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EXECUTIVE SUMMARY 2025

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What does the Steppe Forward Chair seek?

The Steppe Forward Chair, formed by the Autonomous University of Madrid (UAM) and the Forest Science and Technology Center of Catalonia (CTFC), with the collaboration and support of TotalEnergies, aims to generate knowledge to reconcile biodiversity conservation with the development of photovoltaic solar plants, promoting research on agro-steppe ecosystems and their interaction with such development. Based on three lines; Research, Transference, and Outreach, this Chair will enable the writing of scientific publications, the training of a network of researchers, the creation of technical documents available to private and public sectors, the organization of annual outreach events, and the dissemination of knowledge generated in national and international conferences, social media, and more traditional media outlets.

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Renewal of the Chair

On 24 November 2025, the renewal ceremony of the Chair was held, attended by representatives of **TotalEnergies**, the **Forest Science and Technology Center of Catalonia**, and the **Autonomous University of Madrid**. The renewal extends for another year the commitment of the participating institutions to achieving the Chair's objectives.



Renewal ceremony of the Steppe Forward Chair. From left to right: **Roser Maneja** (Director of Research, Forest Science and Technology Center of Catalonia), **Rocío Schettini del Moral** (Director of the Autonomous University of Madrid Foundation), and **Borja Guzmán** (Asset Management and Operations Director, TotalEnergies Renewables Spain).

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What have we achieved in 2025?

This executive summary integrates the activites carried out by the Steppe Forward Chair during the year 2025



RESEARCH LINE — Page **4**



TRANSFERENCE LINE — Page **26**



OUTREACH LINE — Page **35**

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RESEARCH
2025

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Evaluation of the response of steppe birds to the presence of solar photovoltaic plants

Part of the work carried out during 2025 focused on **analysing how the breeding-season space use of several steppe bird species interacts with photovoltaic plants as a function of plant size and surrounding land use**. This analysis is essential for assessing the extent to which these infrastructures may alter movement patterns and for anticipating potential conflicts with these species, **thereby supporting the improved planning of future photovoltaic developments and reducing their environmental impacts**.



To this end, **GPS tracking data from six steppe bird species were used**, combining data collected through the Chair's own tagging programme with data from other research projects conducted by different research groups. These data were integrated with georeferenced information on photovoltaic plants provided by several developers across Spain, with installations classified according to their size. Based on these datasets, **space-use patterns were modelled** to evaluate how the probability of habitat use varies as a function of distance to photovoltaic plants, plant size, and landscape context. The analyses accounted for land-use gradients, individual and temporal variability, and movement decisions by comparing observed locations with mathematically generated alternative available locations.

Overall, **these analyses provide a detailed characterization of the current spatial relationship between steppe birds and photovoltaic plants, identify safe distance thresholds for birds**, and determine how these thresholds vary according to installation size and landscape context. The findings provide valuable information for the planning of future solar energy projects by **facilitating the identification of potentially conflicting areas and contributing to the minimization of impacts** on sensitive species and habitats.

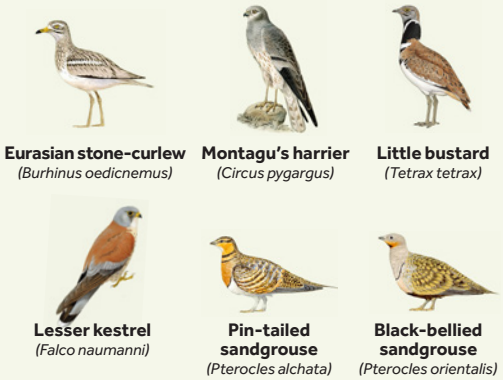
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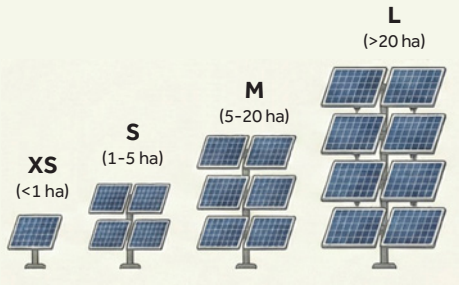
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Methods for evalution the response of steppe birds to solar photovoltaic plants

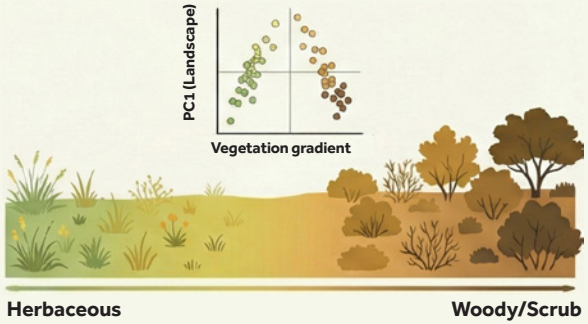
Step 1 Data compilation and classification



Monitoring of key species. Tracking of 288 individuals from 6 species using GPS devices.



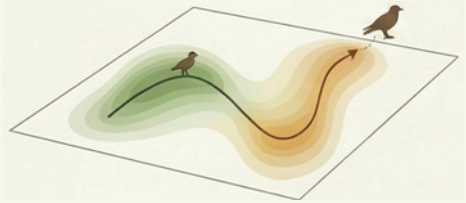
PV classification



Landscape characterization (PCA)
Use of Principal Component Analysis (PCA) to define gradients ranging from herbaceous to woody environments.

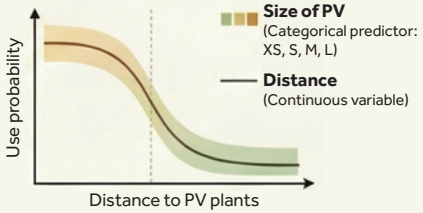
Step 2 Movement and spatial modelling

Brownian Bridge Movement Models (BBMM)



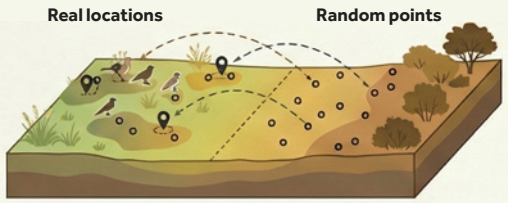
Use Density (UD) estimation to derive surfaces of spatial use probability.

Generalized additive models (GAM)



Evaluation of the probability of use as a function of distance to PV plants and landscape context

Step Selection Functions (SSF)



Comparison of actual locations versus random points to determine habitat preferences at the movement decision-making scale.

