INSECT-FLOWER INTERACTIONS IN THE MEDITERRANEAN AREA: A CITIZEN SCIENCE DATASET COLLATED WITHIN THE LIFE 4 POLLINATORS PROJECT

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Journal of Pollination Ecology, 39(23), 2025, pp 306-315

DOI: 10.26786/1920-7603(2025)872

Received 21 May 2025, accepted 14 October 2025

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Abstract—Pollinators play a vital role in most terrestrial ecosystems, supporting wild plant communities and enhancing agricultural yields. However, despite their ecological and economic importance, they have been experiencing an alarming decline over the past decades. The Mediterranean region, known for harboring highly diverse communities of plants and pollinators, is particularly vulnerable due to intense anthropogenic pressures. Furthermore, the ecological roles of many floral visitors remain poorly understood, hindering conservation efforts. In response, in recent years, growing attention has been directed toward the contribution that citizens can give in support of pollinator research. An increasing number of projects have adopted a Citizen Science approach to enable large-scale data collection. The LIFE 4 Pollinators project (LIFE18/GIE/IT/000755) "Involving people to protect wild bees and other pollinators in the Mediterranean" aims to

promote the conservation of pollinating insects and entomophilous plants across the Mediterranean region by fostering progressive changes in human practices that threaten wild pollinators. In addition to the implementation of several actions to raise awareness, the project launched a web platform to collect photographic records of flower–insect interaction from the public. The platform is expected to remain active for at least ten years, during which we encourage continuing record submissions by interested bodies. With this data paper we are making the current dataset freely accessible to anyone, committing to periodic online updates.

Keywords—Pollinators, Biodiversity Conservation, Natura 2000, Plant diversity, Citizen Science

INTRODUCTION

In most terrestrial ecosystems, pollinators fulfill an essential function, supporting wild plant communities (Vamosi et al. 2006; Potts et al. 2016) and boosting agricultural yields (Klein et al. 2007; Ricketts et al. 2008), thereby contributing significantly to the nutritional security of humankind worldwide (Chaplin-Kramer et al. 2014; Potts et al. 2016). Most recent estimations indicate that 90% of the world flowering plant species are animal–pollinated (Tong et al. 2023), underscoring the intimate interdependence between pollinators and plants.

Despite their reciprocal importance, both plants and pollinators have been undergoing an alarming and severe decline over the past few decades (Lughadha et al. 2020; Wagner 2020), mainly due to land-use changes, unsustainable agricultural practices, environmental pollution, invasive alien species, and climate change (Potts et al. 2010; Bennett et al. 2020; Raven & Wagner 2021). The Mediterranean region harbors highly diverse communities of plants and pollinators (e.g. Potts et al. 2006; Reverté et al. 2023), often subject to considerable anthropogenic pressures. In this context, to date, the ecology of several floral visitors still appears unsubstantiated (Nieto et al. 2014; Ropars et al. 2020). Clearly, this knowledge gap hinders effective conservation efforts, highlighting the urgent need for extensive data collection, especially within protected areas and specifically Natura 2000 sites in the European environment (Popescu et al. 2014; European Parliament 2023).

In recent years, particular attention has been given to the role citizens can play in supporting research and conservation plans on pollinators (Bortolotti & Galloni 2025, and references therein). An increasing number of projects have adopted a Citizen Science approach to encourage large-scale data collection (e.g. Flaminio et al. 2021; Aavik et al. 2025). The approach involves the active participation of the public in research activities across various disciplines (Vohland et al. 2021): through the collection of ecological data, research questions can be answered, awareness be enhanced, and policies be influenced (e.g. Dibner et al. 2018; Irwin 2018).

The LIFE 4 Pollinators project (LIFE18/GIE/IT/000755) "Involving people to protect wild bees and other pollinators in the Mediterranean", implemented between 2019 and 2024, aimed to enhance the conservation of pollinating insects and entomophilous plants across the Mediterranean region by fostering a virtuous cycle promoting progressive changes in anthropogenic practices currently threatening wild pollinators and plants. In addition to producing educational materials, the project has implemented several actions to raise awareness in the four partnering European countries: Italy, Greece, Spain, and Slovenia. Among these actions, the project launched a web platform for the collection of photographic records of flower–insect interactions from the public.

