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Opportunities and challenges for species recovery

WILDLIFE COMEBACK IN EUROPE

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Wildlife Comeback in Europe

Opportunities and challenges for species recovery

Final report to Rewilding Europe by the Zoological Society of London, BirdLife International and the European Bird Census Council

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FOREWORD

Voting for wildlife

FRANS SCHEPERS
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In March this year, when the time came for country-wide municipal elections in the Netherlands, I was undecided as to how to vote. In my municipality, close to the city of Nijmegen, several of the new local political parties remained a mystery to me. Out of curiosity, I decided fill in an online electoral questionnaire.

Halfway through, I was suddenly confronted with an unexpected question: "Do you favour the presence of wolves in our municipality – yes or no?" I was genuinely shocked. It seemed as though the return of animals to the Dutch landscape was being governed by the ballot box!

This line of questioning was clearly sparked by a grey wolf that had shown up in my neighbourhood the previous November, a short distance from my house. During the night it killed several unprotected sheep. It was then captured on wildlife camera when it returned to the same site the following night, where the farmer had left the dead sheep in order to find out more about the perpetrator of the killings.

This was the first confirmed wolf sighting in my municipality since wolves returned to the Netherlands in 2015. Unsurprisingly, the killing of the sheep generated an outpouring of emotion and negative publicity in local and regional media. Yet the farmer simply decided to lock up his sheep overnight from that point onwards. The wolf, probably a juvenile, moved on and disappeared.

The appearance of a wolf so close to home was fairly predictable – across the nearby German border the animal has already reestablished itself in large numbers. Two years before, in a large forest just a few kilometres across the border, I had already found tracks and the remains of a wild boar killed by wolves.

"The story of wildlife comeback in and around my village epitomises what is happening in many other parts of Europe. Despite all the challenges, and the overall decline in nature, there are positive stories to share.

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Seven years on from its return to my country, the wolf is doing well – the first pups were born in 2019, and there are now four packs containing with at least three having pups this year. Between mid-February and end of April 2022 alone, there were an amazing 313 confirmed observations of Dutch wolves. The grey wolf has, excitingly, become a stayer.

Over the last 15 years, I have gladly witnessed other wildlife species make a comeback in my municipality. In addition to wolves, a golden jackal was seen in 2021, while two beaver families inhabit small streams that flow through our village – sadly some have been killed on the road. We have also seen pine martens make a comeback, and there is a badger breeding den close to our house. The otter struggles to recolonise the region despite reintroduction efforts, while wild boar are now heavily hunted because of African swine fever and have nearly disappeared.

I often see peregrines, which are breeding on city buildings in Nijmegen, hunting above my backyard, while the eagle owl, raven and middle spotted woodpecker have recently colonised our nearby forest. And in 2021, immature tree frogs were reintroduced in their hundreds in one of the largest floodplain rewilding areas in our country – the Gelderse Poort – just a few kilometres from my house. I am eagerly anticipating their noisy chorus next year, on warm spring evenings, when the males have become adults.

This story of wildlife comeback in and around my village epitomises what is happening in many other parts of Europe. Despite all the challenges, and the overall decline in nature, there are positive stories to share. Legal protection, dedicated conservation work, species recovery efforts, and various other measures have seen many wildlife species start to make a European recovery.

My little personal story also illustrates that the road to recovery for many wildlife species is not a smooth and easy one, but filled with bumps and potholes. This is why, at Rewilding Europe, we have joined forces with scientific partners to document wildlife comeback across our continent. A first comprehensive overview, published in 2013, sparked huge interest in international media, with a calculated outreach of over 140 million people. Apparently, this topic spoke to the collective imagination, surprising millions who were unaware of the wildlife recovery happening under their very noses.

Now, nearly a decade later, we have updated the status of wildlife comeback in Europe, adding a few more species and providing the latest insights in this new report. In partnership with the Zoological Society of London, BirdLife International, European Bird Census Council, and the Worldwide Fund for Nature, and working with many wildlife experts from all over Europe, we have assessed the status of 24 selected mammal, 25 bird and one reptile species, based on the analysis of extensive datasets collected by researchers, volunteers, institutions, NGOs and authorities, to all which we have to pay tribute for their dedicated efforts. In addition to these individual species accounts, we also present a detailed analysis of the overall comeback, putting it in a wider European context, and looking at opportunities and challenges, both now and going forwards.

Zeroing in on the future of my own neighbourhood, I hope that the promising wildlife comeback of the last 15 years continues to gather pace – after all, life is far more interesting and rewarding when you are surrounded by a rich and complex nature. Given the opportunity, I'll vote for wildlife every time.

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Executive summary

We present an update to "Wildlife Comeback in Europe", a landmark report from 2013 which featured selected species of mammals and birds showing signs of recovery in terms of their abundance and distribution in Europe[1]. Almost a decade later, we revisit the same set of species to see if these positive trends are continuing, while also expanding the number of species included. We present analyses on the drivers behind population recoveries and limits to population growth and discuss our findings in the context of ecosystem regeneration, and coexistence between people and nature in Europe.

We used several data sets to produce detailed accounts for 50 species (24 mammal, 25 bird and one reptile species), and to synthesise the trends for an overall analysis. The key data sets used were the Living Planet Index Database[2], EU Birds Directive Article 12 reporting[3] and the IUCN Red List of Threatened Species[4]. Extensive research was conducted in consultation with expert reviewers in order to describe and explain historical trends for each species and present the latest outlook. The synthesis of the trend data for mammals and birds included in this report is also presented in a scientific manuscript[5]. Our discussion sets the species-based results in context with a series of "Spotlights", which are literature-based summaries of current and important topics on ecosystem health, and coexistence between people and nature focusing on: climate change, ecosystem restoration, monitoring and data gaps, and legal and policy frameworks.

KEY FINDINGS FROM THE SYNTHESIS

Positive trends in abundance and distribution are largely continuing in our focal species

- For most of the species analysed in 2013, we found that increases in both range size and population abundance have continued.
- Among selected mammal species, the Eurasian beaver (*Castor fiber*) showed the largest increase in range, having expanded its range by 835% since 1955, followed by the European bison (*Bison bonasus*), which expanded its range by almost 400% since 1971.
- Relative abundance of the selected mammal species increased by between 17% since 1970 (Eurasian elk *Alces alces*) and over 16,000% since 1960 (Eurasian beaver). Herbivore species increased more on average than carnivores.
- Among birds, 19 of the 25 species have expanded their ranges since the 1980s. Increases in distribution ranged from 7% for Osprey (*Pandion haliaetus*) to 585% for Barnacle goose (*Branta leucopsis*).
- The population sizes of the 25 bird species covered in this report are estimated to have increased by an average of 470%, ranging from 34% since 2002 (Black stork *Ciconia nigra*) to more than 5,000% since 1960 (Barnacle goose).

We found evidence of recent stabilisation or decline in some species

- Among the 50 species selected for this report, one mammal and six bird species exhibit recent declines in their distribution (e.g. Eastern imperial eagle *Aquila heliaca* and Roseate tern *Sterna dougallii*).
- Whilst contraction in range may not necessarily mean a decrease in abundance, some species' populations may currently be declining despite recent recoveries from historical lows (e.g. Audouin's gull *Larus audouinii*, White-headed duck *Oxyura leucocephala*, and some Eurasian lynx *Lynx lynx* populations).

Less positive rates of recovery for selected mammal species are associated with the presence of pressures and more positive rates are associated with whether conservation measures are in place

- For mammal species, we found that increases in abundance were less positive where there were known pressures impacting the population. The most frequently identified pressures were *Exploitation* and *Habitat degradation or change*.
- The same mammal populations also show more positive increases in abundance when conservation management is in place. For mammals, *Harvest management* (such as limiting the

amount of legal hunting permitted), *Reintroductions and translocations*, *Natural expansion and recolonisation* and *Species ecology* were the main reasons recorded for population recovery.

The probability of recovery for selected bird species is associated with the number of different types of pressures acting upon them and how many different conservation measures are in place

- Recovering bird species were less likely to be increasing in the long-term in both range and population size when they were reported to be facing a greater diversity of pressures. The most frequently identified pressures were those associated with *Agriculture and aquaculture*, followed by *Transportation or service corridors* and *Human intrusions or disturbance*, as well as the *Unintentional effects of hunting, fishing & persecution*.
- For bird species, the most frequently recorded driver of recovery was *Legal protection (e.g. from shooting, egg collecting etc. & disturbance)*, followed by *Site/habitat protection* and *Habitat management and restoration*.

KEY INSIGHTS FROM THE SCIENTIFIC LITERATURE

More monitoring is needed to tackle data gaps

- Monitoring of species in Europe is uneven across species groups and regions. Even for the mammal species featured in this report, we could assess quantitative range change for only 12 of the 24 species.
- In the first European Breeding Bird Atlas[6], there were many data gaps for eastern Europe. Citizen science has helped to boost monitoring for the second European Breeding Bird Atlas[7], which was made possible through the efforts of tens of thousands of volunteers.
- A greater understanding of the impact of wildlife comeback on ecosystem function is still needed to inform best practice in rewilding. This could be realised through more collaborations between conservation practitioners and research institutions.

Climate change is a growing pressure for some species whilst benefiting others; wildlife comeback may offer some mitigation through animating the carbon cycle

- Climate change can impact wildlife but it does so differentially. It is thought to have enabled some species to expand their distribution and may provide favourable environmental conditions for other species in future.
- However, other species are threatened by predicted changes in climate. The Ringed seal (*Pusa hispida*) has an especially uncertain future, given its reliance on sea ice and the predicted changes to this habitat as climate change continues.
- Restoring functional ecosystems to supercharge carbon sequestration processes (known as “animating the carbon cycle”) with the aim of getting the carbon budget ‘in check’ could support Europe in reaching its climate mitigation and biodiversity targets. More research is needed, however, to investigate whether reintroducing large-bodied animals to European landscapes and seas could reinvigorate carbon cycling processes (e.g. through trampling or movements within the water column).

Wildlife comeback can contribute to ecosystem restoration and provide economic, social, cultural and health benefits for people

- Wildlife comeback can be a benefit of active management processes, such as rewilding (which comes in many forms), or it can occur naturally, without human interventions.
- Some species have recovered from very depleted levels and their comeback can have a strong impact on ecosystem functions and processes (e.g. restoring trophic guilds, reducing flooding and wildfire control) which are yet to be fully quantified.
- Wildlife economies can benefit local communities – for example, wildlife tourism can generate revenue and jobs, whilst access to nature is increasingly understood to be vital for our health and mental wellbeing.

Strong legal and policy frameworks are needed to promote human wildlife coexistence and manage the increase in some species, especially carnivores

- Applying protective measures and relevant legislation at regional and national levels has underpinned the comeback of many species documented within this report – especially for bird species.
- Carnivore comeback and coexistence may require some communities to adapt and change behaviours. Policies and legislations to ensure that communities are engaged with (e.g. education outreach programmes and participatory approaches), supported (e.g. livestock damage compensation schemes) and are benefitting from coexistence (e.g. enabling sustainable wildlife economy enterprises) are all important to enable and facilitate coexistence.

Changes in regional and global policy offer opportunities to improve ecosystem health

- In light of the global climate and biodiversity crises, regional and global targets have been drawn up recognising the importance of ecosystem processes and their regeneration.
- The EU Nature Directives include protective measures for species and sites (especially through the Natura 2000 Network). Some scientists support their expansion to recognise the importance of ecosystem processes and their regeneration.
- Codification of the "European Climate Law" and the "EU Nature Restoration Law" into national legislation could increase opportunities to maintain and encourage wildlife comeback.
- Rewilding approaches can support the restoration of ecological processes and increase ecosystem health. Inclusion of rewilding as an option within agricultural (e.g. the EU Common Agricultural Policy) and land abandonment policies is suggested to provide another nature-based solution to support European biodiversity and ecosystem health.

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Introduction

REVISITING WILDLIFE COMEBACK IN EUROPE

The 2013 Wildlife Comeback in Europe report[1] showcased the recovery of selected mammal and bird species, highlighting the propensity for wildlife to rebound and recolonise when given the opportunity, through natural processes or conservation interventions. Nearly a decade later, we explore whether we are still witnessing wildlife comeback and where this is happening within the continent. The UN Decade of Ecosystem Restoration[2] presents a timely opportunity to reassess recoveries in species across Europe and to identify the relevance of wildlife comeback for ecosystem health and function, and for society in Europe.

In this new report, we update the individual species accounts originally included in the 2013 Wildlife Comeback in Europe report[1], collating data on abundance and range for each of the selected bird and mammal species. We also expand the taxonomic coverage by 13 species, adding six birds, six mammals and a new reptile species account – the first in these reports for this taxonomic group. Again, we focus solely on species showing positive changes and aim to show the overall patterns in abundance and range changes, exploring differences between species and regions in Europe.

This is framed within our analysis of the drivers behind reported increases for different species and the ongoing pressures which, in some cases, continue to limit their recoveries, providing an overview of the most important factors behind wildlife comeback. In line with the previous report, we provide insights into key areas of interest for rewilding and the recovery of wildlife, to support informed application of rewilding or restoration practices and highlight areas which need further attention for European species.

We use this update to inform readers both on developments in the field of rewilding, and on the many possibilities for its uses within the region. From passive rewilding (allowing space for wildlife to make a comeback) to active conservation measures (e.g. species (re)introductions), we see countless opportunities for positive change both for wildlife and people.

In the remainder of this chapter, we outline the current state of nature in Europe and describe the landscape of conservation policy in which wildlife comeback can be supported and managed. We also introduce the first of a series of "Spotlights" – summaries of relevant topics based on the latest scientific literature and reports – which sets out some key terms and definitions used in this report.

STATE OF NATURE IN EUROPE

The current state of nature in Europe shows a mixed picture. Whilst monitored vertebrate population trends on average are faring better in Europe compared to other regions of the world, the overall trend (24% decline in relative abundance between 1970 and 2016 in the Living Planet Index (LPI) for the wider region of Europe and central Asia[3]) is still negative and varies between taxonomic groups. Within the EU, reporting from member states shows that almost half of bird species that naturally occur in the EU have a 'good' population status and particular improvements have been seen in forest habitats[4]. However, nearly one in eight European bird species are threatened with extinction at the regional level[5], and that figure is around one in five for mammals and reptiles[6].

Threats to species in Europe are still present[7] and climate change is a growing pressure, especially from droughts and reduced precipitation[4]. The current condition of the natural world in Europe should also be framed in a broader historical context, as despite witnessing positive or stable trends in recent decades, there has been centuries of human impact on nature in the region[8] and many recovering wildlife populations remain far below historic levels[9]. Encouragingly, some populations are rebounding, as we see in this report, but it is important to note that the baseline we use is a relatively recent one considering the perspective of the ecological history of Europe.

To fully understand the changing state of nature in Europe, a comprehensive evidence base on trends in European ecosystems is needed, but this is still lacking for many taxonomic groups, particularly for marine species and habitats[4].

To tackle the ongoing challenges of maintaining and restoring healthy ecosystems, and enabling wildlife recovery in Europe, policy frameworks have been developed at the national, regional and global scales, creating the conditions under which relevant laws can be implemented. In the next section we outline some of the main policy instruments referred to throughout the report.

CONSERVATION POLICY AND LEGISLATIONS

Europe benefits from well-established regional biodiversity legislations and policies (see Appendix 2 Table 1 for details of the following key legislations). The European Commission's Birds Directive and Habitats Directive (hereafter referred to as the EU Nature Directives) have provided member states with the frameworks to apply coordinated and funded conservation actions. Species requiring protection, conservation measures or restrictions on exploitation are listed in a series of Annexes against which member states are required to report on periodically. Complementing the EU Nature Directives at a broader European scale, the Bern Convention is a legally binding policy instrument focused on the conservation of wild flora and fauna, especially threatened species.

For the many migratory species that occur in Europe, the Convention on the Conservation of Migratory Species of Wild Animals (hereafter "CMS") provides a framework for their conservation and protection. This is a global instrument but has many regional and species-specific agreements under its auspices. For migratory waterbirds, the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (hereafter "AEWA") is in place to coordinate activity along the migratory flyways to ensure a favourable conservation status for these species. For migratory birds of prey, the Raptors Memorandum of Understanding (hereafter "Raptors MoU") is another agreement under the CMS focused on conservation measures for birds of prey throughout their range.

Also at the global scale, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (hereafter "CITES") focuses on those species facing the specific pressure of international trade. The trade in species listed in the Appendices of this convention is controlled or prohibited, according to the level of threat it poses. Because of the lack of border controls between EU member states, a regional instrument is needed to ensure CITES is implemented uniformly throughout the EU. This is controlled by the EU Wildlife Trade Regulations.

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Other global policy instruments are not specifically focused on European species, but they provide an umbrella under which regional agreements can be tailored. The main policy at the global scale is the Convention on Biological Diversity (CBD) which was agreed upon to conserve and sustainably use biological diversity. The alignment of the EU Nature Directives with the most recent set of global biodiversity targets established by the CBD was evaluated and several of the targets were found to be complementary, but some gaps were identified, such as the narrow taxonomic focus of the Nature Directives [10]. As the next strategic plan of the CBD is being negotiated, discussions are ongoing about what changes might be needed to comply with the draft post-2020 Global Biodiversity Framework, such as evaluating whether the current protected area network in Europe could meet proposed targets [11].

It's not just policies on nature that are relevant to conservation in Europe: the Common Agricultural Policy, Common Fisheries Policy, EU Water Framework Directive and Marine Strategy Framework Directive are all instruments which need to be aligned with global and regional targets on tackling the biodiversity crisis. These policies concern some of the most common drivers of species decline and habitat loss in Europe: agriculture, fisheries, water pollution and transportation [4]. The dual challenges of biodiversity decline and climate change are also intrinsically connected and there are increasing calls to link these two global issues through international policy [12]. To align with international conventions to address the global climate crisis, the European Union adopted the European Green Deal for Nature, seeking to update taxation, energy, transport and climate policies to bring greenhouse gas emissions down by 55% by 2030 (compared to 1990 levels) and to be the first climate neutral continent by 2050 [13]. To strengthen their implementation, these targets are set to be codified into law through the "European Climate Law" [14]. The newly proposed "EU Nature Restoration Law", if adopted, would also strengthen action to tackle issues relating to both nature and climate, and specifically the dual benefits to both issues from ecosystem restoration [15].

In this report, we discuss the policies that are relevant to individual species and document where there is evidence that wildlife recoveries are attributable to the implementation of these frameworks. We also describe how the current policy landscape relates to the themes of this report (Spotlight 6 – Policy, legislation, and opportunities for rewilding within Europe); these themes of wildlife comeback, recovery and rewilding are described in the first "Spotlight".

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SPOTLIGHT 1

REWILDING, ECOSYSTEM RESTORATION AND WILDLIFE COMEBACK

Over the past ten years, interest in and awareness of rewilding and ecosystem restoration has increased, both in the scientific community as well as in the policy and public realms. Some scientists have raised concerns that with a lack of both clear definitions and consistency in usage, we risk conflation of terms, misapplication and a potential loss of uptake and momentum[1,2]. Others have suggested that the transformational potential of rewilding should not be constrained by set definitions and support a pragmatic approach around ecosystem recovery and learning through practice[3–5]. There are many different approaches and definitions in play, so for clarity, we set out a number of key concepts and definitions as we use them (Table 1). We also explain how wildlife comeback and this report aims to contribute to the field.

Table 1. Key definitions of terms as applied within this report.