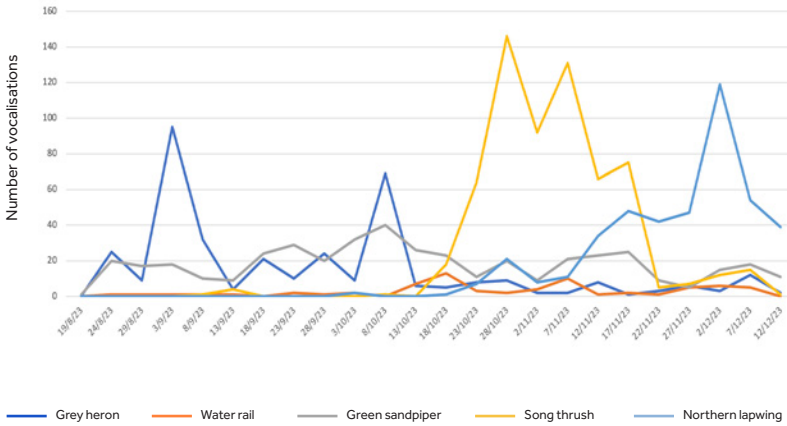
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Evaluation of the Lake Effect of the solar photovoltaic plants on migrating birds

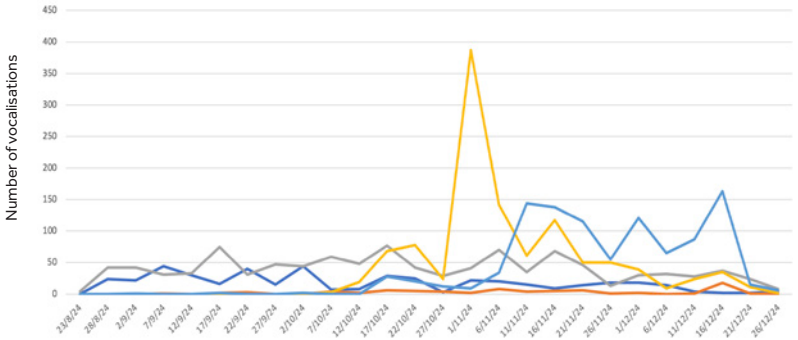
In 2023, a pioneering study based on passive acoustic monitoring was launched to assess the potential attraction effect of photovoltaic panels on nocturnally migrating birds, known as the "lake effect." Although some information on this phenomenon exists, it is largely limited to studies conducted in the United States and remains too scarce to adequately understand the magnitude of the impact in other, much less studied contexts, such as Europe. The study was designed to compare conditions before and after the installation of photovoltaic solar plants, focusing on projects that have already entered the operational phase (a BACI – Before-After Control-Impact design). The issue is being addressed using a novel methodology that has never previously been applied to this type of study, based on recording the vocalizations of birds in flight as they pass through areas occupied by photovoltaic solar facilities. To document conditions after installation, the survey was repeated **in autumn 2025 at the Guillena (Sevilla) and Dehesa Nueva del Rey (Toledo) photovoltaic solar plants**. A total of **30 autonomous sound recorders were deployed, collecting more than 4 TB of acoustic data** for analysis. The data gathered by the recorders, which were retrieved in early 2026, will be analyzed in the near future.



Guillena, year 2023



Guillena, year 2024



In parallel, **a preliminary analysis of the potential lake effect at the Guillena solar plant was carried out**. This is the only study site whose construction was completed in 2024, making it possible to obtain data from both the pre-construction phase and the construction phase, during which nearly all of the solar panels had already been installed at the time of the recordings.

The analysis **provided phenological patterns for five aquatic bird species across both phases**, based on the processing of acoustic recordings conducted during 2023 and 2024. **It also yielded preliminary results regarding the plant's potential lake effect**, although these findings will need to be confirmed through additional recordings once the facility is fully operational.



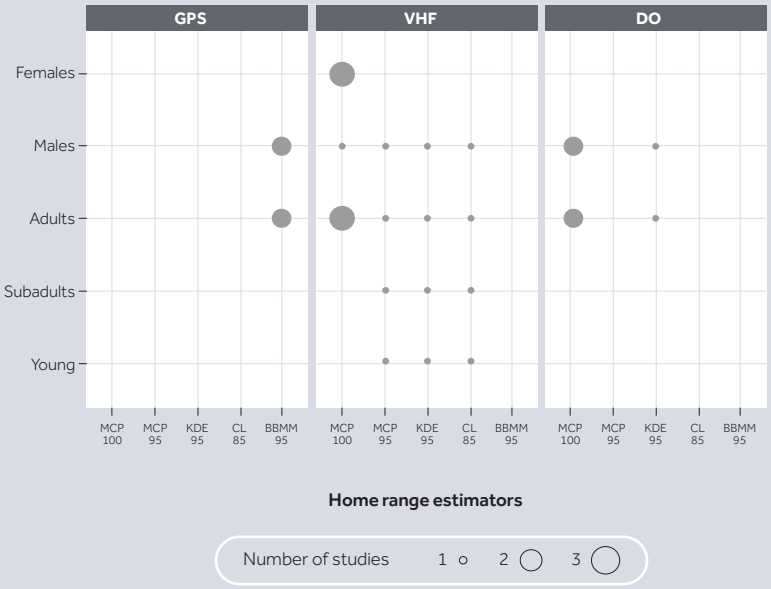
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Compilation of the existing scientific knowledge on the estimation of home ranges of steppe birds tracked using telemetry

In 2025, **the literature review on the characterization of the home ranges of seven species of steppe birds was completed**, incorporating a **meta-analysis of the quantitative results** reported in the reviewed studies. This work made it possible to derive estimates by combining the available scientific literature.

The results confirm that the home range used by a species is not a fixed characteristic, but rather depends on context, varying according to sex, age, stage of the annual cycle, and the tracking technology employed. The **study highlights significant geographical, ecological, and demographic knowledge gaps**—particularly outside Western Europe, during non-breeding periods, and for non-adult age classes—and shows that a large proportion of the GPS tracking data currently available has not yet been translated into published home-range estimates.

Overall, **the study reinforces the need to incorporate basic movement ecology metrics**, such as home range size, **into environmental impact assessments and conservation planning**, ensuring that such assessments are based on spatial information that is representative of the full distribution range and the diverse ecological conditions experienced by these species.