The purpose of developing such web platform was threefold: i) to encourage the adoption of a Citizen Science approach in countries where it was not yet as popular, ii) to raise awareness on pollinator decline and lack of data among citizens through their active engagement, and iii) to generate an open access, noteworthy dataset that would be made accessible to any researcher, practitioner, competent authority or Non-Governmental Organization (NGO) willing to plan pollinator safeguard initiatives.

With the current data paper, we make the dataset publicly available and discuss its potential,

inviting researchers and conservationists to explore and use it.

THE WEB PLATFORM

As part of the LIFE 4 Pollinators project, a web platform was developed in 2021 to collect photographs of insects visiting flowers (https://www.life4pollinators.eu/en/submission). The platform has been designed to be freely accessible to the public to encourage engagement, meaning that no registration is needed to send photo records. Users are invited to upload photographs of insects interacting with flowers (hereafter referred to as "records") and possibly provide additional ecological information.

The primary details to be entered include the date of observation, the geographical coordinates, the habitat type, the abundance of plant individuals within the population, and the kind and status of site protection. Users can identify the observed organisms, by selecting the pollinator taxonomic aggregation from a given list of alternative choices (bee, wasp, beetle, butterfly, moth, hoverfly, and bee fly) and/or by writing the name of the pollinator, and that of the plant (at the taxonomic level they choose). A team of expert taxonomists then identifies the observations uploaded to the platform to the finest possible taxonomic level, refining the first identification provided by the user (Bitonto et al. 2025). The identification process consists of two steps: first, a team member determines the insect and/or plant; then, a second expert confirms the accuracy or adjusts the identification if necessary. Once verified, the images along with their taxonomic information are displayed publicly on the website map (https://www.life4pollinators.eu/en/map).

The platform was promoted on multiple occasions, especially during the 27 bioblitz events organized throughout the project implementation (from 2021 through to 2024). On these occasions, citizen scientists were assisted by expert taxonomists, ensuring that most plant records identified to species level underwent in situ validation. As a result, it was made possible to identify many records at species level even when the photographs alone could not capture the necessary diagnostic traits for accurate identification. Similarly, insect taxonomists assisted in the correct identification of flower visitors relying on the morphological traits visible in the photographs or in the field, since no insect was sampled during the events. . In cases where closely related or cryptic species could not be confidently distinguished visually, the experts relied on their experience or, when possible, consulted entomological collections available for the surveyed areas. However, since a formal taxonomic identification was not possible, **most of the insect records identified at species level should be intended as morphological groups** (e.g. *Bombus terrestris*). This means that the observed individuals exhibited morphological characteristics of the indicated species but discriminating them from similar species was not possible on a visual basis.

The whole process, from photograph upload to record displaying on the website map, is illustrated in Fig. 1.

To standardize the current dataset, plant nomenclature was checked using the Plants of the World Online website (https://powo.science.kew.org). For Hymenoptera Apoidea Anthophila, we followed Ghisbain et al. (2023); Diptera species names were verified through Systema Dipterorum (http://www.diptera.org); Lepidoptera Papilionoidae names followed Wiemers et al. (2018). Names for Coleoptera, wasps, and other Lepidoptera (moths) were checked using the Fauna Europea dataset (de Jong 2016) and the EASIN database for alien species in Europe (https://easin.jrc.ec.europa.eu/easin).