TERM	DEFINITION	REFERENCES
Theory		
Ecosystem restoration	The process of stopping ecological degradation and returning an ecosystem to its former state, as far as is possible, where there is emphasis on composition over processes. There is high fidelity to former species assemblages (unlikely to introduce novel taxa) and target outcomes are guided by historical baseline knowledge, alongside environmental and climatic change scenarios.	3, 6, 7, 8
Rewilding	Regenerating a human-disturbed or degraded ecosystem with the aim that it will become more autonomous (wilder) over time. The focus is on what will increase ecosystem health and functionality. Historical baselines are not used to define targets, but may still inspire successful rewilding. Novel species assemblages and species analogues can be accepted. Different approaches to rewilding include "passive," "trophic," "ecological," "Pleistocene" and "cores, corridors and carnivores", as outlined below in rewilding approaches.	3, 6, 7, 9, 10
Rewilding approaches		
Cores, corridors, and carnivores (the three C's)	An approach developed in, and more commonly used in the Americas, focused on actions that preserve core habitat, establish wildlife corridors and (re)introduce large carnivores. Considers these three elements most impactful for ecosystem regeneration.	4, 9, 11
Passive rewilding	A reduction (towards withdrawal) of human interventions and management actions within the landscape. This is considered to increase autonomous function of an ecosystem, potentially (but not always) resulting in ecosystem regeneration.	7, 12, 13
Trophic rewilding	An approach that uses introductions of large animals (often keystone species such as ungulates, carnivores and scavengers) to stimulate ecological processes through trophic cascades and encourage self-regulating ecosystems.	9, 14, 15
Pleistocene rewilding	Restoration of species assemblages (as closely as possible) to those present within the landscape during the Pleistocene era. Given that some species may be extinct, species analogues can be accepted. There is an emphasis on large 'flagship' species.	9, 12, 16
Ecological rewilding	Restoring ecological processes with minimal human interventions to encourage a self-regulating system. This can include initial interventions to create the right conditions for natural processes to take over, such as dam or dyke removal for reflooding, species (re)introductions to restore trophic networks, but also restoring abiotic disturbance regimes (e.g. floods, fires, closing ditches and drains for rewetting), and increasing spatial connectivity of habitats to encourage autonomous species dispersal.	7, 10, 13, 17
Urban rewilding	The process of regenerating or establishing ecosystem functions within urban areas or human-dominated landscapes. This can apply at different spatial scales from the 'microcosm' (e.g. gardens and buildings) upwards (e.g. industrial estates) and can include different levels of human-wildlife interactions and management interventions.	18–20
Related terms and concepts		
Wild, or 'wildness'	An area of any size, where nature has autonomy, and the ecosystem is self-sustaining. This does not have to be exclusive from humans, or pristine. Can be an aim, or component of restoration and rewilding initiatives.	9, 21
Land abandonment	Describes the process by which a landscape, previously utilised by humans (with any level of disturbance or degradation) is no longer used for production purposes due to rural depopulation. Often applies to agricultural lands and is commonly linked with socio-economic factors (rural to urban shift).	9, 22, 23
Wildlife comeback	Describes the phenomenon of taxa previously in decline in the wild, or extirpated from an area, now exhibiting positive trends in their population size and, or range extent. It is related to, but not equivalent to 'species recovery' – which is measured against a historical baseline and has a set target for recovery[24].	13, 25–28

WILDLIFE COMEBACK IN THE CONTEXT OF REWILDING AND ECOSYSTEM RECOVERY

The reasons for wildlife comeback can vary and can arise from direct human actions (species recovery programmes, reintroductions, population reinforcements, legal protection etc.) or passively following changes within the environment that are favourable to their survival and reproductive success. Therefore, linkages between wildlife comeback and rewilding and ecosystem restoration are **context specific**.

1. Wildlife comeback is not synonymous with rewilding. However, it can be a consequence and/or target for both rewilding and ecosystem restoration efforts.

2. Active rewilding or ecosystem restoration approaches might include wildlife comeback as part of their aims for certain taxa or species assemblages, or to restore certain ecosystem functions.

3. Wildlife comeback is not necessarily a consequence of either rewilding or restoration. There are a whole host of reasons (e.g. life history, cultural reasons) which can contribute to wildlife comeback.

4. Wildlife comeback that occurs independently of restoration or active rewilding efforts may be interpreted, in some contexts, as moving an ecosystem to a wilder state, and hence be considered rewilding in itself. This is the case where a species, such as a top predator, expands into an area with no other functionally similar species, and its presence directly leads to new species interactions and ecological processes.

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A Guide to using the species accounts

The 50 species accounts are organised systematically by taxonomic class (mammals, reptiles and birds) and then by order. Each account gives a snapshot of the species' ecology, status, and trends in distribution and population abundance within Europe, from the historical period to the present day.

Information was compiled on each species' demography, threats faced, drivers of recovery, benefits of comeback and overall outlook for the species. Where information was already available and still relevant from the previous version of the Wildlife Comeback in Europe report[1], this was re-used, augmented with new information sourced through literature searches and from species experts. These accounts have been through an expert review process and species experts are acknowledged at the end of each account. Each species account includes a table summarising the legal measures in place for its protection and a summary of current threats (as stated within the most recent data from the IUCN Red List of Threatened Species™ [2]). In some cases, localised threats are also included. We refer to 'threats' in the species accounts and 'pressures' in other chapters; these terms are used interchangeably and refer to the current and ongoing threats/pressures acting on a species. Details on the spatial boundaries used for Europe, the methods for the population abundance and spatial distribution analyses, important caveats, and other technical details are found in the Methods (Appendix 1).

Mammal species accounts

ICON 4
Population estimates were sourced from the Global and European IUCN Red List species assessments unless otherwise specified. Icon represents the European population in the darker colour sector and the global population in the lighter colour ring. The smallest estimate was chosen where a range was available. Where this was not possible to represent, the circle is empty.

ICONS 1–3
This information was sourced from the most recent IUCN Red List assessments and is provided at a Global, and Regional (European or Mediterranean) level where possible.

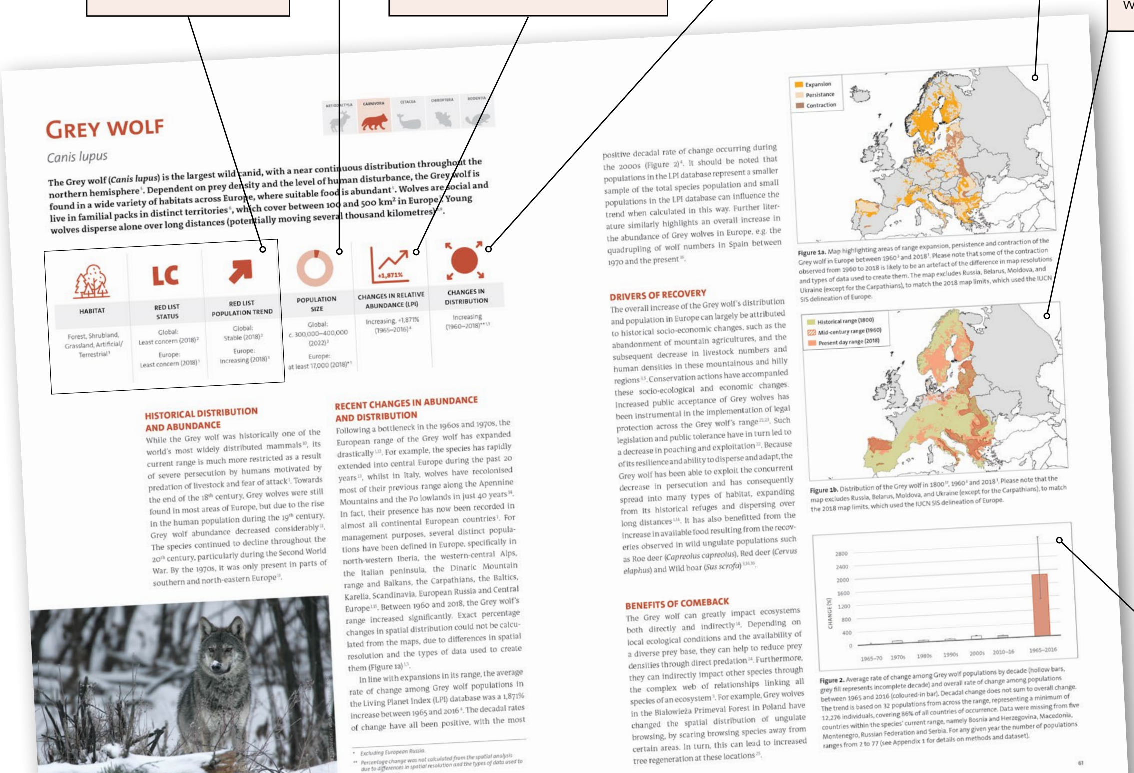
ICON 5
Percentage change was calculated using time series trend data for European populations within the Living Planet Index Database. The year range for species data analysed is provided. N.B. this does not represent absolute changes in numbers of individuals.

ICON 6
The percentage change in species distribution shown here is calculated from the difference in km² between the species' past (1950–60s) range and present day (2010–2021) range (see methods). The year range for species maps analysed is provided. N.B. this figure may be an under or overestimate due to differences in spatial resolution between past and present data. For two species, the 'past' refers to a different timepoint for their range – the Northern chamois which is 1930 and the European bison which is 1971.

MAP A
This map is colour coded to indicate estimated areas of expansion, persistence and contraction between the past (1950–60s) and present day (2010–2021). This analysis was not possible for species which did not have reliable past spatial data available.

MAP B
This map shows the species distribution across three time periods; historical (1500–1900), past (1950–60s) and present (2010–2021). For some species, geospatial data for the historical period was not available or it was excluded under expert guidance.

CHART
Each bar chart represents the average rate of change in abundance in a given time period among the species' populations, based on the population trend data we have for any given species. The bar charts do not show absolute changes in numbers of individuals of each species. The bar charts are intended to represent average trends for the species in the countries we have data for. They are not intended to represent trends outside of the data set they are based on. See associated figure legend for more details on what data were included and the species account text for context of the trend depicted.



ICONS 1–3
This information was sourced from the most recent IUCN Red List assessments and the status and trends are provided at a Global and European level unless stated otherwise in the references.

ICON 4
Population estimates were sourced from the Global and European IUCN Red List species assessments unless otherwise specified in the references. Population sizes from the European Red List of Birds include Greenland, Turkey and the Caucasus. Icon represents the European population in the darker colour sector and the global population in the lighter colour ring. The smallest estimate was chosen where a range was available. Where this was not possible to represent, the circle is empty.

ICON 5
Percentage change of the population size was calculated from the year of the lowest population size for the species until the most recent population estimate available. Unless stated otherwise, this change is calculated for the entire European population.

ICON 6
The percentage change in a species' breeding range, expressed by the change in the number of 50-km squares in which that species is reported to breed between European Breeding Bird Atlas 2 (EBBA2) and the European Breeding Bird Atlas 1 (EBBA1), where comparable (for more information, see Methods).

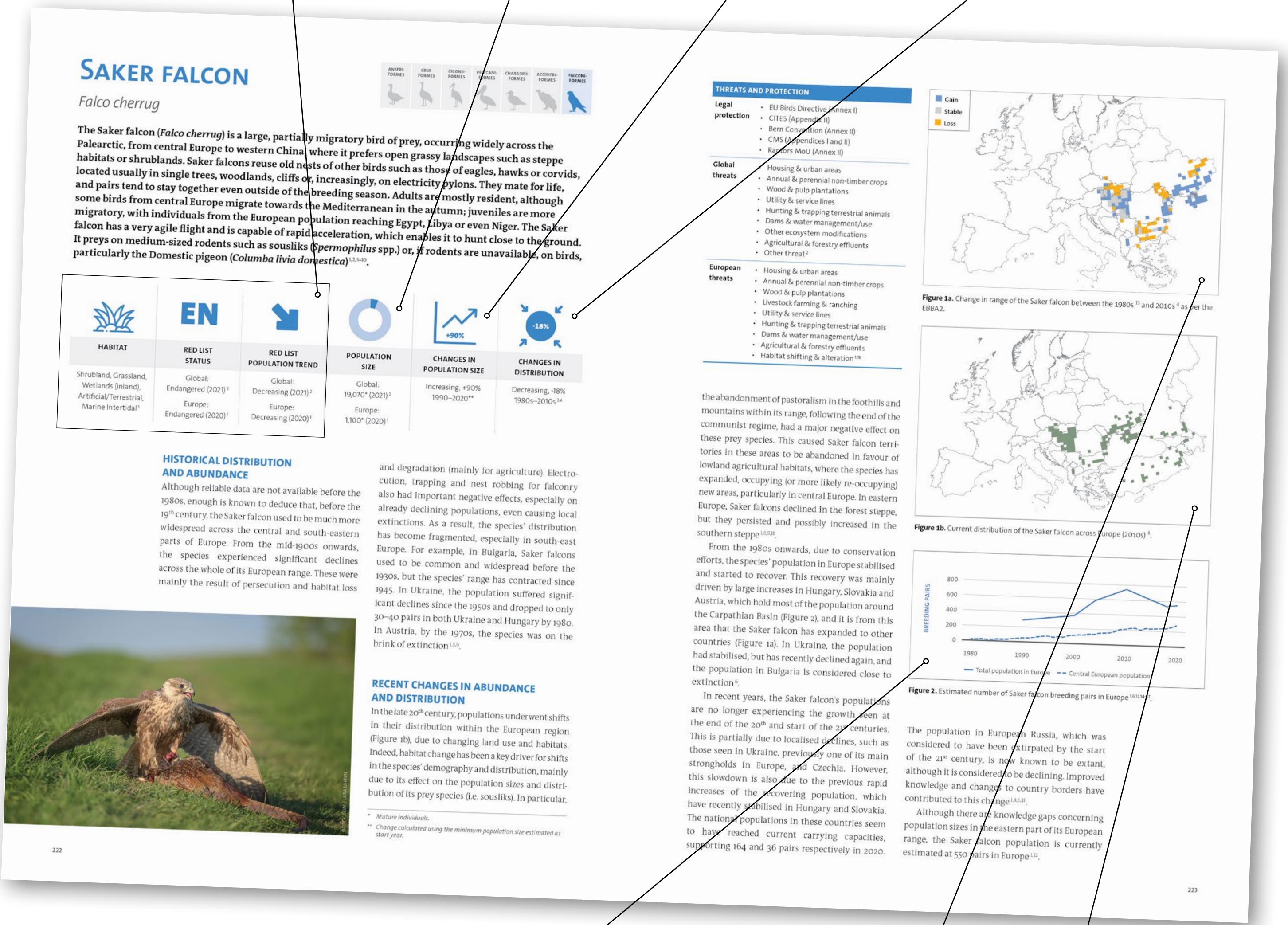


CHART
These graphs include some or all of the following: breeding population estimates (measured in pairs) and / or wintering population estimates (measured in individuals) for all of Europe; breeding and /or wintering population estimates for geographically distinct populations; and the Pan-European Common Bird Monitoring Scheme (PECBMS) index, where available (see Methods for more information).

MAP A
This map shows the change in breeding range: the difference in the number of 50-km square in which these species are reported to breed between EBBA1 and EBBA2. The changes are represented by Blue: gain (local colonisation), Orange: loss (local extinction) and Grey: stable. (for more information, see Methods).

MAP B
This map shows current distribution: the number of 50-km squares in which these species are reported to breed in Europe, sourced from the EBBA2.

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Mammal accounts

ARTIODACTYLA

CARNIVORA

CETACEA

CHIROPTERA

RODENTIA

EURASIAN ELK

ARTIODACTYLA | CARNIVORA | CETACEA | CHIROPTERA | RODENTIA

Alces alces ssp. alces

The Eurasian elk (*Alces alces*) is the largest living deer[15] and occurs as 8 subspecies across the Northern Hemisphere, with all European populations classified as the European subspecies *A. a. alces*[16]. The Eurasian elk is a browse feeder and is found across deciduous, coniferous and mixed-leaf boreal and temperate forests[2,16].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forests, Wetlands[1]	Global: Least Concern (2015)[2] Europe: Least Concern (2006)[1]	Global: Increasing (2015)[2] Europe: Increasing (2006)[1]	Global: 2.2 million (2010)[8] Europe: 885,000*	Increasing, +17% (1970–2016)[10]	Increasing, +31% (1955–2010)[8,11–14]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The modern elk appeared in central Asia[17] around 100,000 years ago, in the late Pleistocene, and by the early Holocene had spread across most of the central and northern European continent[18,19,20]. However, climate warming during the Holocene, combined with overexploitation, disease and conversion of forests to agriculture[21], caused population reductions and range contraction from the southern and western limits[19, 20]. By the early 1800s, the Eurasian elk population had therefore become limited to isolated subpopulations in the north-east of mainland Europe and Fennoscandia[21]. Declines continued until the mid-1850s, followed by a period of rapid recovery[21]. Another phase of decline occurred in the 1920s, attributed to over-exploitation resulting from economic hardship and famine[21]. While populations in modern-day Lithuania, Belarus and eastern Poland recovered somewhat between 1928–38, this was reversed during the Second World War[22], so by the mid-20th century only Scandinavia and Russia remained as strongholds for Eurasian elk populations[19].

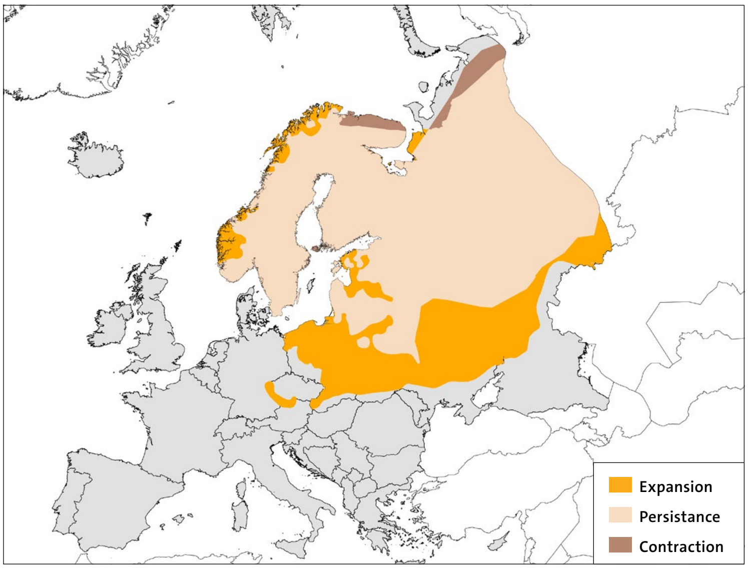


Figure 1a. Map highlighting areas of range expansion, persistence, and contraction of Eurasian elk in Europe between 1955[11–14] and 2010[8].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

By 1955, the species' range had begun to increase, and by 2010 was estimated to be 222% larger than the early 1800s distribution (Figure 1a). With significant spread into Central Europe, the Eurasian elk's current distribution encompasses Fennoscandia, most of northern and central European Russia, the Baltic states, Belarus and extends into Northern Ukraine and Poland[8]. The westward spread in Central Europe shows signs of continuing, with increasing numbers of Eurasian elk migrating into Eastern Germany from Poland, especially in the Oder Delta region[24]. There is also an isolated subpopulation in the border region of the Czech Republic, Austria and Germany, although this has declined in recent years to as few as 20 individuals[7,25].

While the average rate of change among populations included in the Living Planet Database was +17% between 1970 and 2016 (Figure 2), this has not been a stable rise. The greatest recovery occurred prior to this period in the 1960s, slowing in the 1970s and stabilising in the 1980s. This was followed by a period of decline in the

* *Based on literature-reported estimates for individual range countries between 2009 and 2019[3–9].*

1990s, from which recovery generally did not occur until the 2010s. This increase has not been evenly distributed geographically, with the largest increases seen in Sweden[4], Lithuania[4], Russia[26] and Poland[5], compared with stability or even declines elsewhere (e.g. Ukraine[27,28]).