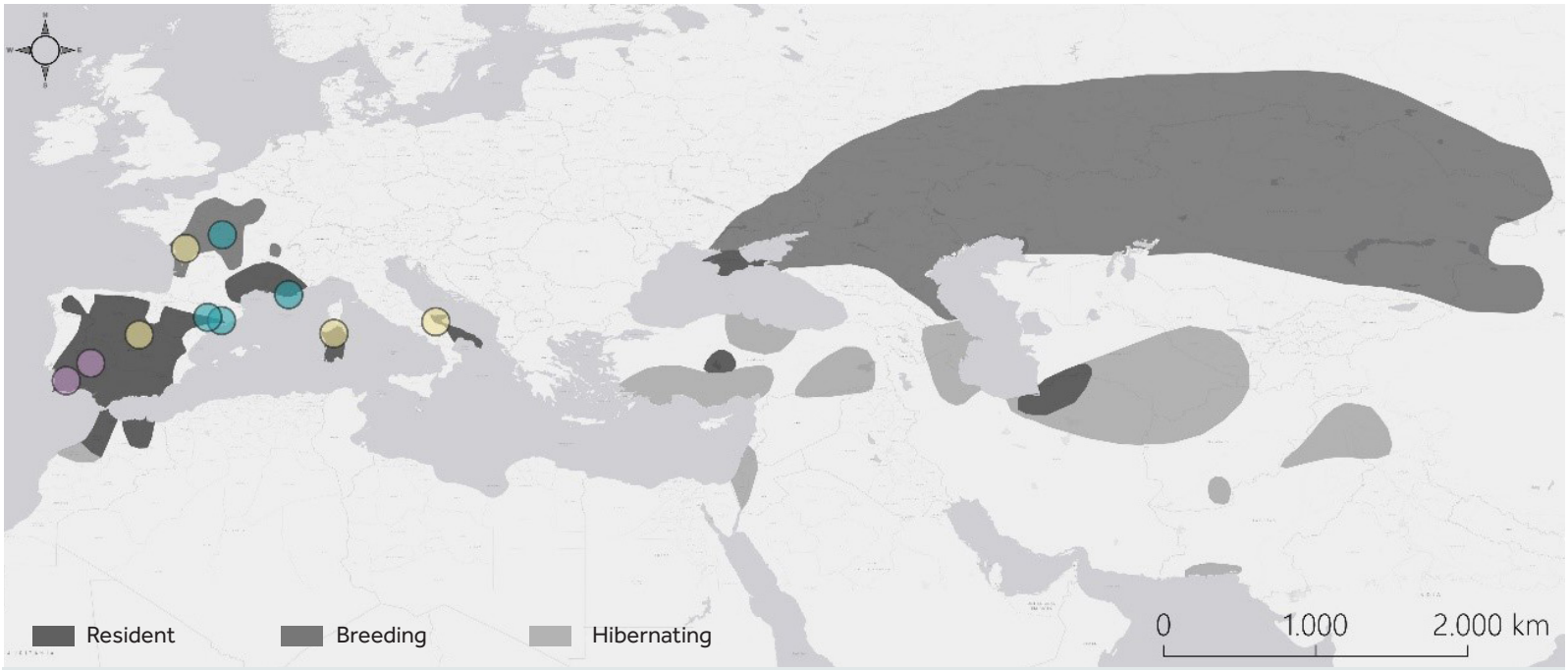


Number of primary studies on the Little bBustard according to the sex and age of the individuals studied (y-axis), the home range estimation method (x-axis), and the tracking method used to obtain location and movement data (boxes). The available studies for this species show a clear bias towards the use of very high frequency (VHF) radio telemetry, particularly for juvenile and subadult individuals. This bias substantially limits the precision of the data obtained and, consequently, the evidence base available to support conservation and management decisions.

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Global distribution map of the Little bustard according to the IUCN (grey area), showing the location of all reviewed studies (circles) and the tracking method used (purple: GPS; blue: VHF; yellow: DO). A clear spatial bias is evident in the available information on home ranges, with studies concentrated in western populations and a complete lack of data for eastern populations.

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Space use and migration patterns of threatened steppe birds

In 2025, work continued on monitoring the abundance and diversity of steppe birds, as well as on tagging individuals with GPS-GSM devices in the provinces of Zaragoza and Sevilla, specifically in Peñaflor and Guillena, where photovoltaic solar projects are located. During 2025, 11 individuals belonging to five species of steppe birds were tagged, further expanding knowledge of how these species use space at both local and broad spatial scales during the pre-operational and operational phases of photovoltaic solar plants.

Both the monitoring and the capture of target species were carried out using methodologies specifically designed for each species. In addition to the 11 individuals tagged in 2025, 14 individuals tagged between 2022 and 2024 continued to provide valuable information. Altogether, the 65 individuals fitted with GPS devices since 2022 have generated nearly 3 million location records, making this project one of the most significant in Spain in terms of pre-operational tagging studies associated with renewable energy projects.

Of the 25 individuals that provided data during 2025, 21 remained within the study areas at some point during the year, with the highest presence of tagged individuals occurring between April and August.



Lesser kestrel pair, one of the study species of the project.

Table 1. Individuals tagged for each species by the Chair since the beginning of the project (2022–2025), with the number of individuals tagged during 2025 shown in parentheses.

Study area	Pin-tailed sand-grouse	Pin-tailed sand-grouse	Eurasian stone-curlew	Little bustard	Lesser kestrel	Montagu's harrier
ZARAGOZA	3 (2)	4 (2)	5 (2)	0	3	0
MADRID	0	0	5	1	2	0
TOLEDO	3	0	2	4	0	0
SEVILLA	0	0	0	8 (2)	15 (3)	10
TOTAL	**6 (2)**	**4 (2)**	**12 (2)**	**13 (2)**	**20 (3)**	**10**

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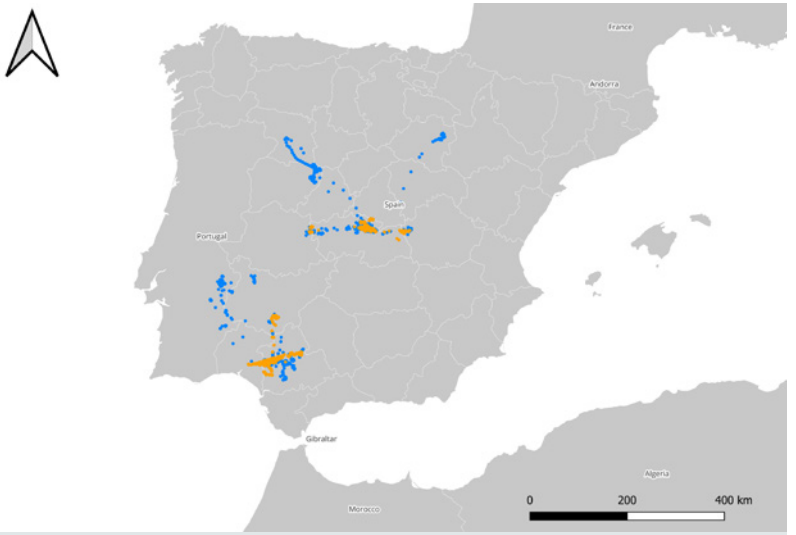
Movements of the Montagu's harrier individuals tagged by the Steppe Forward Chair to date, showing locations recorded during 2022–2024 (blue) and 2025 (orange).

