeus, 1761), *Acleris notana* (Donovan, 1806) and *Idaea dromikos* Hausmann, 2004 (see Appendix for more details), with similarly few confirmed Portuguese records, in some cases also known from a single locality. This is particularly noteworthy for a habitat increasingly constrained by urban encroachment (Fig. 22).



Figure 8 - Rare view of a hidden inner clearing of a mature willow grove with *Frangula alnus* (probably a former alder grove) in a lentic run-off area fed by a hard-water baseflow within hydromorphic arenosols, partially surrounded by sandstone reliefs. *Quercus* spp. and strawberry trees form a peripheral forest. Such sites are not uncommon, despite being altered, but some preserve dozens of medium-to-large-sized *E. cannabinum* stands. Formigal (Caldas da Rainha); 2021.

Marshy alder forests are also particularly favourable through their unique edaphic characteristics: organic matter and alder-associated mycorrhizae contribute to balanced nitrogen availability which, combined with the water characteristics, is readily taken up by plants, favouring extensive stands of *E. cannabinum* capable of vigorous regeneration even after disturbance.

The waterlogged woodland core of this habitat may support *Magnocaricion* helophytes, especially *Carex paniculata* subsp. *lusitanica* (Willd.) Maire, or *Phragmition* species such as *Iris pseudacorus* L. and *Sparganium erectum* L.; in disturbed areas these more readily mix with megaforbs, with *Eupatorium cannabinum* L. typically occurring peripherally.

b) Fluvial ecotones



Figure 9 - Typical scenario of controversial management in regional riverbanks and water channels of central-western Portugal: current interventions focus on drainage and mechanical clearing, while neglecting ecological integrity. *Eupatorium* populations have virtually disappeared from the agricultural landscapes of the modified rivers west of Óbidos. Rio Real (river valley). Óbidos; 2025.

Broad alluvial fluvisols in lowlands, regularly subject to flooding and other unstable conditions, and with a history of intensive land use, have generally shown to be less suitable for this moth or the maintenance of permanent nuclei of *E. cannabinum*, despite some featuring sparse stands of this plant and wooded patches. These areas are generally occupied mainly by tall, annual or nitrophilous ruderal species. In a few sections where agricultural pressure is lower, this plant is still associated with fragmented or degraded alder woodlands dominated by *Salix atrocinerea* Brot., frequently on micro-terraces (habitat 91E0pt1) occasionally occupied by hybrid poplar plantations, a feature that can also be found in habitat 91E0pt3. These habitats frequently include ditches within traditional agricultural parcels, which only support sporadic occurrences of *Eupatorium* where stable moisture and minimal chemical applications persist.

Currently, alluvial micro-terraces are more suitable when associated with interflow or runoff areas from adjacent hillsides or small tributaries. These zones tend to transition toward other habitat types (such as 91E0pt3), as occurs in the vicinity of Quinta dos Bugalhos, or toward the specific conditions described below.

c) Incised valley ecotones

Eupatorium cannabinum also occurs confined to the naturally narrow wet margins of incised valleys, along sandstone and marl reliefs, where relict habitats featuring hazelnut (*Corylus avellana* L.) groves (9160pt2) and *Laurus nobilis* L. (5230pt1) are particularly valuable for conservation. These watercourses frequently include alder formations comprising habitat 91E0pt1. Generally surrounded by mixed forest with oak dominance (*Quercus* spp.) and *Phillyrea* L. groves (5230), these distinct riparian communities are very well represented along the eastern border of the Diapir, facing the Typhonic Valley (Fig. 10).

G. flavago is scarce or possibly occasional in these habitats, potentially owing to the narrow strips of permanently moist, stable soils along the margins that escape both winter flows and summer drought, their degradation, or excessive shade that limits the growth of the host-plant. An exception occurs in edges where wider riparian shelves support wet meadow patches; however, as a result of rural abandonment, these are almost permanently clogged with dense brambles. The scarce records of the moth in such situations possibly result today from dispersal from colonies under different topohydrological circumstances and undetermined distances, where *E. cannabinum* is more abundant and vigorous.



Figure 10 - Typical riparian section of a well-preserved incised valley: canopy dominated by *Alnus lusitanica* and *Corylus avellana* with *Clematis vitalba*. The humid, steep banks feature *Eupatorium cannabinum*, *Hypericum androsaemum* L., the southernmost known population of *Melittis melissophyllum* L. of western Europe, *Carex pendula*, and Dryopteridaceae. Caldas da Rainha Municipality; 2025.

d) Hygrophilous shrublands in catenal contacts

Oligotrophic acidic surfaces on gentle hillslopes with a significant influence of a baseflow allow small patches of hygro-minerotrophic vegetation and may also form a suitable habitat for *G. flavago*. This biotope does not necessarily correspond to a defined forest, stream or watercourse; it is often open and flanked by dry heath and gorse shrublands characterized by understory communities, giving way in damp patches to homologous hygrophilous shrublands. A localised grey dune profile combining wet heath and megaforbs occasionally extends, along with its characteristic species, into sandy inland surfaces further into the typhonic valley. Not uncommonly, *Erica erigena* R. Ross, *Genista ancistrocarpa* Spach and *Carex hispida* Willd. ex Schkuhr are observed alongside *Eupatorium cannabinum*, and may extend into small patches of oligotrophic mire formations.

These biotope types are not rare but somewhat degraded, although remnants still occur contiguously and interact with those previously described. Although lacking host-plants with robust stems in abundance, a few stands remain suitable, and the observation of larvae and small-sized *G. flavago* individuals may indicate a functional niche.

This is part of the landscape found very well represented in the coastal areas from Leiria to Pombal, and also somewhat far from the coast in contact with swamp forests, sometimes featuring abundant nuclei of *E. cannabinum*.