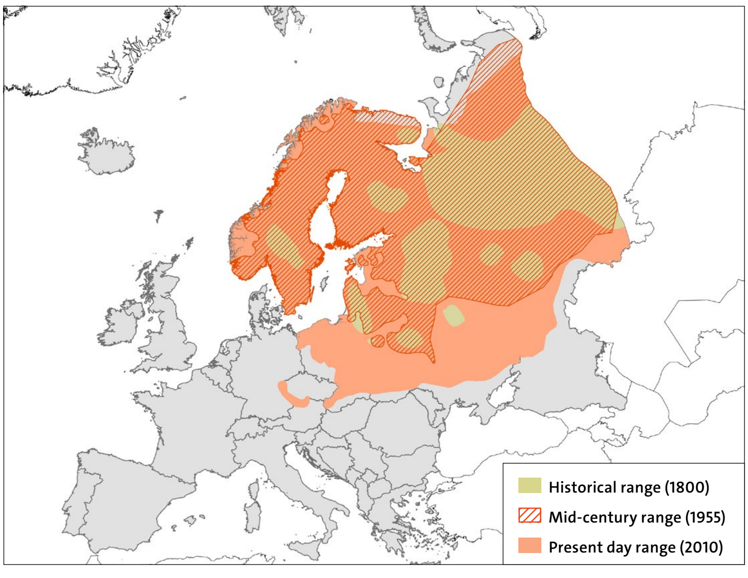
DRIVERS OF RECOVERY

One of the most important factors in the comeback of this species is thought to be changes in hunting practices (such as restrictions on age- and sex-specific harvesting in e.g. Finland[34,35], Norway[34,36] and Sweden[34]) and hunting bans (e.g. in Poland[5]), although the eradication of large predators such as wolves (*Canis lupus*) and bears (*Ursos arctos*) may also have contributed, especially in Scandinavia[34, 36]. Forest management practices have also played a significant role in Fennoscandia[34–36], as regrowth of young saplings after felling provides abundant browse. Regeneration of forest habitats after abandonment of agricultural land has had similar effects[34]. Finally, in some cases, direct intervention has been a catalyst for recovery. For example, the translocation of Eurasian elk from Belarus into the Kampinos forest in Poland in 1951[37].

BENEFITS OF COMEBACK

Eurasian elk play a key functional role in forest ecosystems as grazing, browsing and trampling processes all influence vegetation dynamics[38], and faecal deposition contributes to nutrient cycling[39,40]. Seed dispersal between forest patches by Eurasian elk can also aid maintenance of plant diversity[41]. As an important prey species for large

Figure 1b. Map showing distribution of the Eurasian elk in Europe in the early 1800s[18,19,23], 1955[11–14] and 2010[8].



THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III)[29] • Huntable species in most countries with stable populations, but hunting banned in others, e.g. Poland[5] and Ukraine[27,28]
Current threats (Global)[2]	None listed
Current threats (Europe)[1]	None listed
Current threats (local)	• Biological resource use (hunting & collecting terrestrial animals). Threat of overexploitation and illegal poaching in some areas[7,28] • Transportation & service corridors (roads & railroads) – collision with vehicles is a major cause of mortality[7], and road development may prevent range expansion[7,30] • Invasive & other problematic species, genes & diseases (diseases of unknown cause) – chronic wasting disease has been detected in Norway[31] and Sweden[32] • Climate change and severe weather (other impacts) – changes to precipitation patterns and springtime temperatures may influence calf recruitment and survival[33]

carnivores (especially wolves[42,43]), they are a key component for forest assemblages when considering wider goals of rewilding[42,44]. Finally, Eurasian elk presence has socio-economic benefits: both for their high value as a quarry species, given the widespread cultural importance of hunting, and also for their cultural value as a charismatic native animal[45]. In Poland, there has been strong public opposition to lifting the moratorium on hunting Eurasian elk, and sightings attract visitors to National Parks[46].

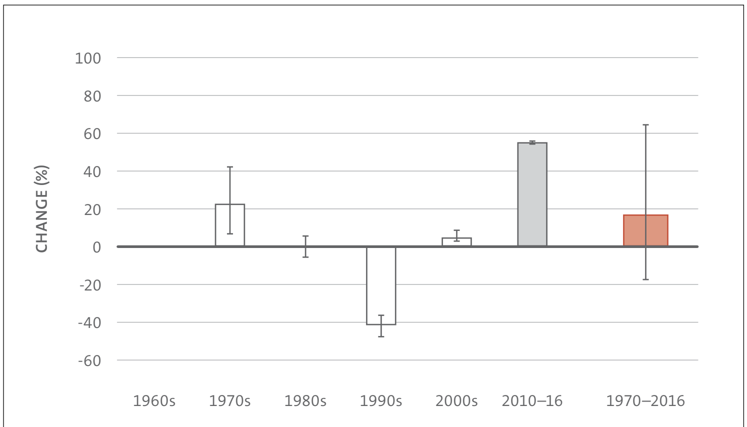


Figure 2. Average rate of change among Eurasian elk populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change between 1970 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 55 populations from across the range, representing a minimum of 609,165 individuals, or 69% of the current estimate of the European Eurasian elk population, covering 71% of all countries of occurrence. Data were missing from four countries within the species' current range, namely the Czech Republic, Moldova, Slovakia and Romania. For any given year the number of populations ranges from 3 to 54 (see Appendix 1 for details on methods and dataset).

OUTLOOK

Although Eurasian elk numbers are high and increasing in existing populations, range expansion is limited. Transport infrastructure is a significant barrier to natural recolonisation of suitable areas[7,30], with vehicle collisions a relatively common cause of mortality[7]. To overcome this, translocations may be required: 5 Eurasian elk calves were successfully introduced into the Lille Vildmose rewilding project in Denmark in 2015 and have since reproduced[47], although a similar attempt in Scotland was unsuccessful[48]. Range expansion and further recovery, especially at the Southern edges, may also be limited by the effects of climate change. Eurasian elk are thermally constrained and there is some evidence that changes to climate could influence recruitment[33,49] and increase the spread of pathogens[50].

As numbers increase, so does the potential for human-wildlife conflict caused by Eurasian elk damage to managed forestry plots and cropland[51]. Over-browsing of native forests, especially at earlier successional stages, can limit regeneration with implications for longer term ecosystem functioning[52]. In countries with high Eurasian elk numbers, controlled hunting regulates population density and alleviates conflict by incentivising landowners to retain elk (due to the local scale, bottom-up nature of hunting licenses in Fennoscandian states)[5,44]. Further opportunities arising from Eurasian elk presence include increasing interest in wildlife tourism, for example "Moose Safaris" in Scandinavia[44]. Given their occasional long distance migratory patterns, future conservation or management actions for Eurasian elk may require transboundary cooperation (primarily in central Europe where recovery is desirable[44]) to manage the potential impacts of threats such as climate change[33,53] and chronic wasting disease[31,32].

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European bison

Bison bonasus

ARTIODACTYLA | CARNIVORA | CETACEA | CHIROPTERA | RODENTIA

The European bison (*Bison bonasus*) is the largest herbivore in Europe and one of the few surviving megafauna species[9,10]. Historically a grazer, occurring in more open habitats in the Pleistocene and early Holocene, the species is currently occupying a 'refuge' habitat of predominantly forest and forest-meadow mosaic[7] which it has adapted to after a reduction of open steppe habitats and an increase in human pressure[1,11]. The European bison is considered a flagship species for the rewilding movement, and currently exists in 45 free-living, isolated subpopulations of just two genetic lines, the Lowland and Lowland-Caucasian[1,7,12,13].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
	VU			+16,626%	+399%
Forest, Grassland, Artificial/terrestrial[1]	Global: Near Threatened (2020)[1]	Global: Increasing (2020)[1]	Global: 6,819* (2020)[3]	Increasing, +16,626% (1960–2016)[4]	Increasing, +399% (1971–2010)[1,5–8]
	Europe: Vulnerable (2006)[2]	Europe: Increasing (2006)[2]	Europe: 6,819* (2020)[3]		

HISTORICAL DISTRIBUTION AND ABUNDANCE

Archaeozoological evidence suggests that the species was once widespread on the continent, reaching from France to Ukraine and up to the Northern shores of the Black Sea[1,9]. The species likely declined initially due to a changing climate[14], with deforestation and over-hunting causing further range contraction and population crashes[9,14,15]. Although later protected as royal game in Poland, Lithuania and Russia, the European distribution significantly reduced from the 15th century from west to east, retracting from over 99% of its Pleistocene distribution by 1890[8]. This process resulted in the persistence of only two populations by the early 20th century[8]. During the First World War and Russian Revolution these surviving natural populations also likely became extinct due to habitat loss, degradation and fragmentation, competition with deer species, and over-hunting[8]. An expedition to the Caucasus in 1927 did not find any sign of European bison in the wild, leaving just 54 captive individuals in existence[8,10]. The current population is descended from 12 founders[6].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Starting in 1952, several reintroductions led to European bison colonising areas in Poland, Belarus, Lithuania, the Russian Federation and Ukraine by 1971[7,12]. Between 1971 and 2020, the European bison's range increased by approximately 399% (Figure 1a)[1,5–8]. However, it should be noted that reliable monitoring was not carried out in 1971, and therefore this range map is an estimation, and the range increase calculation is approximate[7]. Between 2011 and 2020, the European bison's distribution increased by approximately 72%, likely linked to an increase in momentum of European bison reintroduction projects[1,5–8]. For example, a 2019 reintroduction project in Bulgaria means European bison are now present in the Rhodope Mountains for the first time since the Middle Ages[16]. Currently, free-living subpopulations occur in Belarus, Bulgaria, Germany, Latvia, Lithuania, Poland, Romania, the Russian Feder-

* *As well as 501 semi-free ranging and 1,791 in captive breeding projects (33 of the latter are found outside of Europe).*

ation, Slovakia and Ukraine. In total, 33 countries hold European bison in captivity, semi-free ranging or free ranging[3,7]. As of 2020, the estimated area of occupancy of the species is 13,236–22,100 km^2 [1,10].

At the same time, the average rate of change among European bison populations in the Living Planet Index (LPI) database was a 16,626% increase between 1960 and 2016 (Figure 2)[4]. Most of this positive change appears to have occurred in the 1960s and 1970s, with smaller increases in the following two decades (Figure 2)[4]. The literature quotes a doubling every 5–6 years in the 1950s and 1960s, followed by a doubling every 11–12 years subsequently[8]. In the LPI dataset, the increase in average rate of change amongst populations slowed in the 1990s, before rising in magnitude during the 2000s, and from 2010–2016[4]. The slowing of rate of change in the 1980s and 1990s was likely driven by birth rates becoming fixed in some herds at a lower level compared with the first few years after reintroduction, as well as some populations being impacted by heavy poaching[8]. It should be noted that the populations in the LPI database represent a smaller sample of the total European bison population, and that small populations influence the trend when calculated in this way. Overall, the European bison's current situation is much more favourable than prior to its extinction in the wild. Progress in the past decade, for example, has led to the species being downlisted from Vulnerable in 2008 to Near Threatened in 2020[1].

DRIVERS OF RECOVERY

The substantial increase in the European population of this species can undoubtedly be attributed to the large-scale breeding, reintroduction and translocation efforts that have taken place since its precipitous decline in the 20th century[1,8,9]. The first reintroduction took place in 1952 in the Białowieska forest, with this population first reproducing in 1957[8]. Changes in population size as well as genetic integrity are recorded in detail in the annually updated European Bison Pedigree Book (EBPB) [3,8], which provides a central resource to guide reintroduction efforts and maximise genetic diversity. In addition to targeted management, environmental conditions such as winter snow cover and May temperature have been shown to affect the European bison in Białowieska forest, with less snow and warmer temperatures resulting in higher recruitment rates[10]. The species also benefits from supplementary feeding and oak seed mast years, which provide an abundance of food[10]. Currently 91–100% of the free ranging European bison population exists in protected areas such as National Parks and Natura

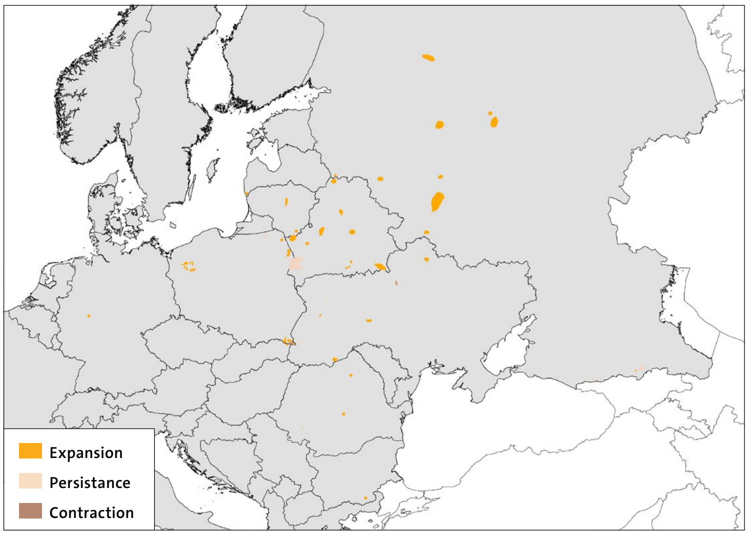

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the European bison in Europe between 1971[5–8] and 2020[1].

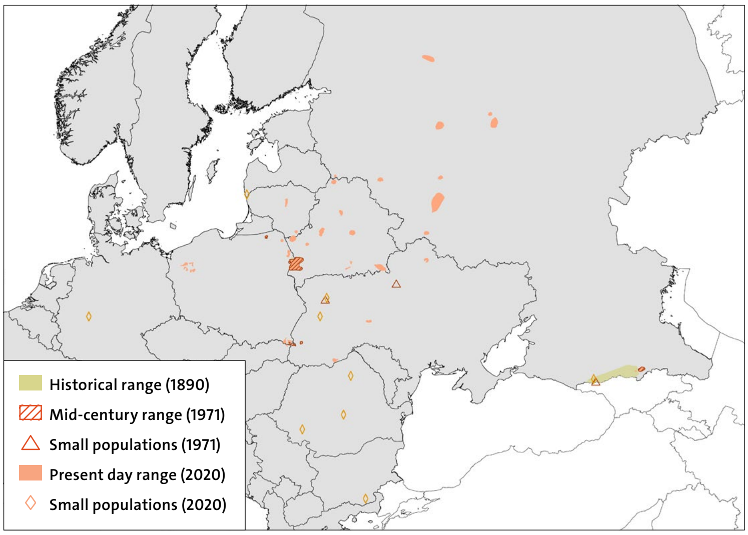

Figure 1b. Distribution of the European bison in 1890[17], 1971[3,10,22,23] and 2020[5].

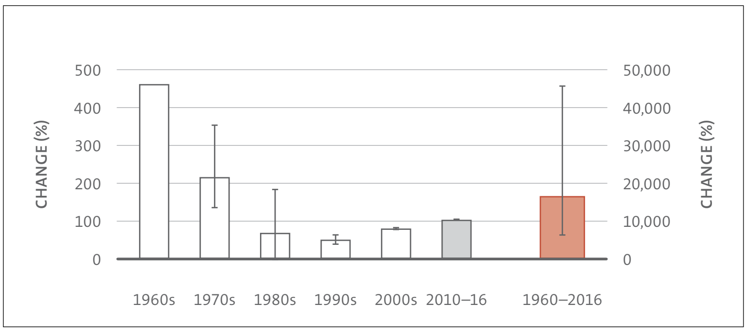

Figure 2. Average rate of change among European bison populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall change between 1960 and 2016 (coloured-in bar, secondary y-axis). Decadal change does not sum to overall change. The trend is based on 20 populations from across the range, representing a minimum of 2,107 individuals, or 31% of the total European population of 2020, covering 60% of all countries of occurrence[4]. Data were missing from four countries within the species' current range, namely Bulgaria, Germany, Latvia, and Romania. For any given year the number of populations ranges from 1 to 17 (see Appendix 1 for details on methods and dataset).

THREATS AND PROTECTION	
Legal protection	• EU Habitats Directive (Annex II and IV)[18] • Bern Convention (Appendix III)[19]
Current threats (Global)[1]	• Agriculture & aquaculture (annual and perennial non-timber crops) • Transportation & service corridors (roads and railroads) • Biological resource use (hunting & trapping terrestrial animals) • Human intrusions & disturbance (recreational activities; war, civil unrest and military exercises) • Invasive & other problematic species, genes & diseases (invasive non-native/ alien species/disease; problematic species/ disease of unknown origin)
Current threats (Europe)[2]	• Residential & commercial development (tourism & recreation areas) • Human intrusions & disturbance (recreational activities) • Invasive & other problematic species, genes & diseases (introduced genetic material)
Current threats (local)	• Agriculture & aquaculture (annual & perennial non-timber crops) – competition for space with farmlands near forests in North-eastern Poland[20] and Lithuania[7] • Invasive & other problematic species, genes & diseases (invasive non-native/ alien species/disease; problematic species/ disease of unknown origin) – e.g. tuberculosis in the Polish European bison populations[6,21]

2000 sites[1]. There are also 501 semi-free ranging individuals, kept in large enclosures in natural conditions, which are important for the species' genetic diversity[6,7].

However, while the species may indeed have a more favourable conservation status at present, the exponential recovery in abundance observed must be considered in the context of the severely depleted state of the population by 1924. Interestingly, there has also not been a concomitant clear expansion in range, with the species' distribution remaining small and fragmented despite recent reintroductions[8].

BENEFITS OF COMEBACK

The European bison plays an important ecological role and is considered a keystone species. It can contribute to the maintenance of heterogenous, partially wooded, partially open landscapes through a variety of natural behaviours, including consuming a large quantity of grasses and shrubs, stripping bark from trees, opening gaps in dense undergrowth, and creating bare soil patches by wallowing, which may be used by insects and reptiles to sunbathe and lay eggs[16,22]. Such processes also allow pioneer plant species to colonise these areas. Furthermore, European bison spread large quantities of nutrients and seeds across their range, through both their dung and general movements. Breeding birds also use the European bison's winter fur as nesting material[16].

OUTLOOK

Despite significant progress, most subpopulations remain isolated and small, with only eight subpopulations being above the minimum viable population threshold[1]. The species also continues to be threatened by low genetic variability[1]. It is therefore recommended that future conservation efforts focus on increasing subpopulation size and restoring gene flow between subpopulations by managing them as a metapopulation at the European scale. This would increase gene flow through either the spontaneous migration of European bison or increased translocation of animals amongst the wider metapopulation[23,24]. Future conservation initiatives should also continue to create suitable, heterogenous habitats. For example, using farmland that is increasingly being abandoned[1,15]. There is also a need to unify the species' legal status among European countries, to facilitate its further coordinated conservation[7]. Adaptive, evidence-based management, sensitive to local conditions, is needed to ensure an effective balance of interventionist management strategies (such as supplementary feeding or culling) with the species' natural ecology, in order to ensure European bison are restored to optimal habitats, large enough to support viable subpopulations[1,12,25].

As European bison are reintroduced, there is the potential for an increase in human-bison conflict[12]. High numbers of European bison in forested areas, for example, are causing increased damage to crops and forests which could be reducing support for their conservation amongst local communities[20,26]. On the other hand, the species can become a source of cultural pride, as demonstrated by communities in the Southern Carpathians in Romania, where European bison were reintroduced in 2014 and have since fostered a sense of ownership and appreciation amongst the local community[16]. Furthermore, European bison watching can provide new eco-tourism and nature-based business opportunities for local areas, attracting tourists and boosting local economies[16]. A European Bison Strategies Species Review, which is pending as of 2022, will serve as a basis for the revised European bison Species Action Plan which should be completed by 2023. It will aim to summarise and address the management issues mentioned above and suggest conservation priorities to ensure the continued success of future European bison conservation initiatives[26].