MONTAGU'S HARRIER

Despite several capture attempts during the spring, no individuals of this species were tagged in 2025. Consequently, data were obtained only during January from a single individual tagged in Sevilla in 2024 while overwintering in Senegal. Data collected since 2022 have revealed the extensive movements made by this species across the Iberian Peninsula before initiating its migration to the Sahel region. Of the ten Montagu's Harriers tagged since the beginning of the project, none was still transmitting data in 2026.







Movements of the Little bustard individuals tagged by the Steppe Forward Chair to date, showing locations recorded during 2022–2024 (blue) and 2025 (orange).

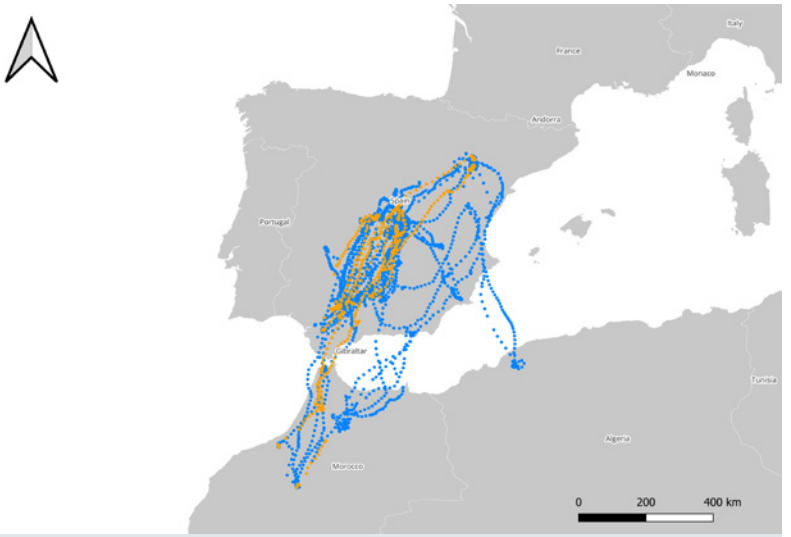
LITTLE BUSTARD

As in previous years, the Little Bustards tagged in 2025 remained in their breeding areas from spring until mid-summer. The only exception was a female that made movements of up to 60 km during this period. Unlike in previous years, when some individuals spent part of the non-breeding season in areas of Portugal or northern regions of the Iberian Peninsula, such as Castile and León, the Little Bustards tagged in 2025 were, at the time of writing this summary (January 2026), wintering in areas close to their breeding sites, making movements that did not exceed 100 km in any case.

At present, seven Little Bustards continue to provide tracking data from the 13 individuals tagged since 2022.





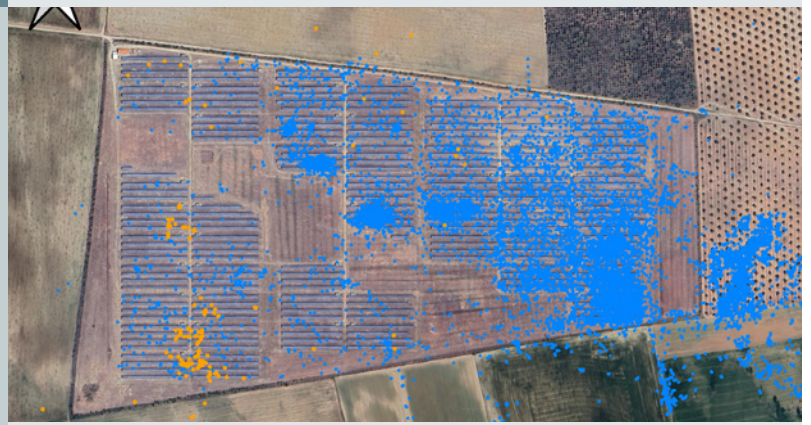


Movements of the Eurasian stone-curlew individuals tagged by the Steppe Forward Chair to date, showing locations recorded during 2022–2024 (blue) and 2025 (orange).

EURASIAN STONE-CURLEW

As in previous monitoring campaigns, most of the tagged stone-curlews carried out several breeding attempts, which were monitored using GPS and accelerometer data. In one individual, although no breeding attempt was detected—as was also the case in 2023 and 2024—the use of the area occupied by the same photovoltaic plant was recorded once again.

Wintering areas were similar to those observed in previous campaigns, being located mainly in North Africa and in the central and southern regions of the Iberian Peninsula. Of the 12 individuals tagged since 2022, two were still providing data at the time of writing this summary. It is possible that some of the 10 individuals that have not recently transmitted data are currently located in areas without network coverage.



Locations of one of the Eurasian stone-curlew individuals tagged in Toledo during the 2022–2024 breeding seasons (blue) and in 2025 (orange). The limited number of locations recorded in 2025 rules out the use of the photovoltaic plant as a nesting site.





Movements of the Lesser kestrel individuals tagged by the Steppe Forward Chair to date, showing locations recorded during 2022–2024 (blue) and 2025 (orange).

LESSER KESTREL

The Lesser kestrels tagged in 2025 provided less information than in previous field seasons, as one individual died, apparently due to predation, while the other two stopped transmitting data for unknown reasons. As a result, no migratory movements could be recorded for these individuals. However, data were obtained on their hunting areas during the breeding and post-breeding periods. These movements were mainly concentrated within a 10 km radius of the breeding site, although one individual visited Doñana National Park in late September.







Movements of the Black-bellied sandgrouse individuals tagged by the Steppe Forward Chair to date, showing locations recorded during 2022–2024 (blue) and 2025 (orange).