II. Life history of *Gortyna flavago* in central-western Portugal

Larval and Pupal Stages:

The life cycle stages of *Gortyna flavago* have been widely recorded in classical and modern European entomological literature. The species overwinters in the egg stage, with hatching probably occurring in February or early March in central-western Portugal, where a few almost mid-instar larvae can already be detected by April in young plant shoots (Fig. 11).

Although larvae may naturally relocate on or between stems, the traces left during the early stages are often subtle, appearing to be predominantly sedentary.



Figure 11 - Early instar larva on *Eupatorium cannabinum*. Nadadouro; 10.iv.2024.



Figure 12 - Recently emerged male specimen expanding its wings below mid-height of an *Eupatorium cannabinum* stem, in an area where high larval abundance had been previously recorded. This is the earliest record for the region, made very close to a newly installed street light near which three large stands of this host-plant occur, constituting an unusual occurrence. Nadadouro; 7.viii.2024.

Larval growth is slow throughout summer. Feeding apparently slows markedly during the final instar for over a month while the larva enlarges a pupal chamber at the base of the host stem. Unless dislodged, full grown larvae remain sedentary, showing little evidence of activity. Upon relocation, they may rapidly re-bore and excavate a new space at the base of another stem, becoming stationary again. Moreover, after three years of observations, the flying period was consistently centred around the same period (September), irrespective of interannual meteorological variation and differences in host-plant development, habitat and location, which may point to the possibility of a mechanism synchronizing the transition to the adult stage. The only exception involving early adult emergence was recorded during the first week of August (Fig. 12).

The interior of the stem consistently contains high levels of moisture or plant fluids. The increasingly sap-rich environment within *Eupatorium* stems may explain specific feeding requirements, in what deserves further study. Feeding efficiency appears high throughout larval development, possibly owing to additional nutrient uptake from flowing sap. The relationship between the larva and its host-plant appears to be highly balanced. *E. cannabinum* produces multiple stems from perennial rhizomes, and a couple of isolated vigorous plants can harbour several larvae from March/April through to August/September, as observed at the Nadadouro site. In August 2024, an isolated vigorous plant was found to contain seven pupal chambers among 21 erect stems; seven additional stems showed no traces of occupation, while another seven contained empty galleries. The stems, characterized by hard, strong walls, are excavated internally only within their lower quarter, with galleries extending slightly below the rhizome block while leaving substantial vascular tissue intact. Consequently, stems are rarely destroyed and generally continue to flower and set seed successfully. Generally, only thinner, secondary stems, or growing in shaded conditions, succumb to the activity of final-instar larvae. In such cases, larvae may move to a new stem to complete feeding or pupate within the existing senescent stem (*Eupatorium* stems do not break easily, even after senescence).

Monitoring the duration of the pupal stage is not feasible due to poor visibility on plants and potential behavioural changes in captivity, and because exact start dates were unknown. In August, larval fresh boring signs are minimal, and few open and resealed galleries with non-parasitized individuals were followed until emergence, roughly indicating that this phase may last between two and three weeks.

The exit hole is prepared slightly above the pupal chamber and remains barely concealed beneath the plant epidermis (Fig. 13). Even enlargement of the chamber does not appear to impede sap circulation and exudation. Construction of the pupal chamber may increase basal fragility and occasionally cause stems to lean, particularly in shaded areas, although complete breakage is uncommon, as already has a natural tendency to lodge, with the distal portion subsequently curving upwards and proceeding to flower. Since the *E. cannabinum* typically grows in dense communities, leaning stems may remain supported by neighbouring plants of similar height. Overall damage is therefore limited. Moreover, the slopes and marginal areas where it thrives are generally subject to little trampling by larger mammals, which tend to follow established tracks.

Stems bearing larval traces and an open exit hole dry naturally during winter and may remain erect until the following season.

A potential advantage of *E. cannabinum* as a host-plant under these biogeographic conditions is its perennial rhizomatous growth, allowing vigorous annual resprouting and persistence at the same site over successive years. This may provide greater spatial continuity of larval resources than annual stems of plants such as *Cirsium palustre*, particularly where suitable habitats are fragmented and host-plants are often confined to small, isolated patches.

This remains a hypothesis, but observations over three years and the author's experience with the plant, activity of *Gortyna flavago* may stimulate basal stem multiplication and resprouting from peripheral sections, potentially enhancing the plant's capacity to remain an optimal host. In the absence of another apparent comparable cause, plants occupied annually appear broader and produce a greater number of stems than unaffected plants, although they do not develop the excessive abundance of thin regrowth observed following mechanical mowing.



Figure 13 - Pupal chamber with a closed exit hole (in the centre) and a false exit hole above, possibly a failed entrance attempt. Nadadouro; 4.viii.2024.

Under non-mined conditions, new shoots emerge from the rhizome, initially growing downwards or horizontally before turning towards the surface as they develop. However, when stems are mined by larvae whose galleries extend into their lower sections during summer, natural winter senescence appears to penetrate to greater depth. As spring approaches, living tissue is therefore situated farther below the rhizome block, potentially forcing regrowth from deeper zones and causing new shoots to emerge more peripherally. This process appears to increase the peripheral width of the rhizome block and may induce a slight increase in stem production while maintaining a relatively robust stem diameter, and a balanced number of stems.

Mating season:

Adult emergence typically occurs from dusk into the night, beginning in late August (rare earlier), peaking in September, and becoming infrequent in early October with only worn-out individuals observed by both methods described. The peak mating period occurs when the host-plant is already fruiting and its inflorescences are withered (ceasing to attract nocturnal pollinators that abound in riparian zones, which in turn attract more predators).