REVIEWED BY:

Prof Kajetan Perzanowski

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Alpine ibex

Capra ibex

ARTIODACTYLA | CARNIVORA | CETACEA | CHIROPTERA | RODENTIA

The Alpine ibex (*Capra ibex*) is a social species[1], which feeds mostly on grasses and herbs[1]. This charismatic species occurs primarily in alpine, rocky and open habitats at high altitudes (700m–3,300m above sea level)[1,5]. Steep, rocky topography is an important feature of Alpine ibex habitat, as it retreats to precipitous slopes when threatened. The species exhibits strong sexual segregation, with males and females almost living in different habitats[6]. Close to extinction in the 19th century, the recovery of the species represents one of Europe's most successful reintroduction initiatives[2].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Grassland and Rocky areas (e.g. inland cliffs, mountain peaks)[1]	Global: Least Concern (2020)[1] Europe: Least Concern (2020)[1]	Global: Stable (2020)[1] Europe: Stable (2020)[1]	Global: 53,154 (2018)[2] Europe: 53,154 (2018)[2]	Increasing, +417% (1975–2016)[3]	Increasing, +342% (1960–2020)[1,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

During the last glaciations, the Alpine ibex ranged over much of Europe including lowland areas in France, Luxembourg, Slovenia, Croatia, the Czech Republic, Slovakia, Hungary and Romania[7]. Following reforestation of low-elevation areas after the Riss glaciation, the species was restricted to the Alpine arc[2].

The species began to decline in the fifteenth century[8], due to over-hunting[8,9], which continued for 300 years[8]. Exploited for its meat and horns, but also for parts and blood, to which medicinal qualities were ascribed, the Alpine ibex was easy prey both because of its nature and the introduction of guns[10]. Legal protection of the species started in Austria in 1523, and the first reintroduction was attempted there in 1699, although neither measure was able to curb its decline[10]. As a result, the Alpine ibex came close to extinction in the early 19th century, with a single population of less than 100 individuals remaining in the Gran Paradiso Massif of the Italian Alps[8]. Protection in Italy came with a total ban on hunting in 1821, which was re-enforced in 1826[10], as well as the establishment of a protected area at Gran Paradiso. Through translocation, this remnant population forms the basis for the entire European population of the species. The first successful reintroduction in Switzerland took place in 1911[11] and since then, reintroductions have been undertaken in 175 areas in the Alps[7].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Between 1960 and 2020, the Alpine ibex's range increased by approximately 342% (Figure 1a). Following widespread reintroductions over the past 70 years, the species currently occurs in several populations in the Alpine arc[2,7]. More specifically, populations are found in Italy, Switzerland, Austria, France, Germany and Slovenia. Outside of its natural Alpine range, the species was also introduced into Bulgaria in the 1980s. As of 2020, the estimated area of occupancy of the species is 123,140 km^2[1].

The average rate of change among the Alpine ibex populations in the Living Planet Index (LPI) database was a 417% increase between 1975 and 2016 (Figure 2)[3]. The most positive rate of change on average among the populations occurred during the 1980s. However, since this time, the average rates of increase have slowed each decade. According to the LPI database, between 2010–2016 the average rate of change among the populations was negative[3]. This negative rate, however, was driven by strong declines in abundance of the two small Alpine ibex populations in Germany and Slovenia. The four much larger populations in the LPI database, in France, Italy, Switzerland and Austria, increased in abundance or remained stable during this time-period. Additional literature highlights that the global population of Alpine ibex has remained stable over the past decade[1,2]. One potential reason for the recent decline in the Slovenian population identified in the LPI database is that outbreaks of disease in the past two decades, such as sarcoptic mange, have been negatively impacting some populations[2,12]. Reasons for the recent abundance decline in the German population could not be identified[3,6,13]. For the large populations which have recently increased, it is likely that some have reached, or are close to reaching, carrying capacity, and therefore continued substantial increases are unlikely[13]. It should be noted that small populations in the LPI database, such as the Germany and Slovenia populations, can influence the trend when calculated in this way.

DRIVERS OF RECOVERY

While the historic decline of the species to one remnant population is thought to have been entirely due to over-exploitation and poaching[17], its recent recovery has been attributed to a four-stage conservation effort[8]: effective protection of the remaining population, captive breeding, reintroduction of captive-bred individuals, and translocation of animals from the reservoir populations to uninhabited sites. Of the current 178 colonies in the Alpine arc, 12% were established before 1950, 82% were founded between 1950 and 2000, and 6% were established after 2000[2]. As a result of these conservation actions, some populations, such as in Switzerland and Austria, have reached high numbers so that culling initiatives have been established by some managers to keep populations at what they perceive to be a sustainable size, thus resulting in little or no change in abundance[5]. Density-dependent regulation may also be taking place[5]. More recently, restocking and translocations have been carried out to create gene flow and increase genetic variation between the isolated populations[1].

Another possible factor influencing the change in population of the Alpine ibex is weather conditions. For example, the Gran Paradiso population is strongly affected by winter conditions, with low snow depth in mild winters in the 1980s resulting in an increase due to adult survival, and this may have also positively affected recruitment[5]. Alternatively, deeper snow is associated with a larger number of avalanches, which may bring with them a higher risk of mortality[8]. However, it is likely that animals are simply more likely to starve in deep snow due to lack of food[13].

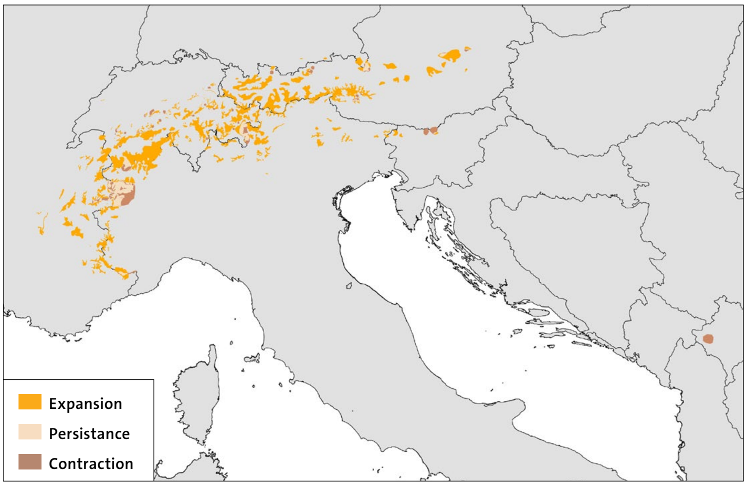

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Alpine ibex in Europe between 1960[4] and 2020[1].

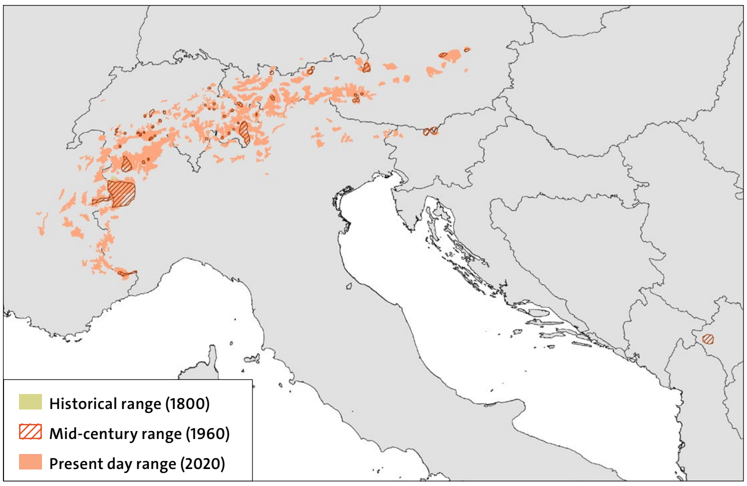

Figure 1b. Distribution of the Alpine ibex in 1800[8], 1960[4] and 2020[1].

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III)[14] • EU Habitats Directive (Annex V)[15] • The species is also nationally protected in France, Italy, Switzerland and Germany[2]
Current threats (Global)[1]	• Human intrusions & disturbance (recreational activities) • Natural system modifications (other ecosystem modifications) • Invasive and other problematic species, genes & diseases (problematic species/ disease of unknown origin) • Climate change & severe weather (habitat shifting & alteration)
Current threats (Europe)[1]	• Human intrusions & disturbance (recreational activities) • Natural system modifications (other ecosystem modifications) • Invasive and other problematic species, genes & diseases (problematic species/ disease of unknown origin) • Climate change & severe weather (habitat shifting & alteration)
Current threats (local)	• Agriculture & aquaculture (livestock farming & ranching) – e.g., encounters with domestic sheep in the Swiss Alps, leading to grazing competition and spread of disease[16] • Invasive and other problematic species, genes & diseases (problematic species/ disease of unknown origin; viral/ prion-induced diseases) – e.g. sarcoptic mange in the eastern Alps and respiratory diseases in Vanoise National Park, France[2,12]

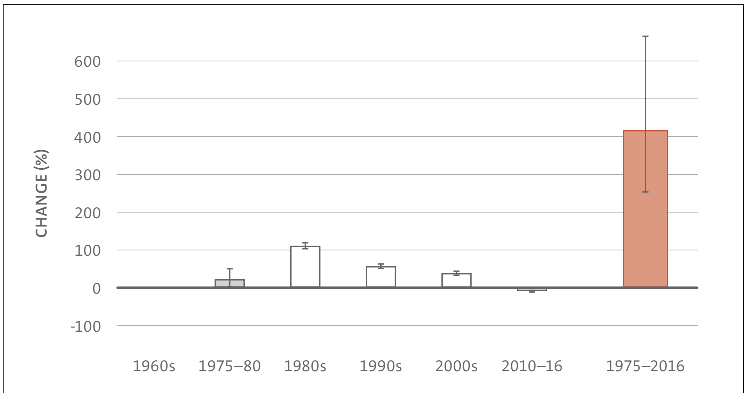

Figure 2. Average rate of change among Alpine ibex populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1975 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 6 populations from across the range, representing a minimum of 38,426 individuals, or 72% of the total European population of 2020, covering 86% of all countries of occurrence. Data was missing from one country within the species' current range, namely Bulgaria, where the species is introduced. For any given year the number of populations ranges from 3 to 6 (see Appendix 1 for details on methods and dataset)[3].

BENEFITS OF COMEBACK

The charismatic Alpine ibex has significant cultural importance, appearing on a wide range of symbols across the European Alps and attracting tourists to the area[6,13,18]. It is also considered a flagship species for conservation actions in the area[18]. As a grazer, the Alpine ibex contributes to the maintenance of alpine grasslands[19]. Where abundant, Alpine ibex provide a food source for alpine predators and scavengers, with their presence facilitating the reintroduction of threatened species, such as wolves (*Canis lupus*) and the bearded vulture (*Gypaetus barbatus*) in the Western Alps[13,20].

OUTLOOK

As the Alpine ibex has a wide distribution and a large and relatively stable population, it is classified as Least Concern on the IUCN Red List[1]. The species' recovery since its near extinction is considered one of the most successful conservation efforts in Europe[2]. However, most populations remain relatively isolated, as the species' distribution is fragmented by glaciers, forests, roads, railways and urban areas[7]. The species also has a low colonising potential, meaning spontaneous recolonisation of new areas is rare and gene flow is likely restricted[1,2]. Considering this, as well as the fact that the species has experienced extreme genetic bottlenecks following near extinctions in the past, the Alpine ibex has very low genetic diversity and high levels of inbreeding[1]. Furthermore, high densities of the species have been linked to a rise in disease[12]. Therefore, to prevent future declines, it has been recommended that individuals are translocated between populations to promote gene flow, and populations should be established between existing populations to increase connectivity[1,7]. Furthermore, a reduction in domestic sheep (*Ovis aries*) and cattle (*Bos taurus*) grazing in locations where the Alpine ibex is to be reintroduced would help to minimise the risk of interspecific disease transmission[1,7].

Where Alpine ibex and domestic sheep and cattle do occur in the same area, encounters are not uncommon. Such encounters are thought to increase the transmission of interspecific diseases, which could increasingly negatively impact the livelihoods of sheep and cattle farmers in the Alps in the future[16]. A recent outbreak of brucellosis in France, for example, led to a cull of the local Alpine ibex population, as the disease could spread to domestic animals and even humans[21]. However, as a symbolic species of the Alps, Alpine ibex also attract nature-based tourists, and in Switzerland, hunters[22,23]. Although the latter is highly regulated, both can boost local economies by increasing the number of visitors to the area. The species continues to be a great media focus. In 2011, Switzerland celebrated the centenary of the reintroduction of the species into the Weißtannen Valley using descendants of individuals that had been stolen from the King of Italy and smuggled over the Swiss border[24]. This celebration was marked by a range of events, as well as the release of more individuals into the reserve[25]. Such events demonstrate the important that place Alpine ibex continue to hold in local culture.

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Iberian Wild Goat

Capra pyrenaica

The Iberian wild goat (also referred to as the Iberian ibex[2]) is an ungulate endemic to the Iberian Peninsula, well-adapted to steep, rocky areas, where competition and risk of predation is reduced[1,3]. Overexploitation and habitat loss led to the extinction of two of the four previously recognised subspecies[4,5], but remaining populations are recovering in range size and abundance[1].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest and Shrubland[1]	Global: Least Concern (2020)[1] Europe: Least Concern (2020)[1]	Global: Increasing (2020)[1] Europe: Increasing (2020)[1]	Global: ~100,000 (2020)[1] Europe: ~100,000 (2020)[1]	Increasing, +3,502% (1966–2012)[34]	N/A*

HISTORICAL DISTRIBUTION AND ABUNDANCE

While the evolutionary origins of this species are unresolved, current consensus suggests *C. pyrenaica* was widespread across the mountainous regions of the Iberian Peninsula by the late Pleistocene, having already diverged from the closely related Alpine ibex (*Capra ibex*)[4–6]. The Iberian wild goat likely retained this broad distribution until the early 1800s, when a period of intense hunting pressure (compounded by habitat reductions resulting from agricultural expansion) contributed to a precipitous decline in numbers[1,4]. According to taxonomic definitions of the time, there were four distinct subspecies of *C. pyrenaica* in the early 19th century (although genetic evidence now raises questions regarding subspecific classification[6–9]). These included *C. p. pyrenaica*, found in the Pyrenees[10], *C. p. hispanica*, found in more eastern and southern Mediterranean Spanish mountain ranges, and *C. p. victoriae*, found in the central regions of the Iberian Peninsula[11]. The fourth subspecies, *C. p. lusitanica* was found in the mountainous region of northern Portugal and across the Spanish border in southern Galicia, but was considered rare[5] and declined severely through the 19th century for the same general reasons as above. It became restricted to a small area in the northwest of the country and eventually became extinct, with the last record occurring in 1890[12]. Even with the establishment of the first reserves in 1905[13,14] and 1918, by the mid-1900s, the species was increasingly restricted in both range and abundance[4].

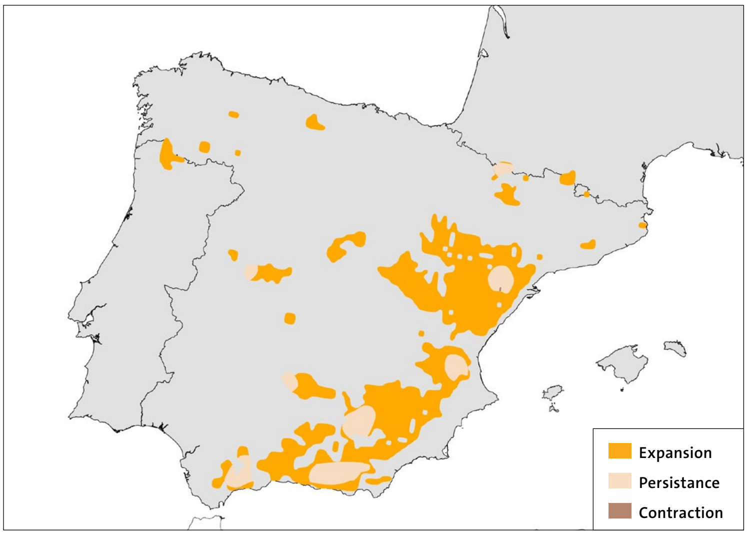

Figure 1a. Map highlighting areas of range expansion, persistence, and contraction of the Iberian wild goat in Europe between 1955[17,18] and 2020[1]. Range shown in 1955 is approximated as little field surveying of this species occurred at this time.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Unfortunately, the Pyrenean population of Iberian wild goat, classified at the time as *C. p. pyrenaica*, became extinct in 2000 despite conservation efforts[15]. This has been attributed to multiple factors, primarily overhunting, and habitat deterioration[4,15,16], but competition with Southern chamois (*Rupicapra pyrenaica pyrenaica*), parasite infections from domestic livestock, climatic conditions, poaching, low fertility and resulting inbreeding depression may also have contributed[14,16]. However, for populations of the

* *Percentage change in area not calculated due to poor resolution of mid-century map.*

two extant subspecies, conservation actions since the 1970s have been successful, leading to an increase in both abundance and distribution. While the range shown in Figure 1 for 1955 is an approximation and may represent a larger area than was occupied, locations of remnant populations at this time are generally accurate[17,18]. Subsequent expansion shown is also accurate, reflecting both natural expansion and the impact of translocations that have occurred (and escapes, in the case of the Portuguese/Galician population[5,11,12]). The surviving populations have experienced notable increases in abundance, reflected in monitored populations listed in the Living Planet Index database, with an average rate of increase of 3,502% between 1966 and 2012 (Figure 2). Similarly, the literature suggests that the species increased from 5,000 individuals in the 1960s to 50,000 by the end of the 20th century[4,14], with further increases occurring in recent decades to give the current estimate of over 100,000 individuals[1].

DRIVERS OF RECOVERY

Recovery in this species has been driven by a range of factors. Natural range expansion has occurred as a result of reduced hunting pressure, lack of large predators[22], and increased habitat availability (due to the abandonment of rural areas and decreased grazing pressure from domestic livestock)[1], as well as population rebounds from past disease, particularly sarcoptic mange (*Sarcoptes scabiei*)[21,23]. Recovery and expansion has also been facilitated by human intervention, in the form of hunting legislation, the establishment of Game Reserves and other protected areas[24], and targeted translocations. Translocations of this species have been occurring within Spain since the 1980s and 1990s[4,23], and more recently (since 2014) into the French Pyrenees[25]. Not all these reintroductions have been intentional, as the recolonisation of areas of Portugal by escapes from an enclosure in Galicia demonstrates[12].

BENEFITS OF COMEBACK

As mixed browsers and grazers, Iberian wild goats can influence vegetation dynamics and are therefore important components of native Iberian ecosystems[5]. Browsing pressure can increase suitable habitat for small herbivores such as wild rabbits (*Oryctolagus cuniculus*), which are

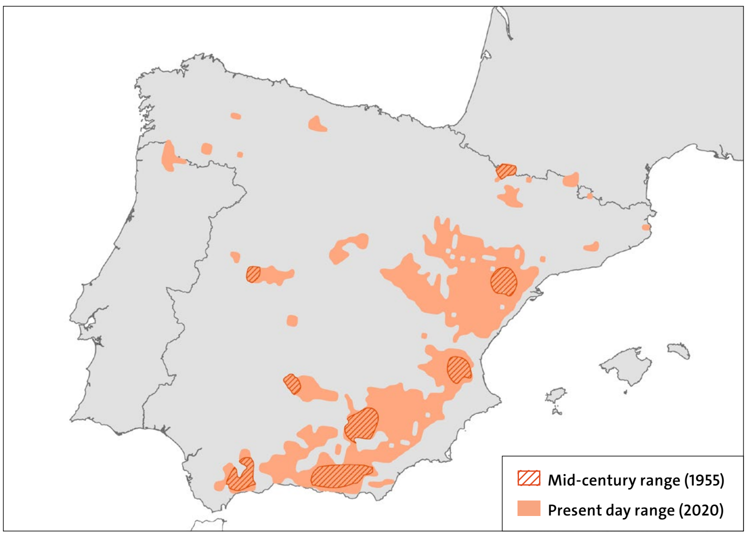

Figure 1b. Distribution of the Iberian wild goat in 1955[17,18] and 2020[1]. Note that a historical map prior to 1950 could not be constructed for this species due to lack of information.