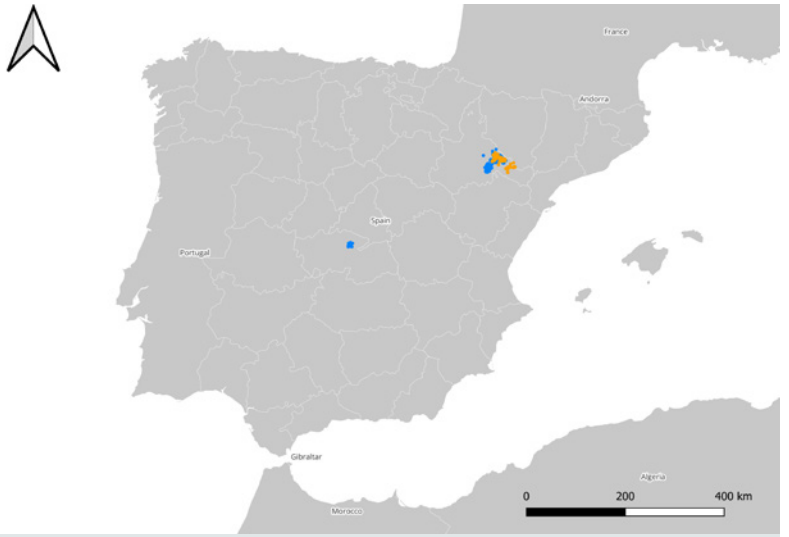
BLACK-BELLIED SANDGROUSE

In 2025, information was obtained only from the two individuals tagged during this campaign. Both exhibited largely sedentary behaviour, without making significant movements away from their tagging area. However, one of the individuals died shortly after being tagged, apparently as a result of predation. The other individual continues to provide data at present.

During the breeding season, GPS and accelerometer data indicated that this individual made two breeding attempts. One attempt was unsuccessful, while in the other the eggs apparently hatched successfully.







Movements of the Pin-tailed sandgrouse individuals tagged by the Steppe Forward Chair to date, showing locations recorded during 2022–2024 (blue) and 2025 (orange).

PIN-TAILED SANDGROUSE

In 2025, two Pin-tailed sandgrouse (Pterocles alchata) individuals were tagged. One of them stopped transmitting location data for unknown reasons approximately one month after being tagged, while the other remains active at present.

The active individual has displayed sedentary behaviour, without undertaking long-distance movements and remaining consistently close to its capture area. Based on GPS and accelerometer data, one breeding attempt was identified for each individual, both of which appeared to be successful during the incubation phase.



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> Publication of research articles

During 2025, **four scientific articles** were drafted and are currently undergoing internal review. Their publication in scientific journals is expected throughout 2026. **These publications will disseminate the results and conclusions of the main analyses and research activities carried out by the Chair over recent years.**

- Differences in nest predation rates between the interior and exterior of photovoltaic power plants.
- Relationship between photovoltaic plants and space use by steppe birds
- Meta-analysis of the existing knowledge about home ranges for steppe birds
- Effectiveness of different Artificial Intelligence tools for the automatic recognition of bird calls in flight.

4 scientific articles (internal revision)



Artificial nest with a camera trap used in the study about nest predation.

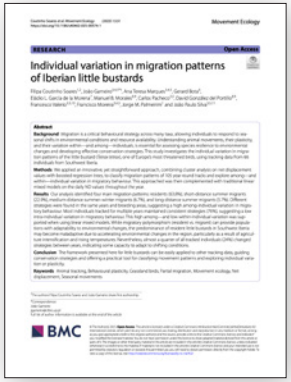
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Furthermore, researchers from the Chair **have collaborated in the preparation and publication of five scientific articles**, by contributing data from the Chair's studies or drawing on their expert knowledge of the Chair's research topics. These publications address migration patterns and ecological corridors of the Little Bustard, the conservation status of steppe birds in Western Europe, models for identifying behavioral patterns based on accelerometer data, and the exposure of steppe biodiversity to renewable energy development.

In addition, **one more article is currently being drafted** on the effects of agricultural intensification on the Lesser Kestrel, in which the Chair has also collaborated.



PUBLISHED

Individual variation in migration patterns of Iberian little bustards

Movement Ecology | Springer Nature Link

Published in the journal Movement Ecology, with the Chair contributing through Dr. David González del Portillo (research technician), Dr. Manuel B. Morales (coordinator), and Dr. Gerard Bota Cabau (coordinator) as co-authors of the article.

Link



PUBLISHED

Alarming conservation status of Western European steppe birds and their habitats: An expert-based review of current threats, traits and knowledge gaps

SCIENCE DIRECT

Published article in the journal Biological Conservation, with contributions from the Chair through Dr. Julia Gómez Catasús (Researcher and first author of the paper), Dr. Carolina Bravo Párraga (Researcher), Dr. David Giralt (Researcher), Dr. David González del Portillo (Technician), Dr. Juan Taba (Researcher), Dr. Manuel B. Morales (Coordinator), and Dr. Gerard Bota Cabau (Coordinator) as co-authors.

Link



PUBLISHED

Behaviour identification and time–activity budget estimation of threatened little bustard using accelerometry

SCIENCE DIRECT

Published in the journal Animal Behaviour, with the Chair contributing through Dr. Carolina Bravo Párraga (researcher and first author), Dr. David Giralt (researcher), Dr. Manuel B. Morales (coordinator), and Dr. Gerard Bota Cabau (coordinator) as co-authors of the article.

Link



ACCEPTED

Identifying the exposure of taxonomic, functional, and phylogenetic diversity of steppe birds to renewable energy developments

bioRxiv

An article has been accepted for publication in the journal Conservation Biology, with contributions from the Chair through Dr. David Giralt (Researcher), Dr. Manuel B. Morales (Coordinator), and Dr. Gerard Bota Cabau (Coordinator), who are co-authors of the paper.

Link



PUBLISHED

Migration strategies, connectivity and corridor features of the partial migrant little bustard (Tetrax tetrax) across the Iberian Peninsula

Movement Ecology | Springer Nature Link

Published article in the journal Movement Ecology, with contributions from the Chair through Dr. David González del Portillo (Technician and first author of the paper), Dr. Manuel B. Morales (Coordinator), and Dr. Gerard Bota Cabau (Coordinator) as co-authors.

Link

> Academical projects development

In 2025, the Chair began supervising two Master's Thesis projects and one Bachelor's Thesis project, while also completing the academic projects initiated in 2024. As in the previous year, the Chair provided coordination and support for these projects, helping to define the research questions, design the methodological approach, and guide the students throughout the entire process. In addition, the Chair supplied the datasets used for the analyses.

The Master's Thesis projects are entitled "**Niche overlap between potential areas for steppe birds and photovoltaic solar plants" and "Using tri-axial accelerometry to study the behaviour of the Eurasian stone-curlew (*Burhinus oedicnemus*) across different habitats in the Iberian Peninsula.**" The Bachelor's Thesis project is entitled "**Behavioural studies using accelerometers: the case of the Eurasian stone-curlew (*Burhinus oedicnemus*)**." The first project contributes to addressing one of the Chair's primary objectives: improving understanding of the relationship between steppe biodiversity and the deployment of photovoltaic solar plants. The second and third projects are more methodological in nature, but are aimed at enhancing our understanding of how steppe birds use space in greater detail.