In order to make the dataset collated so far publicly available to anyone willing to consult it, on April 30th, 2025, the photo records dataset consisting of all records uploaded from May 2021 was downloaded. The dataset exclusively focuses on flower–insect interactions, so all photo records not meeting this criterion, such as pictures of insects on leaves or those of plants alone, were excluded. When a photograph showed multiple insects visiting a plant, each individual interaction was recorded as a separate entry in the dataset (e.g. submission IDs: 2409, 2409a, 2409b). The resulting dataset encompasses a total of 2203 flower-insect interaction records. Data were collected by citizen scientists from eight countries (Fig. 2a), in sites ranging in latitude from 46.74 North in Italy to 28.08 South in Canary Islands and ranging in longitude from -28.71 West in the Azores to 33.25

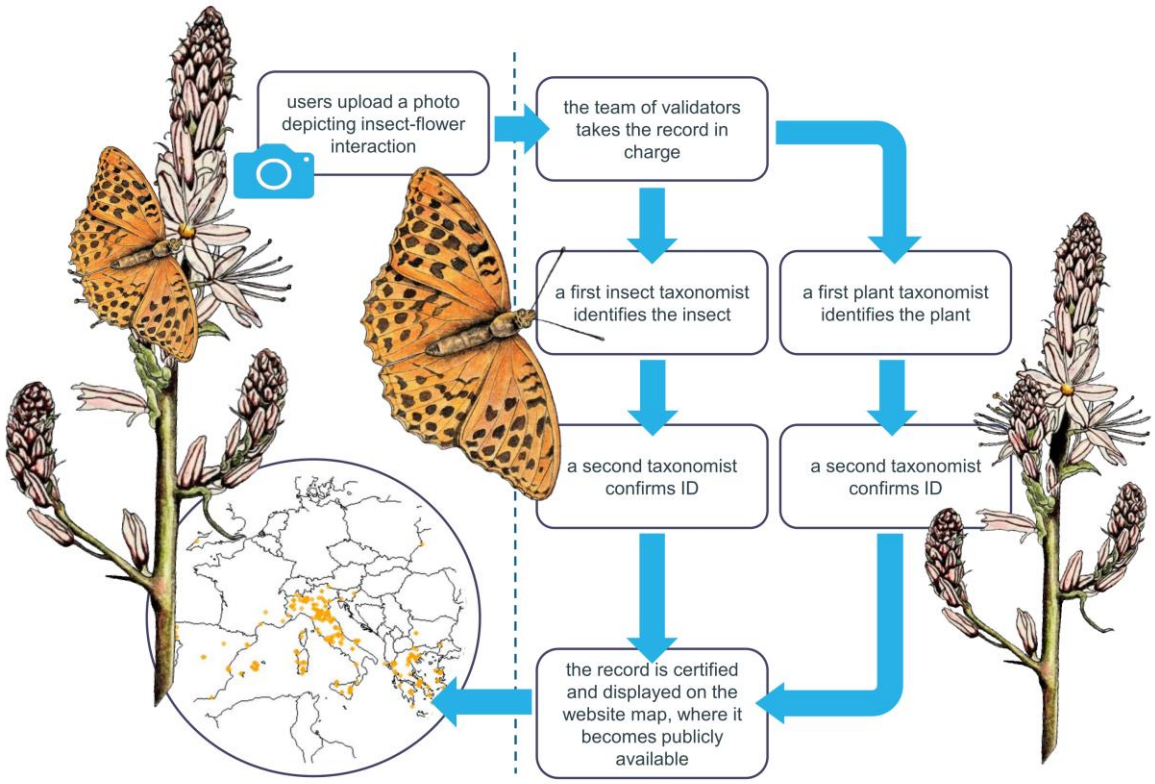

Figure 1. Process of photographic record validation, from the upload to the final certification by the team of expert taxonomists and record display on the website map, where it becomes publicly available. Illustration by Marta Barberis.

East in Cyprus (Fig. 2b). Metadata for each variable is explained in Table 1.

Of the total number of records, 2088 (94.8%) have geographical coordinates, and, of these, 998 observations fall within areas protected under the European Natura 2000 Network (see Table S1 for a complete list of the Natura 2000 sites considered).