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III) [19] • EU Habitats Directive (Annex V) [20] • Protected in France and Portugal to prevent hunting, but huntable in Spain • Subspecies *C. p. victoriae* is listed as Critically Endangered in the Portuguese Red Data Book [12]
Current threats (Global IUCN Red List)	N/A
Current threats (European IUCN Red List) [1]	• Agriculture and aquaculture (annual and perennial non-timber crops; wood and pulp plantations; livestock farming and ranching) • Human intrusions & disturbance (recreational activities) • Invasive and other problematic species, genes & diseases (invasive non-native/alien species/diseases)
Current threats (local)	• Invasive and other problematic species, genes & diseases (invasive non-native/alien species/diseases) – competition with other sympatric ungulates e.g. feral goats (*Capra aegagrus hircus*), introduced mouflon (*Ovis gmelini aries*) and aoudad (*Ammotragus lervia*) [5]; potential for further outbreaks of disease especially sarcoptic mange (*Sarcoptes scabiei*) [21] • Biological resource use (hunting and collecting terrestrial animals) – poaching of individuals has been reported [11]

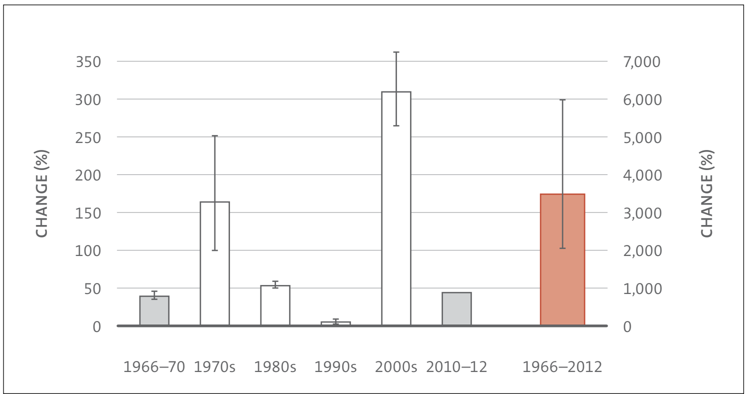

Figure 2. Average rate of change among Iberian wild goat populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall rate of change among populations between 1966 and 2012 (coloured-in bar, secondary y-axis). Note that overall change should be read from the secondary axis on the right-hand side of the graph. Decadal change does not sum to overall change. The trend is based on 9 populations from across the range, representing a minimum of 12,531 individuals, or 13% of the total European population of 2020, covering all countries of occurrence. For any given year the number of populations ranges from 1 to 7 (see Appendix 1 for details on methods and dataset).

the main prey of endemic carnivores such as the Iberian lynx (*Lynx pardinus*) and Iberian imperial eagle (*Aquila adalberti*) [26]. The wild goat itself, and especially its kids, can also act as prey for other ecologically important species like the Grey wolf (*Canis lupus*) and Golden eagle (*Aquila chrysaetos*), although these are not currently found across most of the species' range [5]. The charismatic and culturally emblematic Iberian wild goat can be a successful flagship species and attract visitors to National Parks and reserves [27,28]. Finally, the species is valued as a hunting trophy, with approximately 15,000 individuals now hunted annually [18]. It is therefore an important source of income for rural communities, both from hunting and ecotourism opportunities [5,11].

OUTLOOK

The Iberian wild goat has achieved an impressive recovery over the past 45 years, and its population continues to increase [1]. Habitat modelling suggests there is additional potential for future expansion given the availability of currently unoccupied but environmentally suitable areas [3,29]. Further reintroductions have also been planned to establish populations across Iberia, often as part of larger landscape or habitat conservation programmes [30]. While previously, the subspecies used for translocation was viewed as an important consideration, more recent genetic studies suggest similar levels of genetic differentiation between geographically isolated populations of the same subspecies, and therefore the subspecies distinction is no longer as relevant [8,9].

While the recovery of the Iberian wild goat has ecological benefits, in some areas densities are reaching unsustainable levels, either due to natural population increase in favourable conditions, or lack of dispersal from locations of reintroduction [31]. This overabundance can lead to detrimental effects, such as overbrowsing and overgrazing on threatened plant species [32], increased erosion [33] and its presence can lead to human-wildlife conflict in agricultural areas where Iberian wild goats feed on cereal crops, almond trees (*Prunus dulcis*) and olive trees (*Olea europea*) [5]. To counteract this, culls or increased hunting quotas have been put in place [5,32]. In addition, Iberian wild goat populations may be a source of pathogens or parasites which spill over into domestic ungulates, or vice-versa, so wildlife health surveillance is an important future management consideration [5].

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WESTERN ROE DEER

ARTIODACTYLA | CARNIVORA | CETACEA | CHIROPTERA | RODENTIA

Capreolus capreolus

The Western roe deer (*Capreolus capreolus*) is the most abundant wild ungulate in Europe[7], with a near continuous distribution from the west of the continent to European Russia and the Caucasus[1]. Western roe deer occur in a wide variety of habitats[8], although densities are highest in woodland-field mixtures or woodland with clearings[4], because these provide both food and cover in close proximity[9]. It is considered one of the best-adapted species for cultivated land[10,11]. As an opportunistic and flexible but also selective herbivorous feeder[12], the species' diet varies considerably with season and habitat[8].

	LC			+287%	+29%
HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest, Shrubland, Grassland, Artificial/ Terrestrial[1]	Global: Least Concern (2015)[1] Europe: Least Concern (2006)[2]	Global: Increasing (2015)[1] Europe: Increasing (2006)[2]	Global: 15,000,000 (2015)[1] Europe: 15,000,000 (2006)[2]	Increasing, +287% (1966–2016)[3]	Increasing, +29% (1955–2016)[1,4–6]

HISTORICAL DISTRIBUTION AND ABUNDANCE

First recorded from the Middle Pleistocene about 600,000 years ago, the species was present on most of the European continent during interglacial and mild glacial periods[13]. During the Last Glacial Maximum, however, it was forced into refugia in the Mediterranean and southeastern Europe[13], one of which provided the individuals for recolonisation of western, central and northern Europe around 9,600 years ago[13]. The Western roe deer was abundant throughout Europe and parts of Western Asia historically[10], but declined in abundance and range between the 17th and early 20th century[11], mainly due to over-harvesting[12] and habitat loss, which led to near extinction in parts of southern Europe[1]. In some regions, declines occurred even earlier, such as during the Middle Ages in Great Britain[14], similarly as a result of habitat loss and hunting pressure. Management interventions started the recovery of the species during the 1800s, which accelerated in the subsequent century, particularly after 1945[6,15].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

During the second half of the 20th century, European populations of Western roe deer increased and stabilised in western and central Europe[10], while little distributional change occurred in other parts of eastern central Europe, e.g. in Poland and the Czech Republic[16,17]. Between 1955 and 2016 the species' range increased by approximately 29% (Figure 1a). The Western roe deer is now present across all of mainland Europe, although its distribution is patchier in the far south, e.g. in Italy, Spain and Portugal. While it occurs in most of Great Britain, it is absent from the other large islands of Europe[18].

The average rate of change among the Western roe deer populations in the Living Planet Index (LPI) database was a 287% increase between 1966 and 2016 (Figure 2)[3]. This positive rate of change has fluctuated over the decades, with the rate peaking in the 2000s. However, Western roe deer abundance seems to have stabilised between 2010 and 2016[3]. It should be noted that the populations in the LPI database represent a smaller sample of the total species population, and that small populations influence the trend when calculated in this way.

DRIVERS OF RECOVERY

Initially, legal protection[4], reduced exploitation[4,23] and reintroductions and translocations played an important role in the recovery of the Western roe deer across Europe. This was particularly true in Italy[4], where most of the current southern populations are the result of such management intervention[24], and also applied in England[4,14], and Portugal[21]. Supplementary feeding has also been used where the species is exposed to harsh seasonal conditions, such as in Scandinavia and Spain[6,25]. Increasingly connected populations and local recoveries also led to natural recolonisation, for example in Norway[4] and Finland[4]. A reduction in hunting pressure (e.g. France, Germany, Switzerland and Sweden[4,23]), lower competition and low levels of predation have also been beneficial[4,26].

Most importantly, however, sudden expansion into open agricultural landscapes since the 1960s has been implicated in the recovery of the species over the past 60 years[17,24,27,28]. While one reason for this habitat shift is undoubtedly the Western roe deer's great ecological flexibility, land use changes (such as the planting of more crops in the autumn, meaning increased winter food provision and reduced winter mortality) have also played a role[15,23,26,29]. In addition, the depopulation of rural areas has reduced the level of disturbance and hunting pressure, whilst the expansion of forests and scrubland, and the cessation of extensive grazing in upland areas, have further boosted local Western roe deer populations[15].

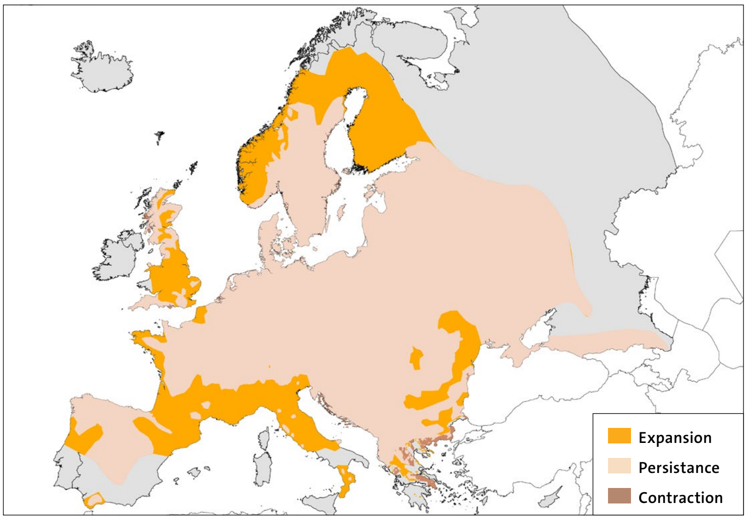

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Western roe deer in Europe between 1955[4–6] and 2016[1].

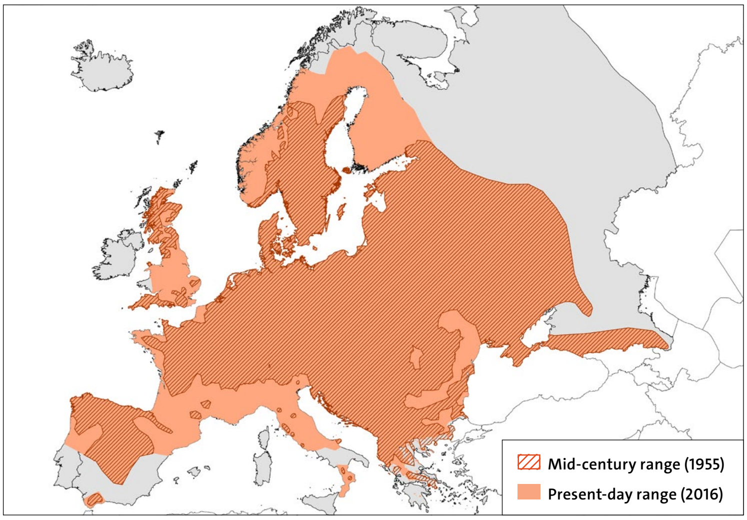

Figure 1b. Distribution of the Western roe deer in 1955[4–6] and 2016[1]. An accurate historical map prior to 1950 was not available for this species[6].

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III)[19]
Current threats (Global)[1]	• Agriculture & aquaculture (livestock farming & ranching) • Biological resource use (hunting & trapping terrestrial animals) • Invasive and other problematic species, genes & diseases (invasive non-native/ alien species/ diseases; Introduced genetic material)
Current threats (Europe)[2]	• Invasive and other problematic species, genes & diseases (invasive non-native/ alien species/ diseases; Introduced genetic material)
Current threats (local)	• Invasive and other problematic species, genes & diseases (problematic native species/ diseases; introduced genetic material) – e.g. *C. c. italicus* threatened by hybridisation with *C. c. capreolus* in Italy[20]. Also, predation by dogs threatens several populations in the Mediterranean[6,15,21]. • Transportation & service corridors (roads & railroads) – e.g. in Portugal, as the road network increases in extent, so do vehicle collisions with Western roe deer[21,22]

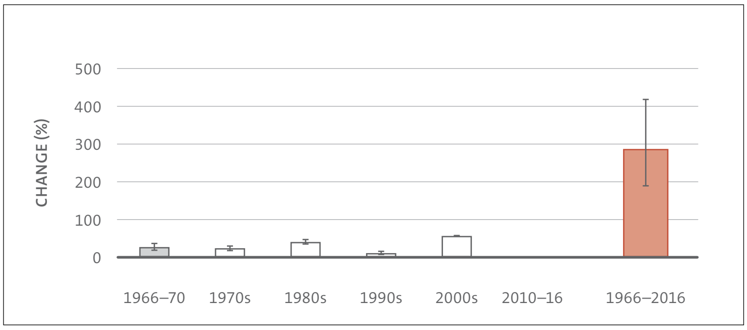

Figure 2. Average rate of change among Western roe deer populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1966 and 2016 (coloured-in bar). The percentage change for 2010–16 is 0.29% and not visible on the chart. Decadal change does not sum to overall change. The trend is based on 59 populations from across the range, representing a minimum of 790,183 individuals, or 5% of the total European population of 2016, covering 39% of all countries of occurrence. Data were missing from 25 countries within the species' current range (namely: Albania, Andorra, Austria, Belgium, Bosnia and Herzegovina, Croatia, Denmark, Estonia, Finland, Germany, Gibraltar, Greece, Liechtenstein, Luxembourg, Macedonia, Moldova, Monaco, Montenegro, Norway, Portugal, Romania, San Marino, Serbia, Slovenia and Spain). For any given year the number of populations ranges from 2 to 49 (see Appendix 1 for details on methods and dataset)[3].

BENEFITS OF COMEBACK

Western roe deer are considered a keystone species, as their herbivorous feeding behaviour can lead to shifts in the composition of forest species[30]. As bulk feeders, they also disperse significant amounts of seeds of a wide variety of species[29]. Furthermore, as they are widespread and abundant, the species represents a key food source for species throughout Europe, with their presence facilitating the reintroduction of rare or threatened carnivores. The Iberian wolf (*Canis lupus signatus*), for example, is currently being reintroduced into Portugal, following the successful reintroduction of Western roe deer to increase prey availability[31]. Wolves typically prefer to feed on wild ungulates rather than livestock, and so the presence of Western roe deer can reduce human-wolf conflict[31].

OUTLOOK

As the Western roe deer is a widespread species with a large population, it is classified as Least Concern by the IUCN[1]. The species can tolerate relatively high levels of hunting pressure, where adequate hunting regimes are in place[1]. Climate change may also facilitate the further expansion of the species in some countries, to northern latitudes and higher elevations[15]. However, in future, Western roe deer numbers may be impacted by the recovery of large predators across Europe and as competition with Red deer (*Cervus elaphus*) intensifies[21]. These issues are unlikely to affect the species as a whole, but could be significant at a local level, and should be taken into account when managing rewilding areas[32]. For example, for Mediterranean populations of Western roe deer, it is currently important to control poaching and the occurrence of feral dogs (*Canis lupus familiaris*), which have been known to predate the species[6]. It should also be noted that the Italian subspecies, *C. c. italicus*, is considered rare, being confined to just a few residual areas of its historic distribution and threatened by hybridisation with *C. c. capreolus* and competition with Common fallow deer (*Dama dama*)[33]. Similar genetically distinct populations also occur in Portugal and Greece[1]. To protect these remnant populations, it has been recommended that their expansion should be facilitated through habitat improvements and further reintroduction programmes[20]. All translocations of Western roe deer should consider the genetic integrity of the source and destination populations[1].

The growth of transportation infrastructure, combined with increasing Western roe deer abundance, has meant that vehicle collisions with the species are frequent, with just over 360,000 incidents a year in Europe[22]. As a flexible herbivore, which has spread throughout forests and arable land, the species can also cause damage to tree saplings and crops, creating potential conflict with landowners[22]. They may also aid the spread of transmissible diseases, such as Bovine Tuberculosis (*Mycobacterium bovis*), which is problematic for both Western roe deer and livestock, and are a host for ticks, which can increase the transmission of Lyme disease (*Borrelia burgdorferi*)[15,29]. Nevertheless, the species is also considered one of Europe's most important game species, with just over 3,000,000 individuals harvested per year. By providing hunting opportunities, it can therefore boost local tourism and economies[22].

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Red deer

Cervus elaphus

ARTIODACTYLA | CARNIVORA | CETACEA | CHIROPTERA | RODENTIA

The Red deer (*Cervus elaphus*) is one of the most widely distributed cervids in Europe, with fragmented populations spanning most of the continent, aside from the far North[1]. The Red deer is a popular and historically important game species, and therefore human intervention has had a significant influence on its phylogeography and distribution[8].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
	LC			+331%	+211%
Forest, Shrubland, Grassland[1]	Global: Least Concern (2015)[1] Europe: N/A	Global: Increasing (2015)[1] Europe: N/A	Global: 2.5 million (2021)[2] Europe: 2.44 million*[3]	Increasing, +331% (1960–2016)[4]	Increasing, +211% (1955–2018)[1,5–7]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The species appeared in Europe around 900,000 years ago[9] and was able to persist in southern Europe and east of the Carpathians during the Last Glacial Maximum[10,11]. As the climate warmed, the Red deer then expanded out of these refugia, and the genetic clades present today can be traced back to this recolonisation event[11–13]. Across most of its native range, Red deer populations declined significantly between the 16th and 19th centuries, and in some places even earlier[3,14], mainly as a result of overhunting, forest loss and competition with domestic livestock[3,15]. Native populations disappeared completely in the Baltic states, Switzerland, Slovenia and Macedonia, while near extinctions occurred in Portugal and Italy[3]. In most other locations, the species became confined to remote forest or mountain areas[3]. In northern Europe, the species' numbers and range began to recover in the 19th century as interest in deer hunting increased, and going into the 20th century translocations and reintroductions became increasingly popular, e.g. into deer parks in England[16] and Norway[17].

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RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

According to available range information, the Red deer has expanded its area of occurrence significantly since 1955, spreading out from refuges or reintroduced populations (Figure 1). For example, in France, the range has expanded from just a few pockets in the north in the 1950s, to now inhabiting nearly all forest tracts across the country after numerous reintroductions[18,19]. More generally however, the expansion shown in Figure 1 is likely an exaggeration resulting from the difference in resolution between the two maps, as the current range shown does not reflect the fragmented nature of many populations and is therefore an overestimate for most countries. In addition, despite the overall positive developments, there has also been some contraction at a sub-regional level, most notably in Greece, where only the population located on Parnitha Mountain remains[20].

* *Based on estimates between 2005 and 2009, excludes Belarus, Bulgaria and Ukraine.*

In terms of abundance, the Red deer has also undergone increases since 1960 – among the monitored populations in the Living Planet Index database, the average rate of change has been an increase of 331% between 1960 and 2016 (Figure 2) [4]. The most notable average increases occurred earlier on in the time period, with an increase of 125% between 1960 and 1970, followed by smaller increases in the 1970s and 1980s. This is supported by literature estimates of trends in central Europe, e.g. Hungary [21], whereas in Mediterranean countries like Italy, population increases occurred slightly later [22]. The 1990s and 2000s were a period of apparent slight decline, which has been linked in some states of eastern Europe to periods of political instability, resulting in greater hunting and poaching pressure [23,24]. Most recently, the trend has been one of continuing recovery, with monitored populations increasing between 2010 and 2016.

DRIVERS OF RECOVERY

In areas where Red deer had previously been exterminated, natural recolonisation [3,32] reintroductions [3,33,34] and farm escapes (e.g. Denmark [3]) are considered to have been the main reasons for the re-establishment of populations. Other contributing factors include improved hunting regulations and protections, improvement of habitat quality and area (Red deer are well suited to fragmented agricultural landscapes with crop fields or meadows providing grazing, interspersed with forested areas providing browse and concealment) [3,32,35]. Rural land abandonment, leading to reforestation, has therefore been beneficial, e.g. in Switzerland, northern Italy and Slovenia, with the reduction of predators and livestock competitors also playing a role [32]. In some areas, however, populations have not yet returned to their former extent, either due to population management for the purposes of reducing forestry damage, or confinement of the species to specific areas by law [3].