2 Final Master's Project coordinated

1 Final Degree's Project coordinated



Eurasian stone-curlew (*Burhinus oedicnemus*)

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4th Steppe Forward Technical Conference

Madrid hosted the 4th Steppe Forward Technical Conference, held in November 2025. This fourth edition introduced several new features, **including a longer format (one and a half days), a more participatory approach, and presentations by internationally renowned experts**. Entitled "Global Challenges and Experiences in Reconciling Photovoltaic Energy with Biodiversity," the conference featured a total of **16 oral presentations and three plenary talks**. The plenary speakers were Stefania Charisiadou, Nature Conservation Policy Officer at the European Commission; Dr. Todd Katzner, researcher at the United States Geological Survey (USGS); and Dr. Bertrand Schatz, researcher at the French National Centre for Scientific Research (CNRS). **The conference was once again highly successful, attracting 283 participants**, who rated both the event's organization and scientific programme very positively, with an average satisfaction score of 4.5 out of 5.



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TRANSFERENCE LINE



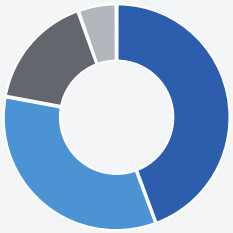
4th Steppe Forward Technical Conference in Madrid



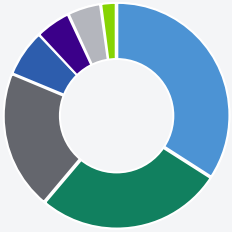


Percentage of participant profile types

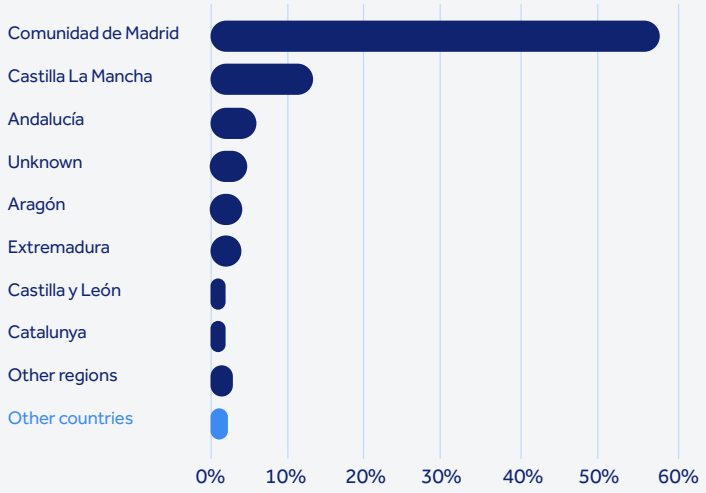
Speakers:
- Scientific community
- Environmental consultancy
- Public administration
- Environmental NGOs



Attendees:
- Environmental consultancy
- Industrial Sector
- Public Administration
- Scientific community
- Unknown
- Environmental NGOs
- Others



Number of assistences according to their origin







Attendees' feedback on the 4th Technical Conference





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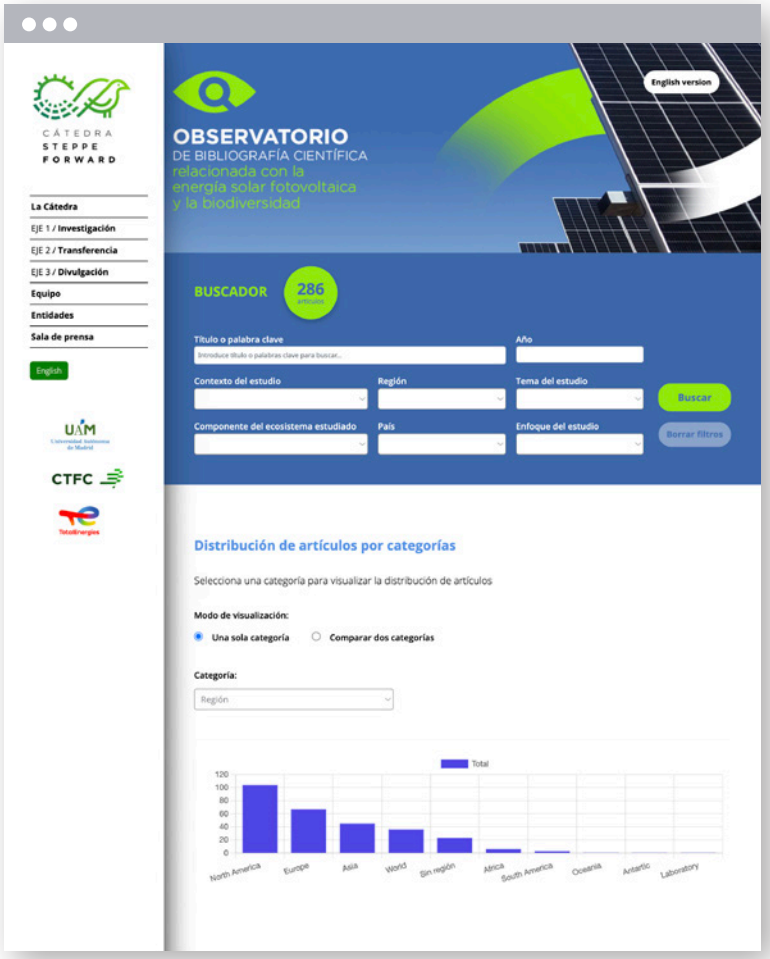
Update of the Observatory of scientific literature related to solar photovoltaic energy and biodiversity

The Observatory of scientific literature related to solar photovoltaic energy and biodiversity has been updated. This online tool, launched in 2023, was developed to provide public and private stakeholders with an up-to-date, web-based repository for the rapid search and consultation of the available scientific knowledge on this topic. A total of **53 scientific articles published in 2025** in international peer-reviewed journals have been added. With this update, the Observatory now provides **access to 286 publications**, further facilitating access to scientific information on the impacts and interactions between solar photovoltaic projects and biodiversity.

The literature compiled to date is predominantly based on studies conducted in North America, followed by Europe and Asia. In terms of ecosystem context, most studies have been carried out in desert environments or agroecosystems. Regarding the ecosystem components assessed, the available research is relatively balanced across different components, although plants are slightly more represented than other components such as soils, birds, or microclimate.