Following wing expansion, adults exhibit low mobility; they typically ascend the stem and remain stationary for several hours, sometimes repositioning without taking flight. This behaviour mirrors that of *Luperina testacea* (Denis & Schiffermüller, 1775), where evening female flyers are also composed of individuals that emerged on previous nights. However, unlike

the latter which mates hours later during a secondary flight period at dawn, *G. flavago* barely flies away and hides in the leaf litter at daybreak.

Both males and females become highly active at twilight the following night, flying around *Eupatorium* patches along woodland edges and in clearings, but also penetrating densely wooded habitats and bramble thickets where some host-plants persist. Females select a low perch and release pheromones, often from the host-plants or very close (Fig. 14). Males meticulously patrol these clusters along edges from dusk onwards for about an hour, then remain perched near the host-plants if not mating successfully, however keeping their antennae raised. Mating (Fig. 1) was recorded between 20:45 and 23:30 (first week of September, western Portugal; UTC+1), in many cases involving females previously observed on preceding nights.

The slow, mid-height (0.5–1.5m), and inquisitive patrolling behaviour of males among the stems and dense vegetation at twilight suggests a potential narrow window of pheromone release by newly emerged females; however, mating involving fresh females (located and monitored at fifteen-minute intervals) was never observed during overnight monitoring. It seems likely that the use of red light did not inhibit the females, especially since older females were successfully tracked and observed mating under similar light conditions.

Activity becomes rare overnight, and finally both sexes find a low position to hide at dawn.

Dispersal and Oviposition:

Despite limited observations of adult feeding (a single instance involving aphid honeydew; Fig. 2), the relative longevity of a captured mated female could indicate a high dispersal potential over at least a week and a half, with very gradual oviposition, although these results may have been influenced by feeding and *ex-situ* protection. Conversely, the recapture of a female at the same site on two consecutive nights (freshly emerged and then mated the following night), and again after a seven-day interval despite cold intervening nights, indicates that at least some individuals may exhibit site fidelity, or returning, maintaining a localized home range within isolated patches or area (Fig. 14). Both sexes were frequently observed at the same locations over consecutive nights, often within the same forest edge.

However, the occasional observation of 1-2 larvae in isolated sites with very limited host-plants, kilometers away from the main colonies, may suggest dispersal behaviour that likely maintains gene flow between subpopulations.

Field observations at Nadadouro and in the vicinity of Quinta dos Bugalhos suggest that oviposition occurs on the first withered leaves near the base of thicker stems (Fig. 15). However, due to the proximity required for observation amidst dense vegetation, and since the species easily interrupts certain behavioural routines when exposed to light, the presence of wild eggs was not observed. Adults observed active after midnight were exclusively females.

Behaviour in limited controlled environments (*ex situ*) offering diverse plant structures, showed a consistent preference for broad, desiccated (brown) leaves on the middle section of the stem, with the eggs concealed in small clutches in a manner typical of the Apameini tribe, with the plant tissues acting as a partial sheath. The female tested exhibited intermittent periods of activity throughout the night, with peak activity at dusk, ending at 3 AM.

In nature, the mid-height hanging *E. cannabinum* leaves often persist through late autumn and fall during winter, potentially leaving egg clutches dependent on undisturbed soil conditions.

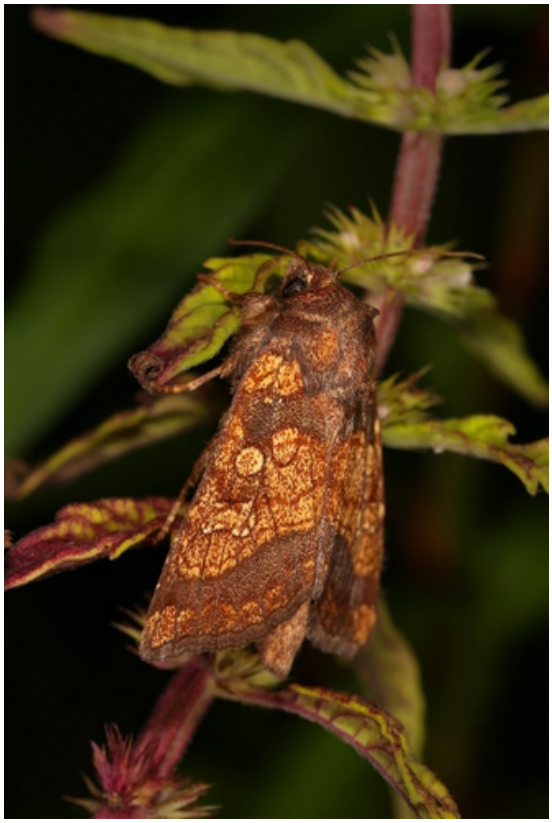

Figure 14 - Female interrupting her calling behaviour on *Lycopus europaeus* L. after being disturbed by a camera flash. A mating pair was located a short distance away. Likely due to the disturbance and the late hour, she was found mating the following night less than 100 m away. A third observation of the same individual was made nearly a week later at the same location, where she appeared partially worn (apparently almost empty of eggs). The identity match was confirmed through image analysis. Nadadouro; 2.ix.2024.



Figure 15 - Oviposition behaviour on a bent stem of *Eupatorium cannabinum*, under *Alnus lusitanica* canopy. Nadadouro; 30.viii.2026.

Inconclusive rearing trials:

Captive breeding at a small scale has not yielded reliable results, despite some outcomes being subject to results and discussion.

Eggs laid by a captive female, kept under urban micro-climate outdoors, hatched between late February and early March. However, these dates may not accurately reflect the natural phenology in the wild. The young larvae were released at the Nadadouro stream (in 2025), in a plot where larvae had not been found in previous years, and developed according to the species' normal phenology.