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III) [26] • Subspecies *C. e. corsicanus*: Bern Convention (Appendix II) [26]; EU Habitats Directive (Annexes II and IV) [27]
Current threats (Global IUCN Red List) [1]	• Residential and commercial development (housing and urban areas) • Agriculture and aquaculture (annual and perennial non-timber crops; Livestock farming and ranching) • Energy production and mining (mining and quarrying) • Transportation and service corridors (roads and railroads) • Biological resource use (logging and wood harvesting) • Human intrusions and disturbance (work and other activities) • Invasive and problematic species, genes and diseases (invasive non-native/alien species/diseases)
Current threats (European IUCN Red List)	N/A
Current threats (local)	• Invasive and other problematic species, genes and diseases (introduced genetic material) – hybridisation with non-native Sika deer (*Cervus nippon*): in Scotland hybrid frequency can be up to 56% [28]; mixing of distinct subspecies through interbreeding of farm-reared and natural populations [11] • Invasive and other problematic species, genes and diseases (invasive non-native/alien species/diseases) – Mediterranean populations generally are affected by predation of feral dogs (*Canis familiaris*) [29] • Natural system modification (fire and fire suppression) – the population on Parnitha mountain is at risk of habitat loss through fire [30] • Biological resource use (hunting and collecting terrestrial animals) – small, isolated populations threatened by poaching in some places e.g. Parnitha mountain in Greece [30], *C. e. corsicanus ssp.* [31]

BENEFITS OF COMEBACK

From a wildlife conservation perspective, the increase in Red deer and other ungulates has facilitated the comeback of top-level predators in Europe [36] The role of Red deer in both maintaining open vegetation areas and as a food resource for predators and scavengers means that they can be a key component of broader rewilding schemes: in the Rhodope Mountain rewilding project, reintroduction of ungulates like Red deer is providing an important prey base for Cinereous (*Aegypius monachus*) and Griffon vultures (*Gyps fulvus*) [37]. In addition, Red deer are an important resource and popular hunting target for humans, due to their large size and the desirability of antlers for trophies, with total harvest for Europe estimated as at least 730,000 individuals in 2017 [38]. Aside from their value as a game species, Red deer presence can also be a significant attraction in terms of tourism, especially during the rutting season [39].

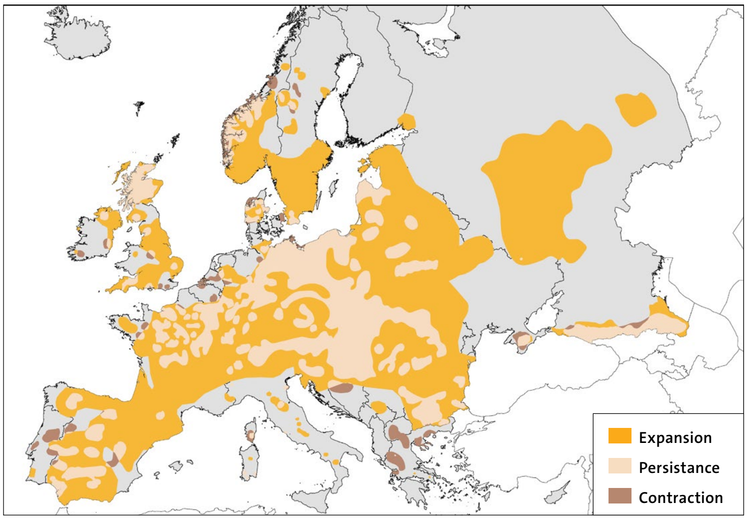

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Red deer in Europe between 1955 [5,6] and 2018 [1,2,7,25]. Note that the current range, and therefore area of expansion, is likely an overestimate due to differences in mapping approach.

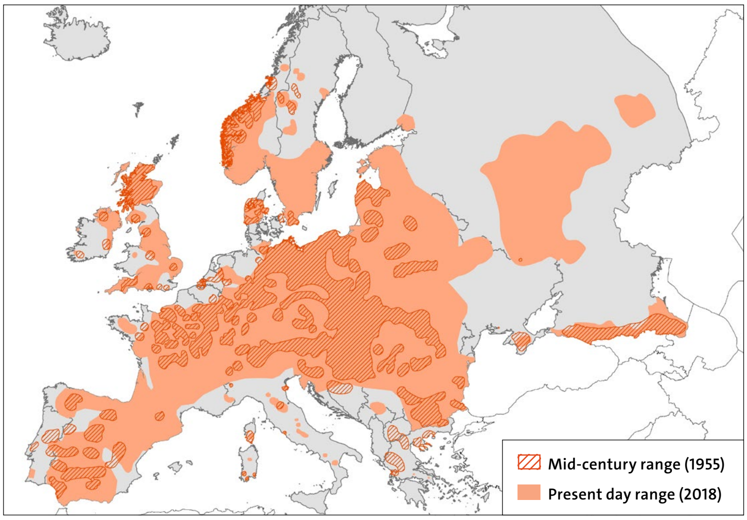

Figure 1b. Distribution of the Red deer in 1955 [5,6] and 2018 [1,2,7,25]. Note that a map could not be constructed for a historical distribution prior to 1950 due to lack of information.

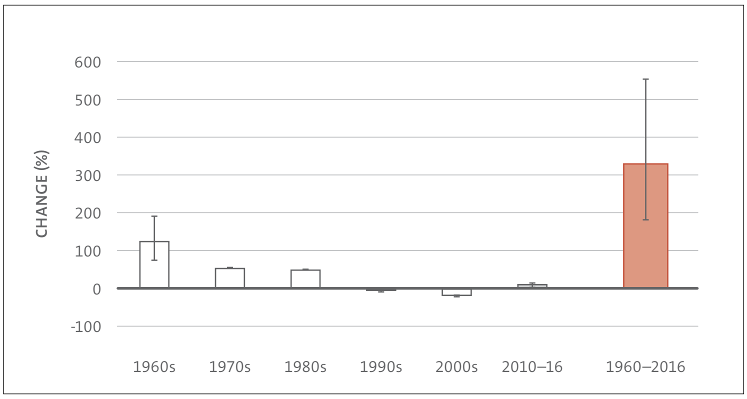

Figure 2. Average rate of change among Red deer populations by decade abundance (hollow bars, grey fill represents incomplete decade) and overall change among populations between 1960 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 63 populations from across the range, representing a minimum of 246,493 individuals, or 11% of the total European population of 2009, covering 64% of all countries of occurrence. Abundance data was available for 21 countries within the range, and missing for 14 (data unavailable for Austria, Belarus, Bosnia and Herzegovina, Denmark, Germany, Greece, Ireland, Luxembourg, Macedonia, Moldova, Montenegro, Portugal, Serbia and Sweden). For any given year the number of populations ranges from 5 to 60 (see Appendix 1 for details on methods and dataset).

OUTLOOK

The IUCN Red List lists the Red deer as Least Concern globally as it is widespread, abundant, and has an increasing population trend overall [1]. However, there are individual isolated and phylogenetically important populations facing unique threats, which may present opportunities for further recovery through conservation intervention. The subspecies *C. e. corsicanus* is separately protected in Annexes II and IV of the EU Habitats Directive, and has been listed as Endangered in the past, but has been downlisted to Least Concern [40] as a result of population recovery through a targeted management programme [31]. This success could be replicated for other threatened populations, such as the Mesola population in mainland Italy [41] and the Parnitha Mountain population in Greece, which is listed as Critically Endangered in the Red Data Book of Threatened Species in Greece [30] due to risk from intentional fires and illegal hunting [20].

While larger populations of Red deer found elsewhere in Europe do not require targeted actions for recovery, other management may be required. Lack of natural predators due to low numbers (or absence) of large carnivores, and interventions by game managers to increase deer numbers for hunting can lead to areas where Red deer densities are too high [42,43]. This can cause ecological damage, as overbrowsing of young trees can prevent the natural regeneration of woodland and influence forest ecosystem structure. Overabundance of Red deer can also increase the prevalence of pathogens which may spill over to other wild or domestic ungulates [44–46]. To deal with these issues, yearly culls are required to limit deer density in many European countries, e.g. Scotland [46] and Hungary [47]. On the Iberian Peninsula, a combination of deer overabundance and urban expansion has led to human-deer conflict as deer damage vegetation in urban green spaces, gardens, and golf courses [48]. Management in these scenarios is more complex as most common methods (e.g. hunting and deer fencing) can be harder to implement in urban areas [48]. Therefore, understanding the dynamics of ungulates in urban, semi-urban and surrounding spaces may be a key area of consideration if Red deer populations continue to increase.

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SOUTHERN CHAMOIS

Rupicapra pyrenaica

The Southern chamois (*Rupicapra pyrenaica*) is a mountain ungulate which occurs as three subspecies in southwestern Europe[1]. As a result of past uncontrolled hunting and competition with livestock, these subspecies survive in fragmented populations limited to the Cantabrian Mountains of northern Spain (Cantabrian chamois – subspecies *R. p. parva*); the Pyrenees in France, Spain and Andorra (Pyrenean chamois – subspecies *R. p. pyrenaica*); and five locations in the central Apennine Mountains in Italy (Apennine chamois – subspecies *R. p. ornata*)[1].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
	LC			+1,549%	
Forests, Shrubland, Grassland[1]	Global: Least Concern (2020)[1] Europe: Least Concern (2020)[1]	Global: Increasing (2020)[1] Europe: Increasing (2020)[1]	Global: 72,900* Europe: 72,900*	Increasing, +1,549% (1970–2014)[4]	Increasing** (1950s[3,5,6]–2020[1])

HISTORICAL DISTRIBUTION AND ABUNDANCE

An ancestor of our modern chamois species, *Procamptoceras brivatense*, existed in the Balkans in the early Pleistocene, before Southern chamois appeared suddenly during the last glaciations in central Europe[7–9]. The Southern (*R. pyrenaica*) and Northern (*R. rupicapra*) chamois species were likely already differentiated at this time, with the Southern chamois found throughout the Iberian Peninsula and across to the Apennine Mountains[9,10]. Over the last 10,000 years, further adaptation to a mountainous environment, in addition to the impacts of climate warming and hunting pressure, reduced its presence to the higher altitudes to which it is restricted today[11]. In the Holocene, the Apennine chamois (*R. p. ornata*) was found throughout the central and southern Apennine Mountains, but its range was then reduced to just the Abruzzo region, where a small population (as low as c. 30 individuals during the interwar period) survived in what is now the Abruzzo, Lazio and Molise National Park (PNALM)[12]. Similarly, the Cantabrian chamois (*R. p. parva)* was widespread throughout the Cantabrian Mountains during the 19th century, but later declined due to the expansion of agriculture and overhunting, so that by the first half of the 20th century it was restricted to the eastern end of its previous range[3,13].

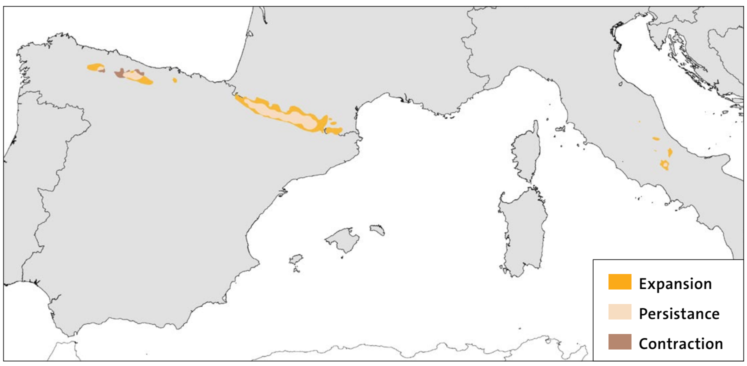

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Southern -chamois in Europe between the 1950s[3,5,6] and 2020[1]. Note that contraction is implied in the Cantabrian region, but this is an artefact of differences in map resolution and does not reflect a true contraction of range in this area.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Since the nadir of this species in the 1950s, populations have recovered as a result of management interventions and natural expansion. Both the Apennine and Cantabrian subspecies have increased in range size since the 1950s (Figure 1) – for the Apennine chamois, reintroduction into suitable areas has increased the distribution from a single population to five populations across the Apennine region[12–14]. In terms of overall population size, the species has also seen a significant recovery, although growth rates (particularly in the Pyrenean subspecies) have been limited by various epizootic outbreaks[9]. These include periodic incidences of Infectious keratoconjunc-

* *(R. p. pyrenaica: 53,000 (this value may be an overestimate of current population due to recent disease outbreaks in this subspecies, 2002)[2]; R. p. parva: 17,400 (2007–2008)[3]; R. p. ornata: 2,500 (2019)[1].*

** *Percentage change not calculated due to poor resolution of mid-century map.*

tivitis (caused by *Mycoplasma conjunctivae*) since the 1970s [15,16], and more recently on the Spanish side of the Pyrenees, severe outbreaks of Pestivirus [17,18], while the Cantabrian subspecies has been affected intermittently by Sarcoptic mange (due to the burrowing mite *Sarcoptes scabiei*) since the first reports in 1993 [19]. Monitored populations included in the Living Planet Index database reflect this generally positive trend, with an average rate of change among these populations calculated as 1,549% between 1970 and 2014 [4] (Figure 2). Note that this figure refers to an average among populations of all 3 subspecies, and therefore may not represent the trend for subspecies individually.

DRIVERS OF RECOVERY

The main driver of recovery for this species has been targeted management to increase population sizes, through the establishment of Game Reserves and Protected Areas and changes to hunting legislation, alongside natural expansion as a result of reduced human pressure due to rural abandonment [25]. For the Apennine chamois specifically, translocations have played a key role in recovery. This subspecies has been under conservation management since the 1920s and was designated as Endangered on the IUCN Red List in 1996 [26]. Individuals from the source location in the PNALM were first translocated into the Majella National Park in 1991, and in 1992 into the Gran Sasso e Monti della Laga National Park [12]. These translocations were very successful and contributed to the subspecies being downlisted to Vulnerable in 2008. They were followed by subsequent translocations into the Sibillini National Park in 2008, and Sirente Velino Natural Park in 2013 [26], creating the 5 established populations seen today. Reinforcements, reintroductions and introductions into new locations have also been carried out for the other two subspecies since the 1980s (e.g. to increase densities in peripheral populations of the Cantabrian Mountains for *R. p. parva* and in the French Pyrenees for *R. p. pyrenaica* [1,13]). However, these actions have been less crucial contributions to overall recovery. Population increases in these populations have primarily been a result of habitat protection and changes to hunting laws to promote population expansion, particularly the establishment of Game Reserves throughout Spain in the 1960s and 1970s, which aimed to conserve the species and regulate hunting at a sustainable level [3,27].

Figure 1b. Distribution of the Southern chamois in the 1950s [3,5,6] and 2020 [1]. Note that no historical distribution could be mapped for this species due to a lack of accurate information for this period.

THREATS AND PROTECTION

Legal protection	• Bern Convention (Appendix III)[20] • EU Habitats Directive (Annex V)[21] • Apennine chamois (*R. p. ornata*) protected under Italian law as an especially protected species, and listed separately from the Southern chamois: - Bern Convention (Appendix II)[20] - EU Habitats Directive (Annexes II and IV)[21] - CITES (Appendix II)[22]
Current threats (Europe)[1]	• Invasive and other problematic species, genes and diseases (invasive non-native/alien species/diseases; problematic native species/diseases)
Current threats (local)	• Climate change and severe weather (habitat shifting and alteration) – warming may reduce availability of cold-adapted foraging, particularly for Apennine population as low-elevation mountains reduce upslope refuges[9,23] • Invasive and other problematic species, genes and diseases (problematic native species) – competition with Red deer (*Cervus elaphus*) for foraging patches may limit population growth in Apennine population[9,24]

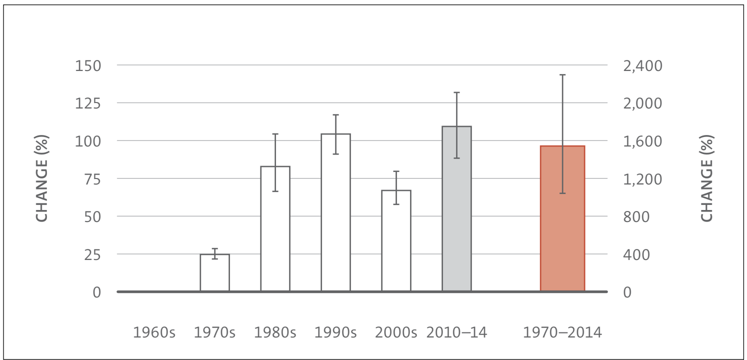

Figure 2. Average rate of change among Southern chamois populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall rate of change among populations between 1970 and 2014 (coloured-in bar, secondary y-axis). Note that overall change should be read from the secondary y-axis on the right-hand side of the chart. Decadal change does not sum to overall change. The trend is based on 31 populations from across the range, representing a minimum of 35,556 individuals, and covering 100% of all countries of occurrence. All 3 subspecies were represented in the data. For any given year the number of populations ranges from 1 to 28 (see Appendix 1 for details on methods and dataset).

BENEFITS OF COMEBACK

The Southern chamois plays a key role in the food web of montane ecosystems. They can be an important prey species for a range of carnivores of conservation importance, including large predators such as the Grey wolf (*Canis lupus*), Brown bear (*Ursus arctos*) and Golden eagle (*Aquila chrysaetos*), as well as scavengers like the Eurasian griffon vulture (*Gyps fulvus*), Eurasian black vulture (*Aegypius monachus*), Egyptian vulture (*Neophron percnopterus*) and Bearded vulture (*Gypaetus barbatus*)[9]. Management of wild ungulates like chamois is therefore considered a useful contribution to mitigating the effects of large carnivores on livestock by providing alternative prey[28]. In addition, in areas of its range where the species is huntable (i.e. most of the range in Spain) the Southern chamois can be an important contributor to rural economies[27]. It can also contribute to wildlife tourism, as is the case in the Apennine Mountains where the endemic Apennine chamois is marketed as one of the Italian "Big Five" (alongside Brown bears, Grey wolves, Golden eagles and Wild boar (*Sus scrofa*)[29,30]) used to attract visitors to the area.

OUTLOOK

The outlook for this species is generally good, as all three subspecies are targets of conservation intervention and are recovering well. In Spain, most populations are located within either Game Reserves or Protected Areas which fall under the Natura 2000 network and therefore must be maintained to a favourable conservation status under EU law[27,31]. In the central Apennines, a network of local NGOs are working with Rewilding Europe to establish corridors between the PNALM, Majella National Park and the Sirente Velino Regional Park, which would aid the Apennine chamois by connecting currently isolated populations and hopefully increasing their range[29].

However, there are also some causes for concern in terms of threats to the Southern chamois, most notably the impact of disease outbreaks[1]. Various epizootics have caused population declines in the past, including Keratoconjunctivitis in the Pyrenean chamois[15] and sarcoptic mange (*Sarcoptes scabiei*) in the Cantabrian chamois[19], but the most damaging has been the Pestivirus outbreak in the Pyrenean chamois[17,18,25,32]. The outbreak was first recorded in 2001 and caused mortality of up to 80% in some regions, and the virus remains endemic throughout the Pyrenees, although impacts on populations vary across the region[17,32]. While disease does not appear to be a major threat to the Apennine population[9], the impact of climate change on cold-adapted foraging plants, compounded by competition with Red deer (*Cervus elaphus*) may limit further recovery or even lead to declines[9], as the original source population in PNALM appears to be decreasing in numbers[33]. Therefore, continued monitoring and further conservation management may be required in future to mitigate the impacts of these factors.