The repository can be accessed through the following link:

Link



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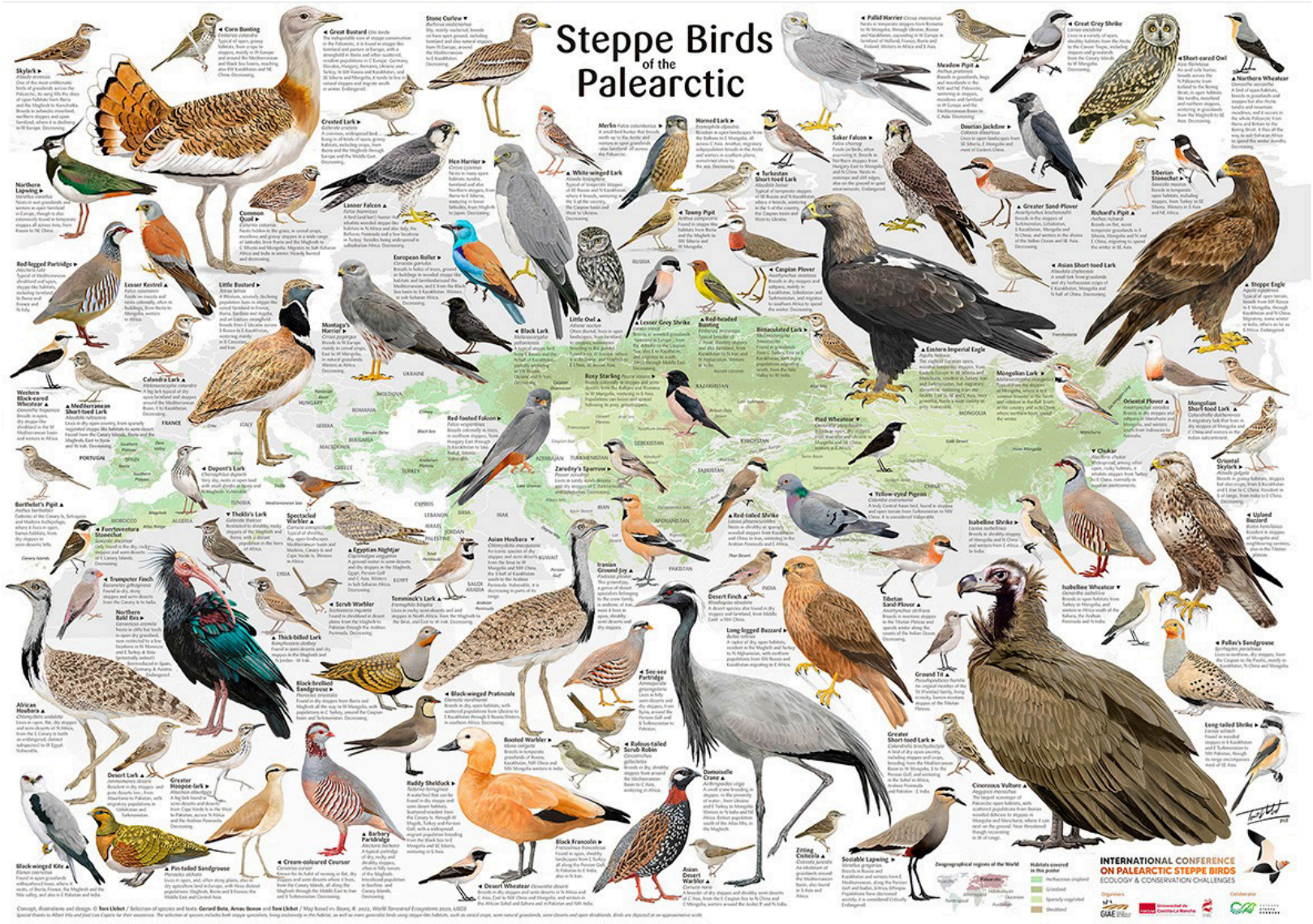
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Coordination of the International Conference on Palearctic Steppe Birds

Between 25 and 29 March 2025, Ciudad Real hosted the I***nternational Conference on Palearctic Steppe Birds***, **with the Chair forming part of the organizing team and serving as the conference's technical secretariat**.
The Chair also organized a round-table discussion on **renewable energy and steppe biodiversity**.
The conference brought together **more than 160 participants from over 10 countries and featured 53 presentations, 5 invited keynote lectures, 2 round-table discussions, and 2 poster sessions**.
The various international contributions highlighted that steppe ecosystems support bird populations of great conservation importance that face serious threats arising from habitat change, agricultural intensification, infrastructure development, climate change, and disease, underscoring the need for multidisciplinary conservation strategies.
The effective conservation of steppe birds requires an integrated approach that combines advanced monitoring, adaptive ecological management, informed infrastructure planning, targeted policy measures, and the active involvement of social, economic, and administrative stakeholders.
Continued interdisciplinary research and proactive international collaboration remain essential to ensuring the long-term sustainability and resilience of these highly vulnerable bird populations.





Illustrated poster of the Palearctic steppe bird community distributed to attendees of the International Conference on Palearctic Steppe Birds.

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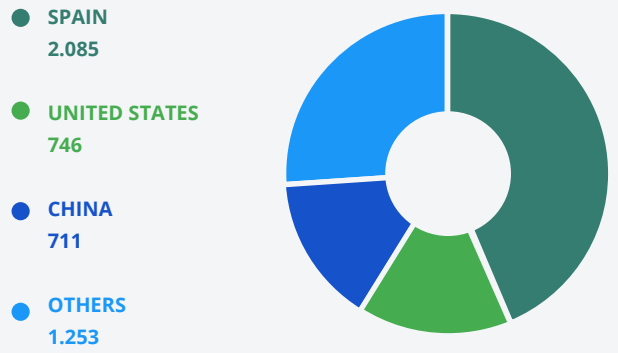
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> Website update