Four captured larvae were reared, fed with detached cultivated stem parts of *E. cannabinum*, but with unsatisfactory results, this reinforces the hypothesis that the species is highly dependent on fresh plant sap. Furthermore, the resulting abnormally small adults possibly exhibited altered behaviour: emerging randomly during a 24-hour period, both males and females struggling violently to escape their cages and refusing to mate, even in outdoor cages placed near cultivated host-plants. This necessitated their release into the wild (lost out of sight), rendering the observations null and unrepresentative of natural behaviour. Such a reaction is common among captive specimens and should not be interpreted as dispersal.

Predation and parasitoids:

Very few cases of predation on *G. flavago* have been witnessed. Nevertheless, bats were occasionally identified hunting just after the twilight period, precisely when the moth peaks its activity: *Myotis escalerai* (Cabrera, 1904) and *Plecotus austriacus* (Fischer, 1829), together with a medium-sized brown-orange-colored horseshoe bat (*Rhinolophus* cf. *mehelyi*), were easily identified at very close range at Nadadouro site.

However, The repeated recaptures of adults during the breeding season suggest that *G. flavago* can exhibit considerable longevity in its natural habitat.

Two malformed pupae from Nadadouro were retained for the identification of a lethal endoparasitoid: *Nemoraea pellucida* (Meigen, 1824), a tachinid inhabiting forest areas, raising the possibility that it may be a common situation.

Despite the presence of fissures exposing the larval and pupal chambers, often caused by plant tissue folding or wrinkling, no predatory interest from *Myrmica* sp. was observed affecting *G. flavago*. This lack of interaction persists even when ant colonies occupy the rhizome block, and despite *Myrmica* sp. being very common and abundant in these humid habitats.

III. Habitat and population dynamics

Negative surveys and vegetation succession:

The presence of *E. cannabinum* alone was not sufficient to predict the occurrence of *G. flavago*. Surveys of apparently suitable host-plant stands, including some comprising several tens of vigorous plants, frequently produced no evidence of larvae and adults. Negative surveys included *E. cannabinum* stands approximately 300 m from Ribeira do Nadadouro, with abundant plants in an area of gentle hillslope runoff, and also sites at Mata das Mestras and Mata do Vimeiro (east of the Caldas da Rainha Typhonic Valley), at woodland edges influenced by hillslope interflow. All had been subjected to vegetation cutting, though not necessarily annually, and yielded no evidence of *G. flavago*. The species was also undetected in other scattered *E. cannabinum* occurrence sites and incised valleys east of the Typhonic Valley, where no visible signs of vegetation cutting were observed.

While some negative results coincided with evident threats or habitat limitations, others had no obvious explanation, suggesting that unknown behavioural preferences or dispersal limitation factors, previous disturbance or less readily detectable environmental pressures may influence occupancy.

The consistent lack of detections in cut stands, regardless of intervention timing or frequency, is compatible with the species' prolonged use of persistent host-plants for endophytic larval development, pupation and possibly oviposition on senescent foliage, requiring structural continuity through winter. For instance, roadside *E. cannabinum* stands (Fig. 16) may retain abundant host-plants while recurrent management prevents moth attraction or completion of its annual cycle, turning these habitats into possible ecological traps, unless specific evolutionary response allow the moth to avoid them.

Conversely, *E. cannabinum* stands colonized fallow or abandoned ground near established populations and were subsequently occupied by *G. flavago* (Fig. 17), indicating that new occupied habitat can develop where neighbouring populations provide sources of both seeds and dispersing females.



Figure 16 - Roadside verge intersecting a "native" runoff line with water accumulation, with hundreds of thin *Eupatorium* stands along a 70 meter stretch. Vegetation management even promotes their multiplication, but surveys for *G. flavago* at this location resulted totally null. Alfeizerão (Alcobaça); 2024.



Figure 17 - Smallholder agriculture fallow along the Ribeira do Nadadouro upstream section, easily evolving into a wet meadow and megaforb vegetation. This site experiences a significant *Eupatorium cannabinum* colonization in fallow and abandoned wet fields. Note upstream one of the groups of *Alnus lusitanica* woodland. This regeneration originates from seedlings of more consolidated plants in nearby undisturbed uncultivated soils; 2026.

New habitat opportunities and regeneration may be temporary, as prolonged abandonment favours succession by *Rubus*, dense scrub and invasive vegetation, eventually increasing shade, suppressing megaforb communities and, particularly where grazing and smallholder agriculture has declined, even promoting woody herb fuel accumulation that may increase the local intensity of wildfires. Traditional low-intensity land use may have helped maintain these habitats at an intermediate successional stage. In particular, sheep grazing tends to maintain the margins of wet meadows while avoiding *E. cannabinum* and other inherently peripheral, unpalatable megaforbs. Habitat persistence therefore appears incompatible with both recurrent indiscriminate clearance and unrestricted vegetation succession.

Negative surveys further north:

Along the Nazaré-Pombal coast (National Pine Forests), extending slightly inland into more rugged and consolidated terrain, *E. cannabinum* was known from several apparently suitable habitats, including riparian galleries in dune depressions and small streams and seepage along hygrophilous scrublands. Although some stands recovered after the 2017 severe fires, others were subsequently destroyed by land-management interventions, and recent surveys across coastal and adjacent inland habitats yielded *no G. flavago*, with many Eupatorium populations destroyed. However, historical occurrence or persistence of undetected populations cannot be excluded.