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Northern chamois

Rupicapra rupicapra

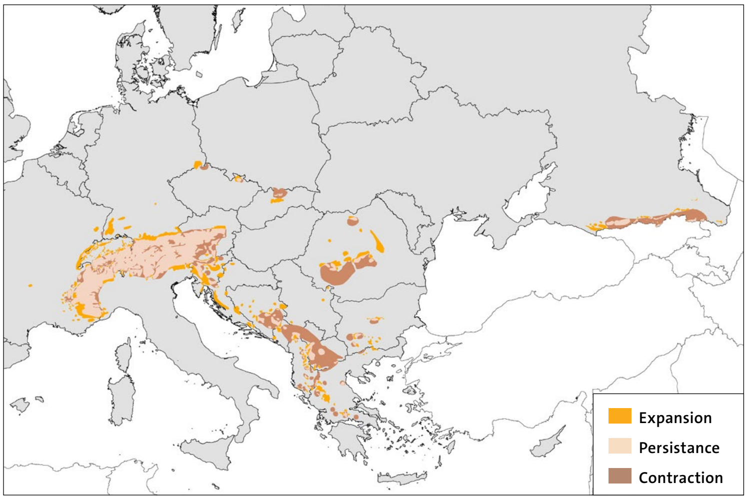
The Northern chamois (*Rupicapra rupicapra*) is an herbivorous goat-antelope native to central and southern Europe and Asia minor[2] and the most abundant mountain-dwelling ungulate in Europe[6]. It occurs in seven subspecies: *R. r. balcanica*, *R. r. carpatica*, *R. r. cartusiana*, *R. r. rupicapra*, *R. r. tatrica*, *R. r. asiatica* and *R. r. caucasica*[2]. Part of the latter subspecies' range occurs outside of our definition of Europe. This report does not consider the subspecies *R. r. asiatica*, as its distribution is entirely outside of our Europe definition[2]. The Northern chamois is adapted to rocky terrain at high altitudes and occurs in a variety of habitats including alpine meadows, open rocky areas, mixed broadleaf woodland, and coniferous woodland in steep, mountainous areas[3,7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest, Shrubland, Grassland, Rocky areas (eg. inland cliffs, mountain peaks)[1]	Global: Least Concern (2020)[2] Europe: Least Concern (2006)[1]	Global: Stable (2020)[2] Europe: Unknown (2006)[1]	Global: 543,370 (2021)*[3] Europe: 525,370 (2021)**[3]	Increasing, +1,045% (1960–2016)[4]	Increasing, (1930–2020)***[2,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

With its origins potentially in Asia, an unknown species of chamois was first recorded in eastern Europe approximately 800,000 years ago. The Northern chamois is thought to have started colonising the continent at the beginning of the Würm glaciations (some 80,000 years ago)[8]. Mountain ranges were occupied after the retreat of the glaciers, which likely explains its current distribution[8]. During the beginning of the Würm, the Northern chamois occurred from the Caucasus to the Alpine arc[6]. The species experienced a range contraction in the post-Neolithic period, with the already severely fragmented populations becoming restricted to just the higher altitudes of Europe's mountains. This contraction most likely occurred due to a combination of overexploitation by people at lower altitudes and environmental change[3,9]. Such overexploitation continued into the 20th century, especially during and after the World Wars, when unregulated hunting and poaching with more sophisticated weaponry led to some Northern chamois populations becoming significantly reduced[10].

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Northern chamois in Europe between 1930[5] and 2020[2]. Please note that contraction observed from 1930 to 2020 is likely to be an artefact of the difference in map resolution between the two time periods.



RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

As the 1930 distribution for the Northern chamois shown in Figure 1b is coarser in resolution than the present-day map[11], calculating a reliable estimate for the change in spatial distribution is difficult. At least part of the apparent changes in range is likely an artefact of different map resolutions as opposed to a genuine decline in range size (Figure 1a)[11]. The species has been able to persist in most of Europe's

* *Includes 18,000 introduced R. r. rupicapra in New Zealand.*

** *This included the total population number for R. r. caucasica, of which half of its distribution occurs outside of our definition of Europe, in Georgia and Azerbaijan, and also the total population for R. r. asiatica, which occurs in Turkey and Georgia.*

*** *Percentage change was not calculated from the spatial analysis due to differences in map resolutions.*

large mountain ranges. It primarily occurs in the Alpine arc countries, with smaller, often more fragmented, populations in the Jura, Vosges, Black Forest, Swabian Jura, Dinaric Alps, Rhodope Mountains, Carpathians and the Caucasus. In total, the Northern chamois occurs in 18 European countries[1].

The average rate of change among the Northern chamois populations in the Living Planet Index (LPI) database was a 1,045% increase between 1960 and 2016 (Figure 2)[4]. This positive rate of change has fluctuated over the decades, with the rate peaking in the 1970s and slowing in the 2000s and between 2010–2016. Potential reasons for the overall average rate of increase among populations include the abandonment of rural areas as well as conservation actions, such as hunting bans or strict hunting quotas, and to a lesser extent, reintroduction efforts[2]. The slowing of the rate of change increase for some populations in recent decades could be explained by populations experiencing negative density dependence[12]. It should be noted that the populations in the LPI database represent a smaller sample of the total species population, and that small populations influence the trend when calculated in this way. Further literature also highlights that although the species has experienced an increase in abundance, the sub-species *R. r. caucasica* continues to decline, whilst some populations of the sub-species *R. r. rupicapra* are also declining locally[12,13].

DRIVERS OF RECOVERY

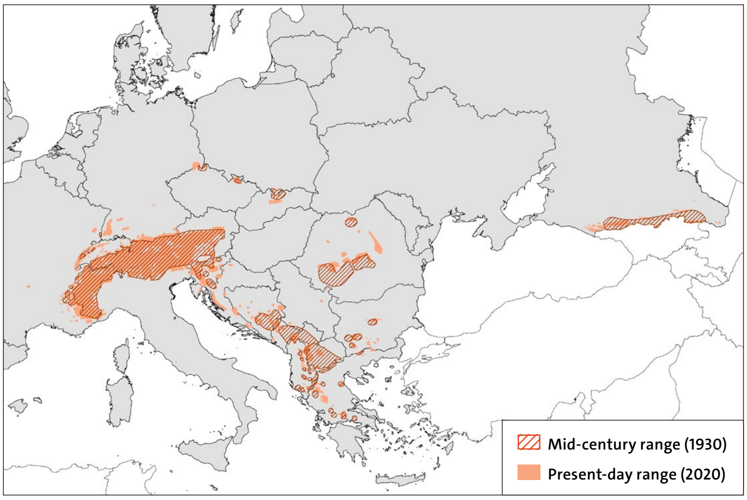
The increase in abundance and distribution of the Northern chamois can be attributed to a variety of conservation actions. These include, for all subspecies, ensuring sustainable harvesting, reducing poaching, reducing human disturbance, protecting the genetic integrity of populations by reducing translocations between sub-species, and extensive monitoring programmes, especially of vulnerable populations[18]. There have been successful reintroductions of various sub-species, including *R. r. cartusiana*[18] into the Grande Chartreuse mountain massif of France, *R. r. balcanica* into the Velebit Mountains of Croatia and Vitosha Nature Park in Bulgaria, and *R. r. carpatica* into the Rodnei Mountains of Romania[10]. Several protected areas have also been created, such as in Romania and the Italian Alps, which have been shown to play a key role in the recovery of various populations[10]. Hunting bans or harvesting quotas have been established in several countries across the species' range, for example, in Greece, chamois hunting has been banned since 1969, which has contributed to the recovery of *R. r. balcanica*[10].

However, it should be mentioned that although the species is increasing in population size overall, certain subspecies remain threatened (*R. r. cartusiana*, *R. r. tatrica* and *R. r. balcanica*), likely linked to continued illegal hunting, hybridisation with the abundant *R. r. rupicapra*, small and fragmented populations, disease, and stochastic events[3].

BENEFITS OF COMEBACK

The Northern chamois is an important grazing species, which contributes to the maintenance of subalpine pastures in medium and high altitudinal zones[10,19]. Where locally abundant, the species is also important prey for some of Europe's key large carnivores, including the Eurasian lynx (*Lynx lynx*), for which the Northern chamois is one of its main and preferred prey items[3,20,21]. Northern chamois also provide a food source for rare scavengers, including the Bearded vulture (*Gypaetus barbatus*)[3]. The species is included in European rewilding schemes, contributing to the reestablishment of biodiverse ecosystems[19].

Figure 1b. Distribution of the Northern chamois in 1930[5] and 2020[2]. An accurate historical map prior to 1930 was not available for this species[11,12]. The 1930 map was used to represent the species' mid-century distribution, as although it is dated earlier than the typical mid-century time-period, it is the best available map for the Northern chamois' likely mid-century distribution in terms of resolution and accuracy[11,12].



THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III)[14] • EU Habitats Directive (Annex V)[15] • The subspecies *R. r. balcanica* and *R. r. tatrica* are listed in Annexes II and IV of the EU Habitats Directive, but not Annex V[15]. • The species is also nationally protected in several countries, including Greece, Bulgaria and Poland[2].
Current threats (Global)[2]	• Residential & commercial development (housing & urban areas; tourism & recreation) • Agriculture & aquaculture (annual & perennial non-timber crops; livestock farming & ranching) • Biological resource use (hunting & trapping terrestrial animals) • Human intrusions & disturbance (recreational activities) • Invasive and other problematic species, genes & diseases (Invasive non-native/alien species/diseases; problematic native species/diseases; problematic species/disease of unknown origin; viral/prion-induced diseases)
Current threats (Europe)[1]	• Human intrusions & disturbance (recreational activities) • Invasive and other problematic species, genes & diseases (invasive non-native/alien species/diseases; problematic native species/diseases; Introduced genetic material; viral/prion-induced diseases)
Current threats (local)	• Residential & commercial development (housing & urban areas) – habitat loss due to urban land demands and infrastructure of an expanding population in e.g. Albania[16] and Greece[17] • Agriculture & aquaculture (livestock farming & ranching) – shift from traditional sheep-goat grazing to intensive cattle grazing leading to habitat degradation and loss in Greece[17] • Biological resource use (hunting & trapping terrestrial animals) – poaching and hunting in Greece[16,17] • Invasive and other problematic species, genes & diseases (problematic native species/diseases) – e.g. sarcoptic mange in the eastern Alps[3]

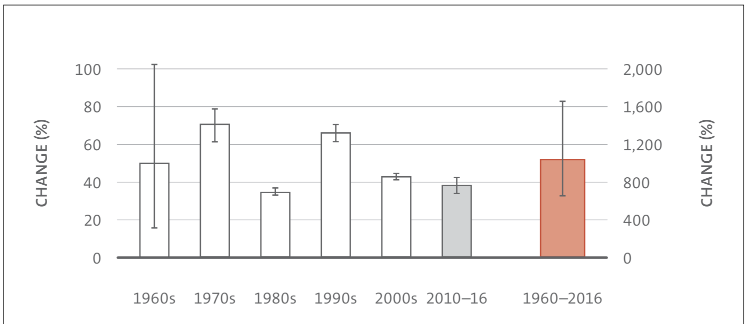


Figure 2. Average rate of change among Northern chamois populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall change between 1960 and 2016 (coloured-in bar, secondary y-axis). Decadal change does not sum to overall change. The trend is based on 31 populations from across the range, representing a minimum of 82,616 individuals, or 16% of the total European population in 2021, covering 56% of all countries of occurrence. Data were missing from eight countries within the species' current range: Austria, Bosnia and Herzegovina, Croatia, Germany, Macedonia, Montenegro, Serbia and Slovenia. For any given year, the number of populations ranges from 1 to 23 year (see Appendix X for details on methods and dataset)[4].

OUTLOOK

As the Northern chamois is a widespread species with a large population, it is classified as Least Concern by the IUCN[2]. However, aside from the most populous subspecies, the alpine *R. r. rupicapra*, most of its other subspecies' populations remain small, isolated, and in some cases, declining and threatened. For example, both *R. r. balcanica* and *R. r. tatrica* are listed separately in Annexes II and IV of the EU Habitats Directive, whilst the subspecies *R. r. tatrica*, *R. r. cartusiana* and *R. r. caucasica* are listed as either Endangered or Vulnerable on the IUCN Red List[2,3]. This suggests there is much scope for further recovery of individual subspecies. Interbreeding with the abundant alpine subspecies, and the resulting potential for outbreeding depression and loss of local adaptations, is of particular concern for these threatened subspecies[3]. It is therefore recommended that translocations between different subspecies' populations should be avoided, to prevent genetic extinction of rarer subspecies[3]. Similarly, most subspecies and populations are not currently monitored, which should be a priority for establishing the effective future management of the subspecies, and species as a whole[3]. The potential impacts of climate change and presence of diseases in the species should also be closely monitored[11,12]. For some populations, over-harvesting remains a concern. Therefore, sustainable harvesting quotas, which consider sex and age classes, should be established across the Northern chamois' range[2]. Furthermore, the introduction of competitors, such as Red deer (*Cervus elaphus*), should be avoided in areas inhabited by Northern chamois[12].

There are no major conflicts with human-related activities for the Northern chamois, except for the species occasionally damaging silver fir (*Abies alba*) saplings[3]. The species typically displays anthropogenic risk avoidance behaviour, avoiding, for example, roads and hunting grounds[17]. The Northern chamois has been identified as a widely used symbolic species in several locations throughout its range, suggesting it has an important cultural value for humans[22]. The species can also attract nature-based tourism, for example, in the Velebit Mountains of Croatia, which can subsequently boost local economies[19].

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Wild boar

Sus scrofa

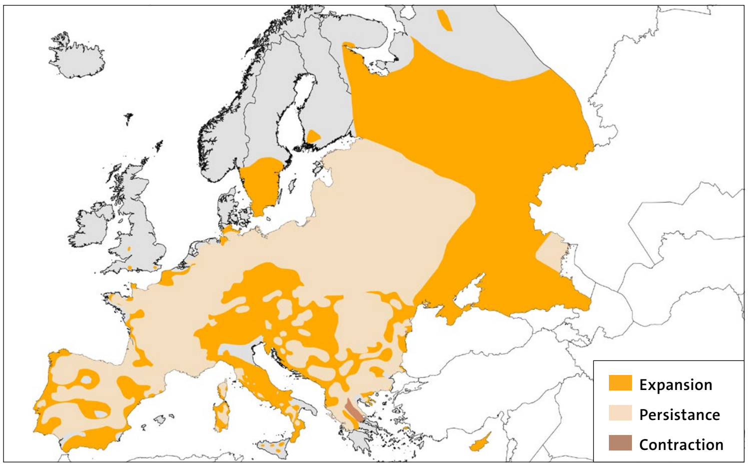
The Wild boar (*Sus scrofa*) is one of the world's most widely distributed large mammals[11], present in its wild or feral form on every continent except Antarctica, with a range that has been greatly expanded by humans[2]. It is a highly adaptable and fecund species[11], able to quickly reach high population densities[12,13]. In Europe, Wild boars typically favour deciduous and mixed forests, particularly oak-dominated forests, but it is also found in agricultural landscapes[11,14]. As an omnivore, the Wild boar eats almost anything from grass, nuts, berries and roots to invertebrates, carrion, and small reptiles. It also frequently consumes agricultural crops[14].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forests[1]	Global: Least Concern (2018)[2] Europe: Least Concern (2006)[1]	Global: Unknown (2018)[2] Europe: Increasing (2006)[1]	Global: Unknown[2] Europe: At least 15,000,000*[3–5]	Increasing, +390% (1967–2016)[6]	Increasing, +116% (1955–2018)[2,3,7–10]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Molecular analysis suggests that the Wild boar originated in south-east Asia from where it dispersed across Eurasia, even to islands where other species of the genus *Sus* existed[15,16]. The species was widely distributed throughout Europe during the early and mid-Holocene[17], with domestic stock first thought to have been bred from these wild relatives around 9,000 years ago[15]. Wild boar arrived in Britain and Ireland in the early Mesolithic[18], but were extirpated there in the 17th century[14]. The range of the species contracted in several locations between the 17th and 19th centuries (e.g. in the Baltic states, Hungary, Czech Republic), due to a combination of changes in land use practices and overhunting, with climate cooling and high Grey wolf (*Canis lupus*) densities implicated in some regions[19]. It was extirpated from Denmark in the 19th century[14] and Switzerland by the turn of the 20th century[19]. Following this severe reduction in number and range, slight recoveries occurred in Russia, Italy, Spain, and Germany in the mid to late 20th century[14], and populations were established from escaped animals in Britain and Sweden[9,20].

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Wild boar in Europe between 1955[3,7–10] and 2018[2,3,9,10].



RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Since the 1950s, the species has undergone a significant range expansion, in many places expanding past its recorded extent at the end of the 19th century (Figure 1b)[19]. Between 1955 and 2018, the Wild boar's range increased by approximately 116% (Figure 1a)[2,3,7–10]. The species is currently extant in 39 European countries, extending from Portugal and the United Kingdom in the west, to Russia and Ukraine in the east[2].

The average rate of change among Wild boar populations in the Living Planet Index (LPI) database was a 390% increase between 1967 and 2016 (Figure 2)[6]. This positive change was especially high during the 2000s. However, the average rate of change among populations stabi-

* *Conservative estimate based on hunting statistics.*

lised during the 1990s, possibly due to Classical swine fever epidemics [6,9]. Furthermore, the average rate of change became slightly negative between 2010–2016 [6]. Although exact causes for this negative change in some populations were not identified in the LPI database [6], several studies in the past decade have stated that an African swine fever epidemic in European Wild boar populations has led to local population density decreases, starting in Poland and the Baltic states [3,21,22]. It has also been suggested that particularly severe winters in central Europe have led to a stagnation of population growth in recent years [9]. On the other hand, it should be noted that a different indicator, a normalised index on national hunting bags, showed that Wild boar numbers have increased in Europe during this time period [4]. In general, models predict that Wild boar population growth will only increase, as climate change creates more suitable climatic conditions, and boosts the abundance of favourable food sources [23].

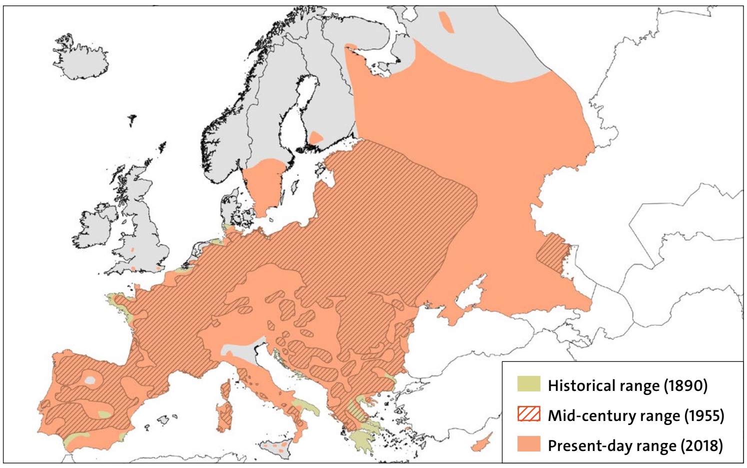
DRIVERS OF RECOVERY

A wide variety of reasons for the resurgence of the Wild boar in the latter half of the previous century have been cited in the literature. Among them are deliberate and accidental reintroductions [14,19,25], restocking [10], warmer winters with less snow leading to greater survival and reproductive success [19,25,26], hunting control and improper management [19,27], and a lack of large predators [13]. Furthermore, there has been improved access to forage earlier in the spring season through more frequent mast years in their preferred forest and woodland habitats. Climate warming has increased pollination of Oak (*Quercus spp.*) and Beech (*Fagus spp.*) trees, leading to higher seeding rates in autumn [11,19,28]. Moreover, the increasing number and size of arable fields due to intensive agriculture, provides an ad libitum source of food for the species [3,19]. Supplementary feeding, often provided by those wishing to hunt Wild boar, is also thought to locally increase population sizes, although it is illegal in some countries [10,29,30]. In addition, reforestation has increased in Europe in the past two decades , whilst land abandonment in some countries has led to larger areas of scrubland, both of which the species is able to disperse into [19,31,32]. The species is both highly adaptable and remarkably resilient, appearing to thrive under climate change, and certain forms of habitat modification [2,11,23].