To maximize interoperability and satisfy FAIR principles, the dataset has been standardized by adopting the Darwin Core standard (Wieczorek et al. 2012), following the structure suggested by Salim et al. (2022) for the organization of data on plant-pollinator interactions. The xslx dataset file, as well as the Darwin Core ZIP Archive are publicly available in Zenodo: https://doi.org/10.5281/zenodo.16949654. The Darwin Core ZIP Archive comprehends: i) four .txt files (one core and three extensions), ii) a meta.xml file, and iii) an eml.xml file.

Discussion

This dataset is among the first to focus on flower–insect interactions in the Mediterranean area, a biodiversity hotspot subject to considerable anthropogenic pressures. Gathered through the LIFE 4 Pollinators web platform, this dataset supplies policy makers and protected area managers with critical data to plan targeted conservation strategies. Unfortunately, due to the lack of partners from Northern African Countries, the current dataset still misses records from that area, but we commit to keep promoting the platform and its usage in any future occasion (e.g. international congresses), especially targeting potentially interested representatives from those areas, who may play a fundamental role in engaging local people and facilitate participation.

In addition to that valuable contribution that such an initiative can give to large-scale data collection, the educational outcome of actively involving the public must not be overlooked. On one hand, through their active participation, outreached citizens gain a deeper understanding of ecological systems, making scientific processes more transparent and accessible. On the other hand, a second critical output may be a change of attitude towards the targeted organisms (Flaminio