Habitat resilience under disturbance regimes:

The topohydrological settings occupied by *G. flavago* also differ in their response to episodic disturbance. Lowland larger riverine systems are more exposed to flooding (Fig. 18), whereas open hillside habitats with a mix of megaforbs and hygrophilous scrub may be more vulnerable to summer wildfire. Marshy alder and stable interflow systems on slightly elevated terrain with luxuriant summer succulent foliage vegetation have proven to be comparatively buffered from these extremes, as well as riparian galleries embedded in broader sections of steep-sided humid valleys. During the severe fires of 2017, humid riparian and nemoral vegetation remained unburnt at some of both types of site, whereas more open coastal scrubby humid ecotones burned severely; *E. cannabinum* nevertheless regenerated rapidly in the latter and was sometimes among the first species to resprout. The survival of *G. flavago* during fire remains unknown; any protection afforded to larvae by their basal, partly subterranean position in moist stems and soil remains hypothetical.



Figure 18 - Active alluvial systems and floodplains, characterized by fluctuating flood regimes, high sediment loads, and variable water levels, rarely meet the conditions required for the permanent proliferation of *Eupatorium cannabinum*, which prefers moist yet well-drained soils in more hydrologically stable catenal contacts. Instead, these dynamic environments naturally favour other plants and specialized endophytic marsh lepidopterans better adapted to hydrological fluctuations. Poças do Vau, Óbidos; 2026.

Conversely, during the extreme flooding in early 2026 after Storm Kristin, the Nadadouro upstream hydromorphic system maintained essentially unchanged water levels, while extensive areas upstream the Rio Tornada valley were strongly affected, including lowlands in the vicinity of Quinta dos Bugalhos, where, due to partial rural abandonment and vegetation management, *Eupatorium* was not well represented in the hygrophilous niche most suitable for escaping floods. Following the storms throughout the entire 2026 season, no records were made in these areas of the Vidais parish. In the worst-case scenario, this localized collapse coincided with relatively recent, extensive, and profound deforestation extending over kilometers along the surrounding slopes due to modern eucalyptus rotation practices. A couple of years ago, these practices disrupted water runoff pathways and hygrophilous shrublands that intermingled with megaforbs. Furthermore, machinery-induced erosion and subsequent bank collapses have also severely affected the margins of the lower riparian zones (Fig. 19b).

The intrinsic relationship between the ecology of different topohydrological settings typically reduces the probability of synchronous extreme events through habitat diversity, thereby allowing for recolonization. Moreover, the contrasting responses suggest that more stable habitats may provide long-term refugial conditions, especially under rising anthropogenic pressure, while more disturbance-prone habitats contribute periodically to habitat availability and spatial continuity.



Figure 19 a/b - Earthworks effects after a forest monoculture rotation: a) upland runoff/interflow formerly supported semi-open hygrophilous scrublands and megaforbs in relative abundance; b) a slightly lower zone a few hundred meters away, where erosion and landslides impact an ecologically outstanding marshy area characterized by rare and protected megaforb vegetation. Both sites are located upstream of a degraded woodland whose edges hosted significant numbers of *G. flavago*; The first *G. flavago* regional record in 2023 (2º national record) originates halfway between sites, prior to the main interventions. Freguesia de Vidais (Caldas da Rainha); 2025(a)/2026(b).

Population persistence under changing landscapes:

Riparian tall-herb (megaforb) communities often persist as remnants of natural river-valley vegetation and refugia for hygrophilous plants in heavily modified landscapes (Rodwell, 1995; van der Maarel, 2005). However, in Portugal's west region this applies to a limited range of species, especially considering that, under a Mediterranean climate, the edaphic moisture ecotone can be very narrow.

Contemporary pressures include intensive forestry, agriculture, orchard management and far-reaching effects of agrochemical exposure, hydrological overexploitation, invasive vegetation and urban expansion, and stands lagging behind any functional or sustainable criteria (Fig. 21).

Historically, before such extensive landscape transformations, marshy ground, springs and narrow riparian margins with heliophilic edge habitats often escaped intensive cultivation, with traditional agricultural practices also preserving small riparian fragments and culturally recognized sites, particularly springs associated with interflow zones. Increasing mechanization and disregard or lack of legal restrictions now facilitates intervention within many of these formerly marginal habitats, leaving only ruderal plants and some nitrophilous helophytes on deep ditches. This process has been accelerating: several *E. cannabinum* sites known from earlier floristic surveys were substantially altered or destroyed between 2019 and 2023 (example in Fig. 20).



Figure 20 - One of many instances of direct, severe destruction of marshy woodlands with hydrologically stable margins, previously regenerating from an earlier harvest. Regionally, traditional smallholder subsistence farming and low human population density restricted land-use conversion in these difficult-to-manage topohydrographic features, long-term preserving core and marginal vegetation. Neighborhood of Formigal (Imaginário; Caldas da Rainha); 2026.



Figure 21 - Inappropriate land use in riparian ecosystems: Drainage and Umbrella Pine (*Pinus pinea* L.) planting in naturally saturated soils, with the application of herbicides. Concelho de Óbidos.

These changes acquire greater significance in the context of the fragmented regional distribution and the persistence of *G. flavago*. Sites supporting the highest recorded densities may have functioned as source populations, while larvae were also found in small, apparently isolated patches and newly established *E. cannabinum* stands near existing populations became occupied. Although no individuals were recorded at more than one location, these observations, together with the spatial proximity of several occupied sites, are consistent with a metapopulation structure at the local scale. Regional persistence may therefore depend on a heterogeneous network of core population and smaller, sometimes transient habitats that may facilitate dispersal and recolonization. This spatial complementarity may be particularly important where suitable humid ecotones are naturally restricted and increasingly fragmented by land-use change.

Light pollution:

The study area where *G. flavago* was rediscovered is largely urbanized, with locally high levels of street lighting and extensive diffuse artificial light particularly under the frequent cloudy conditions of summer.