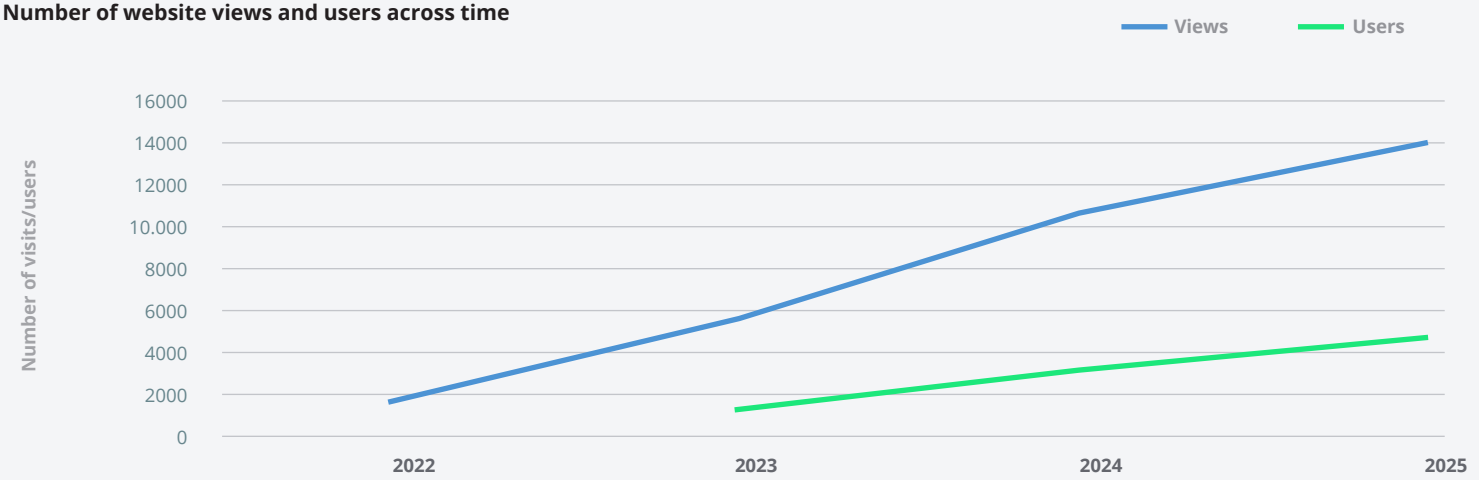
The project website has been updated to include the latest information on the tagged individuals and their movements, as well as scientific publications and outreach activities produced to date. Additional modifications have also been implemented to improve the website's online visibility, including changes to URL structure and search engine keywords.

In 2025, the website received more than 14,000 page views (31% more than the previous year) from 4,795 users (50% more than the previous year). Approximately 90% of users came from 81 countries, with the largest audiences from Spain, the United States, and China.

Users' country of origin



Number of website views and users across time



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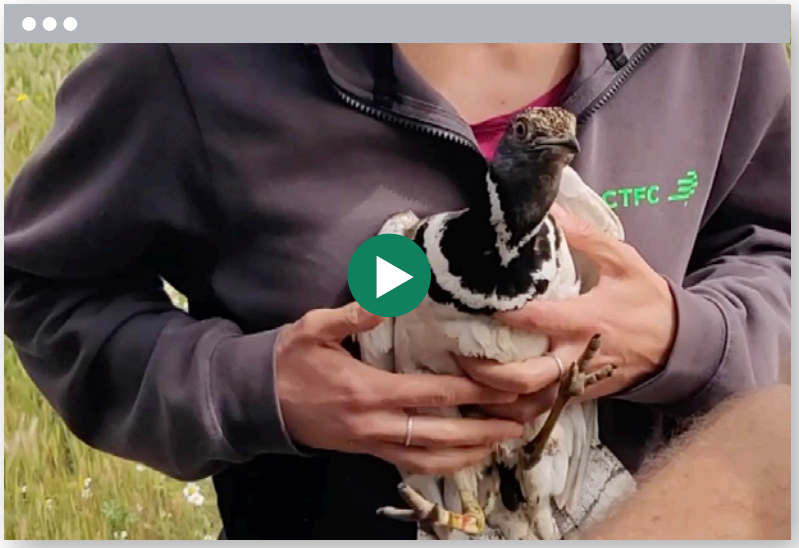
> Media coverage

The Chair participated in **a public media interview** through **Dr. Gerard Bota Cabau**, Coordinator of the Chair, on **EFE's Mangas Verdes** podcast, where the objectives and ongoing work of the Chair were discussed. The interview is available at:

Link ▶

Creation of outreach videos

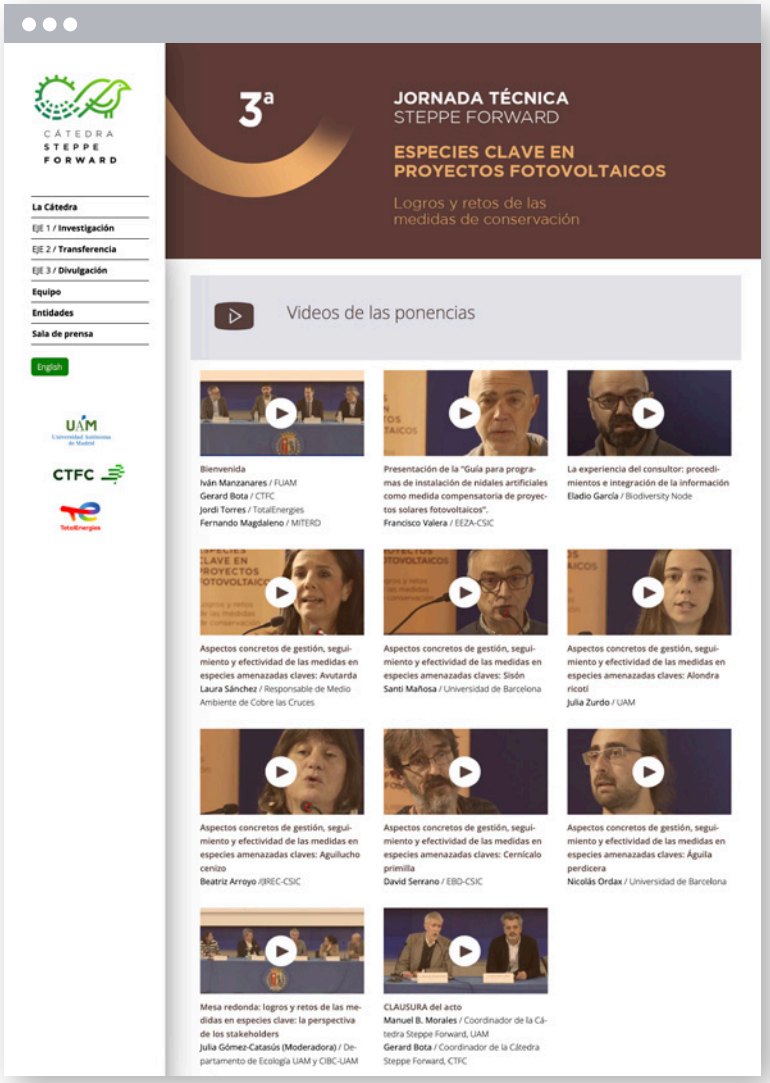
During 2025, two new videos were produced presenting the main findings from the first five years of the Steppe Forward Chair. Featuring high-quality visual production, these videos provide a synthesis of the principal milestones achieved in the areas of Research and Knowledge Transfer since the start of the Chair.





Videos can be consulted here:

Link



Furthermore, all p**resentations from the 3rd Steppe Forward Technical Conference** have been uploaded to the website in video format, together with statistics on participants and attendees, as well as an evaluation of the event.

Link ▶



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