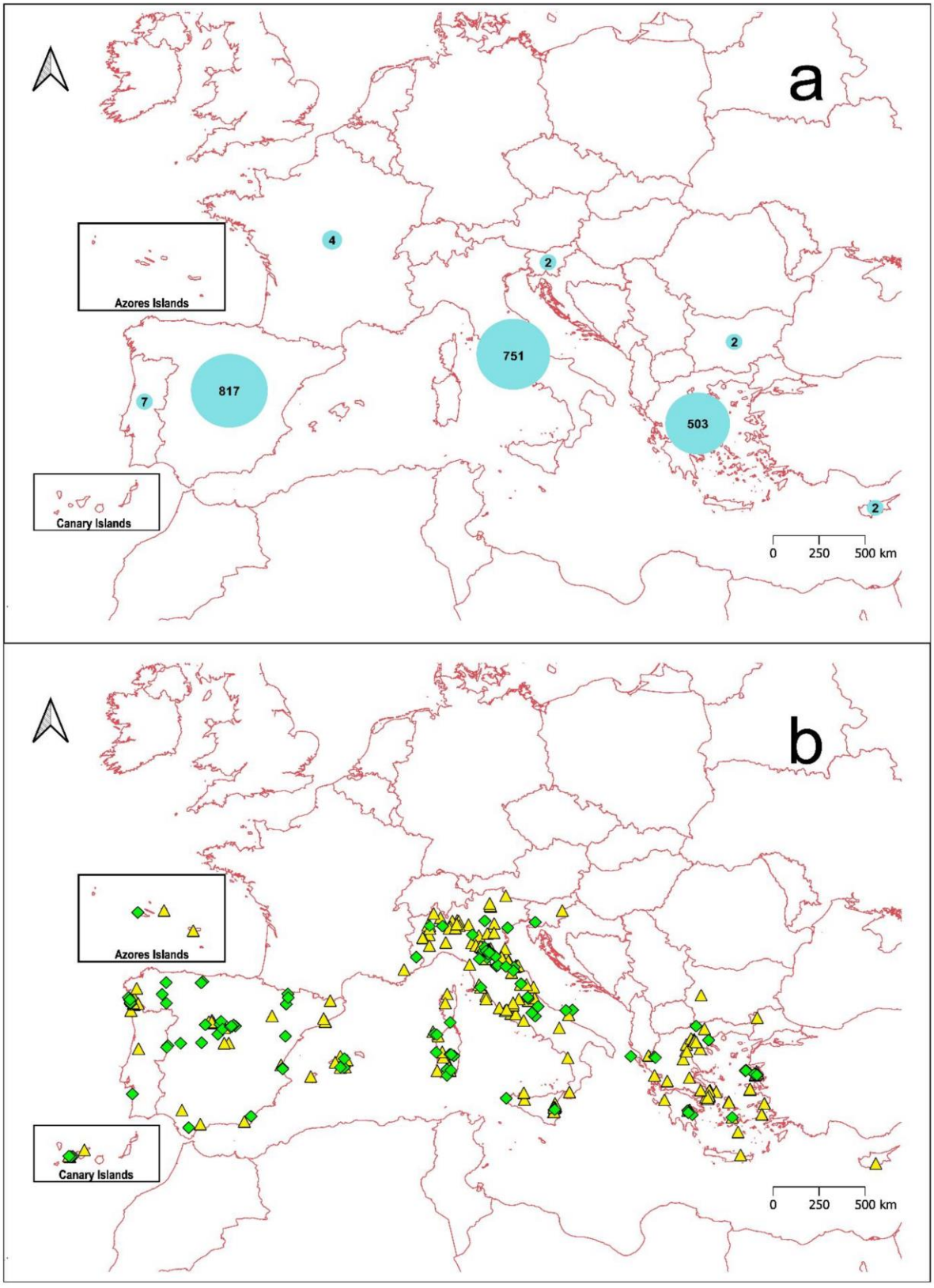

Figure 2. Number of records submitted by Country (a). Geographical distribution of the sites where the observations were recorded (b). Yellow triangles represent observations recorded outside Natura 2000 sites, while green diamonds represent observations recorded within Natura 2000 sites. The map does not depict records for whom no coordinates were provided by users (5.3%).

Table 1. Explanation of the metadata used for the dataset.

Metadata item	Title of .txt file	Format	Description
eventID	event	Text	Numerical (or alphanumerical) code to identify each submitted record. Numerical codes followed by progressive letters indicate that a single observation has been split into 2+ records (e.g. when the photograph depicted 2+ floral visitors).
eventDate	event	Text	The date on which the photograph was taken (YYYY-MM-DD). When followed by an asterisk the given date was deduced *a posteriori*, assuming that the date of observation was the same as the date of record submission.
decimalLatitude	event	Text	The decimalized latitude of the site in which the photograph was taken. Cells containing "na" indicate that the user did not provide the information.
decimalLongitude	event	Text	The decimalized longitude of the site in which the photograph was taken. Cells containing "na" indicate that the user did not provide the information.
geodeticDatum	event	Categorical	The ellipsoid, geodetic datum upon which the geographic coordinates are based.
country	event	Categorical	The country where the record was taken.
countryCode	event	Categorical	The standard country code according to ISO 3166-1-alpha-2
habitat	event	Text	The type of landscape surrounding the observation site. Options are "urban", "periurban", "hills", "mountain", "lowland", "island", "archaeological site", "seaside", "riverside", "lakeside", or a combination of multiple answers. This could either be entered by users or – when missing – deducted *a posteriori* by consulting a map.
samplingProtocol	event	Text	Protocol adopted for sampling.
samplingEffort	event	Text	Sampling effort.
eventRemarks	event	Text	Whether the area is part of the Natura 2000 network or not. Two are the alternative answers: "Outside Natura 2000" and the Natura 2000 code(s) the site pertains to. Cells containing "na" indicate that no geographical coordinates were provided for the record. This was deduced *a posteriori*, consulting the Natura 2000 – Spatial data database.
occurrenceID	floral visitor	Text	A unique identifier assigned to each insect taxon occurrence observed visiting a flower.
scientificName	floral visitor	Text	The scientific name of the floral visitor depicted in the photographic record, at the finest taxonomical level insect experts could reach.
occurrenceRemarks	floral visitor	Categorical	Behavior of flower-visiting insects as reported by citizen scientists at the time of photo upload.
organismQuantity	plants	Categorical	Users could either choose between the following alternative answers: "individual/singular plant", "less than ten", "more than ten".
organismQuantityType	plants	Categorical	The type of quantification system used for the assessment of the quantity of individual plants.
occurrenceID	plants	Text	A unique identifier for each plant taxon recorded by citizen scientists.
scientificName	plants	Text	The scientific name of the plant depicted in the photographic record, at the finest taxonomical level plant experts could reach.
resourceID	relationship	Text	An identifier for the resource that is the subject of the relationship (insects).
relatedResourceID	relationship	Text	An identifier for a related resource (plants).
relationshipOfResource	relationship	Categorical	The interaction of the visiting insect with the flower.
relationshipOfResourceID	relationship	Categorical	An identifier for the relationship type that connects the insect to the flower.

et al. 2021). Indeed, people provided with information on conservation issues and engaged in Citizen Science projects are more likely to undertake conservation actions than others (Lewandowski & Oberhauser 2017).