The most relevant core population of this moth (Nadadouro) occurs where high-quality habitat patches persist amid ongoing urban development, including housing, gardens and associated street infrastructure. Artificial illumination is only locally attenuated by dense riparian tree cover within the wooded core and edge areas. Although the species appears tolerant of current urban light levels at Nadadouro under these conditions, the behavioural responses observed throughout this study suggest that this may have its limits, with stronger illumination potentially increasing light avoidance.

Night-time light distribution was therefore mapped across the study area (Fig. 22a/b), with the Nadadouro site highlighted at a more detailed scale (Fig. 22b). This issue may become particularly relevant to planned riparian restoration near urban centres, welcome actions given habitat loss elsewhere through agricultural intensification or excessive abandonment; wavelength-adapting or limiting artificial lighting in these restored habitats may favour biodiversity.

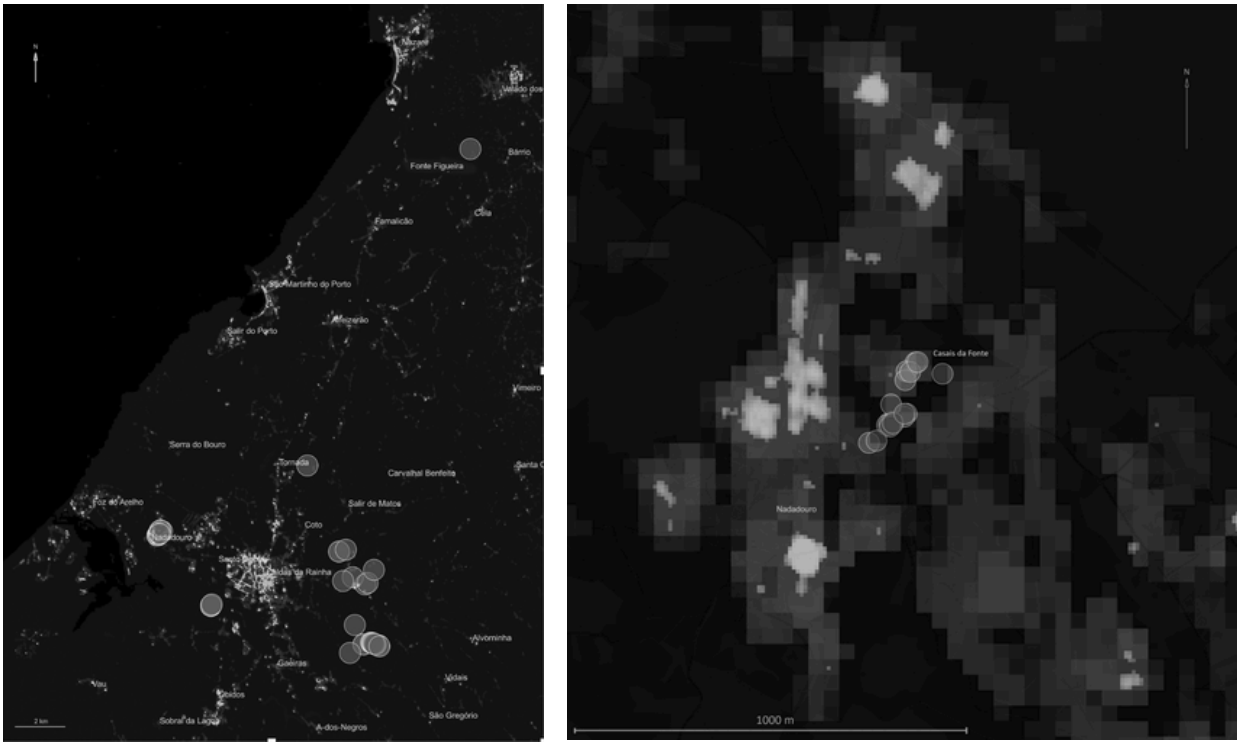

Figure 22a/b - a) Night-time light satellite observation on 11.xii.2024. The overlay combines the 10m spatial definition of light sources with the 40m band to capture atmospheric radiance diffusion. b) observation of artificial light in the upstream area of the Nadadouro stream. The shallow valley features peripheral and diffused lighting (especially under cloud cover, not here represented), partially attenuated by dense tree canopies reducing upward light propagation.
The dark circles represent *G. flavago* documented records (imagery) between 2023 and 2025.
SDGSAT-1 imagery courtesy of the Sustainable Development Goals Big Data International Research Center (CBAS) and the Chinese Academy of Sciences (CAS).

Conservation

The apparent restriction of *G. flavago* to a small number of localized populations and its dependence on a spatially restricted network of humid habitats warrant targeted conservation measures in central-western Portugal. Priority should be given to maintaining the known core populations, together with smaller occupied patches and intervening habitat that may contribute to dispersal and recolonization.

Protection should therefore extend beyond individual host-plant stands to the hydrological and vegetation processes that maintain suitable riparian and interflow ecotones. Management of *E. cannabinum* stands should preserve their structural continuity throughout the year. Recurrent mowing or clearance of occupied and potentially suitable stands should be avoided, while excessive succession by *Rubus*, scrub and invasive vegetation may require selective control where it causes substantial shading or displacement of megaforb vegetation. Such intervention should be spatially limited or carried out rotationally across micro-sites. Where low-intensity grazing maintains open wet-meadow margins without substantial consumption or damage of *E. cannabinum*, its continuation may be compatible with habitat maintenance.

Conservation of the underlying hydrology is equally important. Drainage, water abstraction (boreholes), soil sealing and other modifications capable of altering groundwater, lateral interflow or riparian flow should be avoided in and around *G. flavago* habitat. Appropriate separation from intensive forestry and orchards would also reduce direct habitat alteration and potential exposure to agrochemical drift, while invasive vegetation should be controlled where it compromises native riparian and megaforb communities. In urbanized sites, unnecessary artificial illumination immediately adjacent to breeding patches should be minimized or adapted where practicable.

Formal recognition of the most important population nuclei, potentially through small protected areas or site-specific management agreements, would facilitate their long-term conservation. Where connectivity has been lost, restoration should favour natural regeneration of *E. cannabinum* and associated native vegetation, supplemented where necessary by locally sourced material, rather than isolated planting without suitable hydrological conditions and provision for appropriate long-term maintenance. Monitoring should remain minimally invasive and include both established populations and apparently suitable unoccupied stands, allowing changes in occupancy, habitat condition and connectivity to be detected while the species' Portuguese distribution remains incompletely known.

Conclusions

The rediscovery of *Gortyna flavago* after more than six decades without records in Portugal reveals a species that may have been historically overlooked, but appears to be rare and highly localised in the study region. In central-western Portugal, its strong fidelity to *Eupatorium cannabinum* and dependence on a restricted combination of persistent soil moisture, adequate drainage, vegetation structure and microclimatic conditions contrast with the broader ecological plasticity reported elsewhere in Europe.

The fragmented distribution of occupied sites, some separated by only a few kilometres within networks of humid habitats, notably across Óbidos Lagoon and Rio Tornada system, together with the occurrence of small, newly colonized host-plant patches within a few hundred metres of core populations, suggests potential connectivity among local population nuclei. The observed adult longevity, behavioural characteristics and flight capability further support the likelihood of medium-distance dispersal, possibly facilitated by olfactory detection of *Eupatorium cannabinum*. Collectively, these spatial and biological characteristics are consistent with a local metapopulation structure, although no individuals were recorded at more than one site during the survey period.

At this Atlanto-Mediterranean range margin, humid riparian and associated ecotones may act as bioclimatic refugia for moisture-dependent biodiversity, warranting conservation under increasing anthropogenic pressure (Keppel et al., 2012; Zhang et al., 2023). The Portuguese distribution of *G. flavago* nevertheless remains incompletely known. The localized nature of the populations documented here, together with negative surveys in apparently suitable habitats across Beira Litoral, means that historical occurrence or the persistence of additional undetected populations cannot be excluded. Further studies are therefore essential to establish its full distribution and to determine whether the ecological patterns identified here remain consistent under different environmental conditions across its range.

Acknowledgments

My first sincere gratitude goes to the anonymous contributors to the data collection for this paper. Once more, a special thanks goes to Martin Corley for challenging me to publish years ago. I am also grateful to the reviewers and the editorial team for their dedication to processing such a lengthy manuscript. Finally, I wish to thank everyone who has contributed to ensuring that effective conservation solutions are already being planned and implemented to prevent the decline of this species.

Appendix

Field records obtained at Nadadouro (Casais da Fonte), through direct nocturnal searches using handheld flashlights include *Acleris notana* (Donovan, 1806) on 16.v.2026; *Caloptilia elongella* (Linnaeus, 1761) at Nadadouro on 29.vii.2025, 13.viii.2025 and 9.vii.2026 (two records); and *Idaea dromikos* Hausmann, 2004 at Quinta dos Bugalhos on 10.viii.2025 (two records), with a substantial number of additional observations at Nadadouro in 2025 and 2026, mainly between July and August. Approximately six records on 8 and 14 October suggest a possible partial second generation, coinciding with an exceptionally warm early autumn. At Nadadouro, adults were observed in abundance directly beneath alder trees (*Alnus glutinosa*), with oviposition and larval feeding observed exclusively on fallen alder leaf litter. Larvae were detected within this leaf-litter substrate from August to July of the following year. Similar observations of the feeding niche of *I. dromikos*, associated with fallen alder leaf litter, were made near Mosteiro de Folques, Arganil (40.22612° N, 7.99447° W), with the first record of the species on 6.viii.2023. For consistency, observations made after midnight are assigned to the preceding calendar date, corresponding to the beginning of the nocturnal survey.

References

ALFA. 2004. *Tipos de Habitat Naturais e Semi-Naturais do Anexo I da Directiva 92/43/CEE (Portugal continental): Fichas de Caracterização Ecológica e de Gestão para o Plano Sectorial da Rede Natura 2000*. Associação Lusitana de Fitossociologia, Lisboa.

Bernays, E. & Graham, M. 1988. On the evolution of host specificity in phytophagous arthropods. *Ecology* **69** (4): 886-892.

Bretherton, R. F., Goater, B. & Lorimer, R. I. 1983. In: Heath, J. & Emmet, A. M. (eds.) *The Moths and Butterflies of Great Britain and Ireland* **10** (Noctuidae, part 2): 1-459. Harley Books, Colchester.

Calle, J. A. 1982. *Noctuidos españoles. Boletín del Servicio contra Plagas e Inspección Fitopatológica*, Fuera de Serie **1**: 1-430. Ministerio de Agricultura, Pesca y Alimentación, Madrid.

Carapeto, A., Francisco, A., Pereira, P. & Porto, M. (eds.) 2020. L*ista Vermelha da Flora Vascular de Portugal Continental*. Coleção Botânica em Português **7**: 1-374. Imprensa Nacional-Casa da Moeda, Lisboa.

CBAS/CAS. 2026. SDGSAT-1 *Satellite Imagery*. Sustainable Development Goals Big Data International Research Center & Chinese Academy of Sciences (consultado em outubro de 2026).

Corley, M. F. V. 2015. *Lepidoptera of Continental Portugal. A fully revised list*. Martin Corley, Faringdon. 288 pp.