One of the disadvantages often brought by data collected through a Citizen Science approach is the potential geographical bias, particularly if contributors are free to choose their observation locations (Gregory et al. 2005; Herrera 2019). In this case, over 90% of the photo records constituting the current dataset come from the project partners' countries Spain, Italy and Greece, where most of the activities were implemented. This result is due to the numerous in-person events held in these places, confirming the effectiveness of face-to-face events in engaging people (Requier et al. 2020). Having said that, it's important to notice that our records cover a range of climates and elevations, in different levels of urbanization and protection, making the dataset a valuable contribution to flower–insect interaction research and conservation efforts.

Of the 27 bioblitz events organized through the project's implementation, 23 took place within Natura 2000 sites. As data on flower–insect interactions are deficient for Natura 2000 sites, such information represents an important step for filling in the current gap. Though qualitative, in fact, the flower–pollinator networks derived from this dataset may help point the direction that conservation measures should take, supporting an approach where species interactions are the units to conserve within ecosystems (Borchardt et al. 2021).

The web platform will remain active for at least ten years, during which we foresee a continuous increase in records submitted by citizen scientists. With this data paper, we are making the current dataset freely accessible to anyone, while committing to periodic online updates and providing the data upon request at any time. Remembering to use a proper citation of our work, we warmly encourage anyone to use or consult the dataset.

Acknowledgements

We would like to thank Gherardo Bogo, Martina Capacci, Giovanna Dante, Elise Maria Keller, Mariacristina Laureti for providing valuable suggestions and/or for contributing to the identification process. We are also grateful to the competent authorities responsible for the management of the sites where the LIFE 4 Pollinators bioblitzes were conducted. We extend our acknowledgement to all the citizen scientists who uploaded their observations.

Fundings

This work was implemented under the LIFE 4 Pollinators project (LIFE18/GIE/IT/000755). The University of the Aegean was partially supported by the Green Fund for the implementation of the LIFE 4 Pollinators project's actions in Greece. The web server currently hosting the LIFE 4 Pollinators web platform is provided by LifeWatch Italy through the project "LifeWatchPLUS (CIR- 517 01_00028)", funded by the European Union – Next Generation EU. MG (partially), ER (fully) were supported by the Italian National Recovery and Resilience Plan (NRRP), Project title "National Biodiversity Future Center -NBFC". CUP J33C22001190001 / F83C22000730006. FFB's PhD grant was co-financed by the European Union- FSE REACT EU – PON R&I 2014–2020. AT, JMS and LN were partially supported by PolinIslas (ref. OAPN 2713/2021) project. AT was also partially supported by IslandLife ERC project under the Horizon 2020 Research and Innovation Programme (ref. 101054177).

Author contribution

Concept and design MB, FFB & MG, Writing MB & FFB (equal), Coordination of the validation process MB, FFB & RC, IT support and platform management GS, Project coordination MG, Validation process, Review and Editing all authors.

Disclosure statement

The authors declare no competing interests.

Data availability statement – OK?

The xslx dataset file, as well as the Darwin Core ZIP Archive are publicly available in Zenodo: https://doi.org/10.5281/zenodo.16949654. The Darwin Core ZIP Archive comprehends: i) four .txt files (one core and three extensions), ii) a meta.xml file, and iii) an eml.xml file.

Appendices

Additional supporting information may be found in the online version of this article:

Table S1. Observations falling within Natura 2000 sites.

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 ISSN 1920-7603