De Frenne, P., Zellweger, F., Rodríguez-Sánchez, F., Scheffers, B. R., Hylander, K., Luoto, M., Vellend, M., Verheyen, K. & Lenoir, J. 2019. Global buffering of temperatures under forest canopies. *Nature Ecology & Evolution* **3** (5): 744-749. DOI: 10.1038/s41559-019-0842-1.

Ebert, G. (ed.) 1998. *Die Schmetterlinge Baden-Württembergs* **7**: Nachtfalter V. 582 pp. Eugen Ulmer, Stuttgart.

Esri. 2026. *World Hillshade Map Server Elevation Tiles*. Environmental Systems Research Institute. [consultado em outubro de 2026].

European Commission. 1992. *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Official Journal of the European Communities* L 206.

Farminhão, J. (coord.) 2021. *Sítios de Interesse Botânico de Portugal Continental*. Tomo II. Coleção Botânica em Português **5** (2). Imprensa Nacional-Casa da Moeda, Lisboa.

Fibiger, M. 1990. *Noctuidae Europaeae* **1**: *Noctuinae I*. 208 pp. Entomological Press, Sorø.

Flora-On. 2005-2025. *Flora de Portugal Interativa*. https://flora-on.pt/ (accessed October 2026).

Fojt, W. & Harding, M. 1995. Thirty years of change in the vegetation communities of three valley mires in Suffolk, England. *Journal of Applied Ecology* **32** (3): 561-577. DOI: 10.2307/2404653.

GBIF.org. 2025. GBIF *Occurrence Search*. https://www.gbif.org/occurrence/search (accessed October 2026).

Heath, J. & Emmet, A. M. (eds.) 1983. *The Moths and Butterflies of Great Britain and Ireland.* Vol. **10**. *Noctuidae (Part II) and Agaristidae*. Harley Books, Colchester.

Henwood, B. & Sterling, P. 2020. *Field Guide to the Caterpillars of Great Britain and Ireland.* 448 pp. Bloomsbury Wildlife.

iNaturalist. 2008-2025. *iNaturalist Network*. iNaturalist (accessed October 2026).

Keppel, G., Van Niel, K. P., Wardell-Johnson, G. W., Yates, C. J., Byrne, M., Mucina, L., Schut, A. G. T., Hopper, S. D. & Franklin, S. E. 2012. Refugia: identifying and understanding safe havens for biodiversity under climate change. *Global Ecology and Biogeography* **21** (4): 393-404. DOI: 10.1111/j.1466-8238.2011.00686.x.

Leraut, P. 2019. *Moths of Europe* **4**: *Noctuidae II*. 575 pp. N.A.P. Editions, Verrières-le-Buisson.

Martin, L. A. & Pullin, A. S. 2004. Host-plant specialisation and habitat restriction in an endangered insect, *Lycaena dispar batavus* (Lepidoptera: Lycaenidae) I. Larval feeding and oviposition preferences. *European Journal of Entomology* **101** (1): 51-56.

OpenStreetMap Contributors. 2026. *Planet dump* [Portugal spatial data]. OpenStreetMap Foundation. OpenStreetMap (accessed October 2026).

Parenzan, P. & Scalercio, S. 1996. Nuove segnalazioni di nottuidi (Lepidoptera) per l'Italia meridionale (Contributi alla conoscenza della lepidotterofauna dell'Italia meridionale. XIX). *Entomologica* **30**: 105-133.

plemos. 2026. *iNaturalist observations of Gortyna flavago on/between 2023 and 2026* [data set]. iNaturalist. Available from: iNaturalist dataset (accessed September 2026).

QGIS Development Team. 2026. *QGIS Geographic Information System*. QGIS Association. QGIS (accessed October 2026).

Rivas-Martínez, S., Rivas-Sáenz, S. & Penas, A. 2011. Worldwide bioclimatic classification system. *Global Geobotany* **1**: 1-634.

Robinson, G. S., Ackery, P. R., Kitching, I. J., Beccaloni, G. W. & Hernández, L. M. 2023. *HOSTS - a Database of the World's Lepidopteran Hostplants*. Natural History Museum, London. Available at: HOSTS database (accessed 2025).

Rodwell, J. S. 1995. *British Plant Communities* **4**: *Aquatic Communities, Swamps and Tall-Herb Fens*. Cambridge University Press, Cambridge.

Silva Cruz, M. A. & Gonçalves, T. 1961. Notas Lepidopterológicas IV. Uma nova contribuição para o inventário dos heteróceros portugueses. *Memórias e Estudos do Museu Zoológico da Universidade de Coimbra* **269**: 75.

Skinner, B. 2009. *Colour Identification Guide to Moths of the British Isles*. 325 pp. Apollo Books, Stenstrup.

South, R. 1907. *The Moths of the British Isles*. Frederick Warne & Co., London & New York.

van der Maarel, E. (ed.) 2005. *Vegetation Ecology*. Blackwell Publishing, Oxford.

Waring, P. & Townsend, M. 2017. *Field Guide to the Moths of Great Britain and Ireland*. Bloomsbury Wildlife.

Zêzere, J. L. 2005. A geomorfologia da região das Caldas da Rainha. In: Aires-Barros, L. (coord.), *Caldas da Rainha: Património das Águas*: 57-65. Assírio & Alvim, Lisboa.

Zhang, X., Ci, X., Hu, J., Bai, Y., Thornhill, A. H., Conran, J. G. & Li, J. 2023. Riparian areas as a conservation priority under climate change. *Science of the Total Environment* **858** (2): 159879. DOI: 10.1016/j.scitotenv.2022.159879.

Zilli, A., Ronkay, L. & Fibiger, M. 2005. *Noctuidae Europaeae* **8**: *Apameini*. 323 pp. Entomological Press, Sorø.