BENEFITS OF COMEBACK

Wild boar are considered ecosystem engineers, creating intense soil disturbances through their rooting behaviour [33]. This rooting behaviour has been associated with both positive and negative environmental impacts. It can damage vulnerable ecosystems, destroying habitats for ground-dwelling and tunnelling species [34]. In Spain, for example, the presence of Wild boar in a wetland ecosystem was associated with negative impacts on wild European rabbits (*Oryctolagus cuniculus*) and the whole community of waterbirds [35]. Alternatively, there is some evidence that its rooting behaviour can be beneficial for various pioneer species, through the creation of bare patches suitable for colonisation, which in turn can benefit other species such as the rare Grizzled skipper butterfly (*Pyrgus malvae*) in the Nether-

Figure 1b. Distribution of the Wild boar in 1890 [8,10,19], 1955 [3,7–10] and 2018 [2,3,9,10]. Please note that the historical map is at a much lower spatial resolution than the mid-century and present-day maps.



THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III) – only subspecies *S. s .meridionalis* is listed [24] • The species occurs in a large number of Protected Areas [2].
Current threats (Global) [2]	• Agriculture & aquaculture (livestock farming & ranching) • Biological resource use (hunting & trapping terrestrial animals) • Invasive and other problematic species, genes & diseases (invasive non-native/alien species/diseases)
Current threats (Europe) [1]	N/A
Current threats (local)	• Invasive & other problematic species, genes & diseases (viral/prion-induced diseases) – e.g. African swine fever is causing recent declines in abundance in some local areas, such as in Poland and the Baltic States [3,21,22].

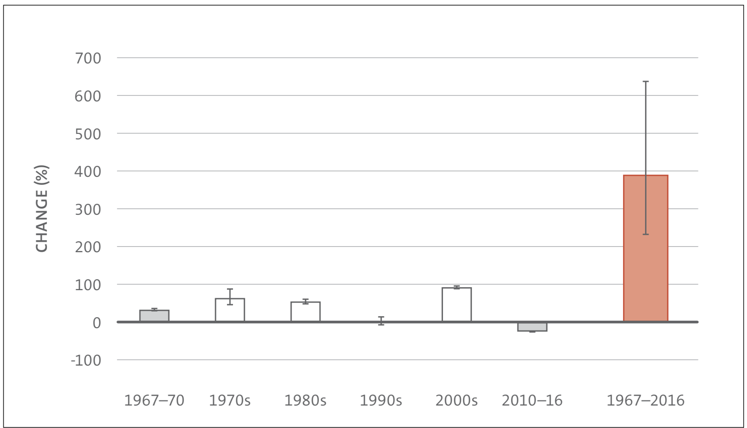


Figure 2. Average rate of change in Wild boar populations by decade (hollow bars, grey fill represents incomplete decade) and overall change between 1967 and 2016 (coloured-in bar) [6]. Decadal change does not sum to overall change. The trend is based on data from 73 populations from across the range, representing a minimum of 239,694 individuals, covering 41% of all countries of occurrence. Data were missing from 23 countries within the species current range: Albania, Andorra, Austria, Belgium, Bosnia and Herzegovina, Croatia, Cyprus, Finland, France, Germany, Greece, Liechtenstein, Luxembourg, Macedonia, Moldova, Monaco, Montenegro, Netherlands, Portugal, Romania, San Marino, Slovenia, Sweden. For any given year the number of populations ranges from 2 to 66 (see Appendix 1 for details on methods and dataset.

lands [36]. Similarly, a study in Scotland found that Wild boar could be seasonally useful for habitat management, as their rooting behaviour in autumn and winter can help to break up Bracken (*Pteridium aquilinum*), the spread of which is a concern for land managers [37]. This benefit, however, does not extend to plant species in subsequent succession stages, where repeated rooting behaviour can permanently damage seedlings, significantly reducing overall vegetation cover [37,38]. Furthermore, their omnivorous diet has been shown to be problematic for ground-nesting birds, such as waterbirds breeding on shores, as they frequently feed on eggs [39]. Although one study did find that the Wild boar may have less impact on nest survival than originally thought [40].

OUTLOOK

As mentioned before, the Wild boar is a highly adaptable and resilient species, able to thrive in a time of rapid habitat and climate change [2]. In fact, it is thought ongoing climate change will further accelerate Wild boar population growth and range expansion [23]. As the species has the potential to negatively impact ecosystems and vulnerable species, future conservation efforts should focus on researching its impacts on ecosystems and other species, particularly in Protected Areas, and carefully managing populations so that population growth is limited, and Wild boar density is kept at a tolerable level [9,41,42]. Action also needs to be taken to ensure the species does not become adapted to urban areas, where Wild boar numbers have been increasing [3,41,42]. Population viability analysis (PVA) with perturbation analyses could be used to allow focused management and control efforts [41]. However, it should be noted that recreational hunters often do not wish for Wild boar populations to be controlled, and therefore strategies to change hunters' mindsets and prevent actions which intentionally increase Wild boar populations are needed [9]. Centralised Wild boar management on the regional or national scale, and international coordination which involves different stakeholders, is also essential in order to manage the species effectively and limit the spread of Wild boar-related diseases [13,27,43].

As population abundance and range has increased, so has the number of incidences of human-wildlife conflict involving Wild boar [11,13,42]. Their often-destructive behaviour and omnivorous diet means that, as well as potentially driving reductions in local biodiversity, economic and social costs also frequently occur, such as damage to property, infrastructure and crops [44]. They have also been known to spread several diseases, such as African swine fever and Tuberculosis, and are increasingly involved in traffic accidents [42,44]. On the other hand, in many locations, Wild boar are a popular game species and a delicacy, thus their presence may be welcome [42]. As mentioned above, this can create conflict between stakeholders who wish to control population abundance, and those who intend to hunt Wild boar, which needs to be carefully managed [9,13,27,43].

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Golden jackal

Canis aureus

ARTIODACTYLA | **CARNIVORA** | CETACEA | CHIROPTERA | RODENTIA

The Golden jackal (*Canis aureus*) is a medium-sized canid[5,6] with omnivorous, generalist and opportunistic foraging habits[5]. This dietary flexibility, alongside their ability to adapt to varying conditions[5], may be one of many factors responsible for the remarkable expansion of this species in recent years, with populations now found even in countries with no historic record of jackal presence[4,7,8].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
	LC			+886%	+331%
Forest, Shrubland, Grassland, Wetlands, Artificial/Terrestrial[2]	Global: Least Concern (2018)[1] Europe: Least Concern (2018)[2]	Global: Increasing (2018)[1] Europe: Increasing (2018)[2]	Global: Unknown[1] Europe: 97,000–117,000 (2018)[2]	Increasing, +886% (2001–2015)[3]	Increasing, +331% (1960–2018)[4,33]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Reconstructing the early history of the Golden jackal is challenging due to controversy over the identity of subfossil remains and the origins of different populations[9]. However, this species is likely to have appeared in the far south-east of Europe at some point in the Holocene, possibly migrating westwards from the Caucasus[9,10]. The early distribution was likely limited to the Adriatic coastline and Greek islands such as Samos, with consistent records of Golden jackal presence on the mainland continent not occurring until the Middle Ages[9,11]. By the 19th century, its distribution had expanded but remained limited to the Balkans, with populations stretching inland from the west coast of the Black Sea in Bulgaria, Greece and Turkey, and along the Dalmatian coast and down to the Ionian sea[9]. Going into the early 20th century, populations were also found further inland in Romania, Serbia, Bulgaria and as far north as Hungary, but a period of decline between 1920 and 1950 resulted in contractions back to smaller nuclei along the Balkan coastlines and some fragmented populations further inland[4,9].

STEFAN STEFANOV

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Since the 1950s, changes in Golden jackal populations have been characterised by significant expansions, even into areas far beyond their historic range[4,8,11]. The first wave of expansion occurred in the late 1940s and 1950s, followed by decline in the 1960s and 1970s due to human persecution and habitat loss[8,12]. In the 1980s there was a significant recovery, and this expansion out of population refuges and across the Balkan peninsula into the rest of Europe continues to the present day, with populations established across the south-east and more central parts of the continent[4,8,13] (Figure 1). Recently, individuals have even been reported as far from the original nuclei as the Netherlands[14], Lithuania[15] and Denmark[16]. For 10 of the European countries where Golden jackals have been reported, the first sighting in that country occurred in the past decade, reflecting the fact that a significant proportion of this expansion is into novel territory, rather than recolonisation of the historic range[7].

The increase in range size has also been paired with population growth, with the Pannonian-Balkan, Adriatic and Peloponnese subpopulations all still listed as increasing by the IUCN[2]. This is reflected in the few monitored populations present in the Living Planet Index dataset, with the average rate of change among these populations calculated as +886% between 2001 and 2015[3] (Figure 2).

DRIVERS OF RECOVERY

Multiple reasons have been suggested for the remarkable growth in population and distribution of this species. The initial recovery in the 1960s was likely catalysed by the introduction of legal protection in Bulgaria and subsequent reduction in human persecution, with rapid population growth in this area then acting as a source for expansion further afield[9]. In addition, land use changes likely facilitated comeback, as abandonment of agricultural land in rural regions reduced the amount of intensively farmed areas and increased habitat availability of shrubby vegetation well suited to the Golden jackal[19]. However, these factors do not necessarily explain the remarkable scale of its expansion compared to other European carnivores. One alternative hypothesis is that climate change has allowed this canid to expand northwards, as it is a southern European species adapted to warmer climates[20]. It has also been suggested that the persecution and subsequent reduction in Grey wolf (*Canis lupus*) numbers may have enabled the expansion of the Golden jackal by increasing prey availability and reducing competition, as predicted by the meso-predator release hypothesis[4]. However, the populations of both species, and their areas of occupation, are currently increasing, so it is unlikely that this interaction is still influencing Golden jackal population dynamics[2,21,22]. It is perhaps most likely that the combination of these factors, alongside the plasticity of Golden jackal habitat use and diet, have contributed to the expansion seen[4,8,19].

BENEFITS OF COMEBACK

Within its native range, the Golden jackal plays an important functional role as a meso-predator, involved in complex interactions between prey species and other predators[23]. Given the opportunistic nature of their foraging habits, Golden jackals tend to have a low impact on species diversity, as they normally consume whichever food source is most abundant[24]. By consuming improperly discarded remains of both domestic and hunted animals, Golden jackals provide a useful and economically valuable ecosystem service, especially in countries with low availability of organised animal waste disposal such as Serbia[25]. Finally, when present in agricultural areas, crop-pest rodents such as voles and field mice can be a significant component of Golden jackal diet and therefore their presence can help to reduce the damage done by these pests[24,25].

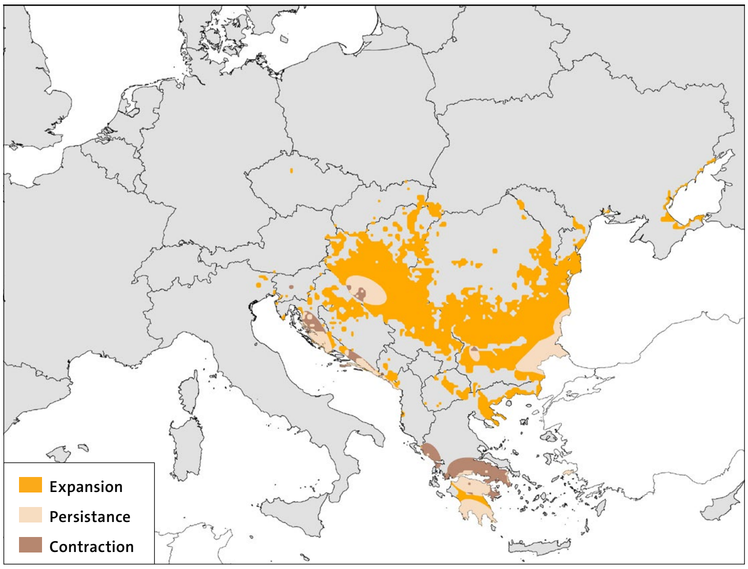

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Golden jackal in Europe between 1960[4,17] and 2018 (redrawn from Ranc et al.[33]).

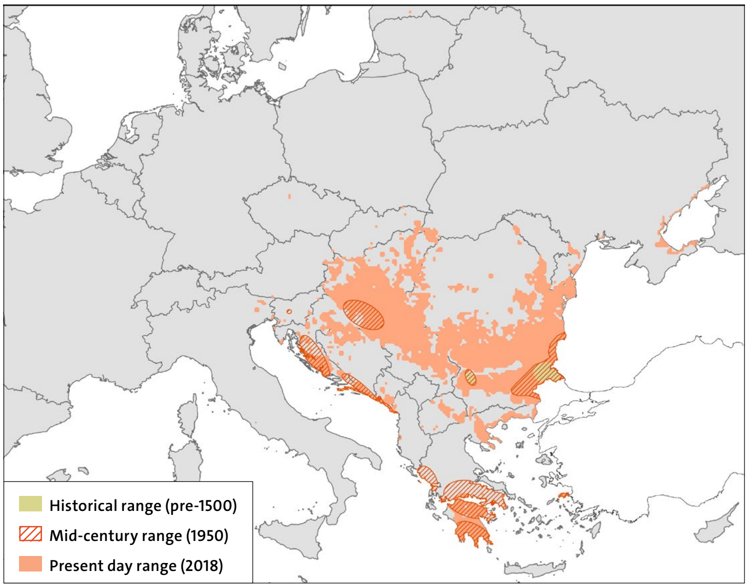

Figure 1b. Distribution of the Golden jackal in the 1500s[4], 1960[4,17] and 2018 (redrawn from Ranc et al.[33]).

OUTLOOK

Given the increasing population size and significant range expansion, the Golden jackal is listed as Least Concern by the IUCN[2]. There is significant potential for further expansion – Golden jackals can disperse large distances – and given their ecological plasticity, it is likely that there are large

THREATS AND PROTECTION	
Legal protection	• EU Habitats Directive (Annex V) [18] • Nationally protected (i.e. hunting illegal beyond exceptional circumstances) in Albania, Germany, Italy, FYR Macedonia, Poland and Switzerland [8] • Huntable species in accordance with legislation in most other range countries (other than Greece, Estonia, Czech Republic and Belarus, where it is unprotected) [8]
Current threats (Global IUCN Red List) [1]	None listed
Current threats* (European Red List) [2]	• Agriculture and aquaculture (annual and perennial non-timber crops) • Transportation and service corridors (roads and railroads) • Biological resource use (hunting and trapping terrestrial animals)
Current threats (local)	• Other threat – Samos Island population in Greece is listed as Endangered according to Criterion D due to its small population size (~80 individuals) and both genetic and geographic isolation from other populations [2]

* *While these categories are listed as threats on the IUCN Red List European Assessment for the species, this reflects factors which may generally be causing non-natural mortality. Given that this species is expanding rapidly at a European scale, these do not represent threats which may be contributing to declines or limiting recovery.*

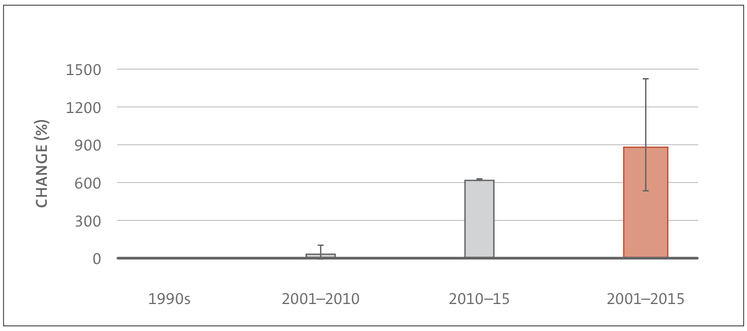

Figure 2. Average rate of change among Golden jackal populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 2001 and 2015 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 4 populations from across the range, representing a minimum of 32608 individuals, or at least 28% of the total European population of 2018, covering 19% of all countries of occurrence. Data were missing from 17 countries within the species' current range (Albania, Austria, Bosnia and Herzegovina, Croatia, Czech Republic, Denmark, Estonia, Italy, Latvia, Greece, Macedonia, Montenegro, Moldova, Russian Federation, Serbia, Slovenia and Ukraine. For any given year the number of populations ranges from 1 to 3 (see Appendix 1 for details on methods and dataset).

areas of Western Europe that are suitable for this species, including urban areas [14,26–28]. Reproductive populations are becoming established in countries where previously only vagrant individuals were observed, such as Poland [29], demonstrating that these dispersing individuals can become founders of permanent populations. It is possible that further climate warming will facilitate dispersal and expansion by reducing barriers to dispersal such as snowy regions (especially at higher altitudes) and by making northerly latitudes more favourable to this species as winters become milder [9,20].

Because of the species' high adaptability, the conservation of the Golden jackal in Europe is first and foremost a political and sociological problem, particularly as it moves into areas outside its historical range [7,8,11]. The canid is often viewed negatively by members of the public due to the perceived impact of predation on domestic livestock and valuable game species [7,11]. However, there is little evidence that either of these are large components of Golden jackal diet when there are other food sources available, especially given that Golden jackals are primarily scavengers of wild and domestic large ungulate carcasses rather than active hunters [24,30,31]. This perception can influence policy and management decisions, for example in the Baltic states where Golden jackals have been designated as an alien species despite genetic evidence supporting natural rather than anthropogenic spread into the area [11]. Following this designation, some governments have encouraged eradication of the species, and several individuals were shot in Estonia, Latvia and Lithuania in the mid-2010s [8]. Determining the appropriate interpretation of legislation such as the EU Habitats Directive for this species, and whether further protection, such as application of the existing Carnivore Guidelines, needs to be put in place to manage hunting is a key next step [7,8,32]. This is especially the case given the wide dispersal ability and ongoing expansion of this species, and transboundary cooperation will be necessary to ensure it is managed effectively. Another important component of this will be improved research focus on this species. Suitable monitoring programmes to track distribution across the continent are lacking, especially as the species is regularly confused with other medium-sized canids [29]. Overall, given the plasticity and resilience of this species, it is likely that the Golden jackal will continue its expansion across Europe.

REVIEWED BY:

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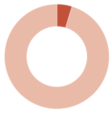
ARTIODACTYLA | **CARNIVORA** | CETACEA | CHIROPTERA | RODENTIA

Grey wolf

Canis lupus

The Grey wolf (*Canis lupus*) is the largest wild canid, with a near continuous distribution throughout the northern hemisphere[5]. Dependent on prey density and the level of human disturbance, the Grey wolf is found in a wide variety of habitats across Europe, where suitable food is abundant[5]. Wolves are social and live in familial packs in distinct territories[6], which cover between 100 and 500 km² in Europe[7]. Young wolves disperse alone over long distances (potentially moving several thousand kilometres)[8,9].



HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest, Shrubland, Grassland, Artificial/ Terrestrial[1]	Global: Least concern (2018)[2] Europe: Least concern (2018)[1]	Global: Stable (2018)[2] Europe: Increasing (2018)[1]	Global: c. 300,000–400,000 (2022)[3] Europe: at least 17,000 (2018)*[1]	Increasing, +1,871% (1965–2016)[4]	Increasing (1960–2018)**[1,3]

HISTORICAL DISTRIBUTION AND ABUNDANCE

While the Grey wolf was historically one of the world's most widely distributed mammals[10], its current range is much more restricted as a result of severe persecution by humans motivated by predation of livestock and fear of attack[1]. Towards the end of the 18th century, Grey wolves were still found in most areas of Europe, but due to the rise in the human population during the 19th century, Grey wolf abundance decreased considerably[11]. The species continued to decline throughout the 20th century, particularly during the Second World War. By the 1970s, it was only present in parts of southern and north-eastern Europe[11].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Following a bottleneck in the 1960s and 1970s, the European range of the Grey wolf has expanded drastically[1,12]. For example, the species has rapidly extended into central Europe during the past 20 years[13], whilst in Italy, wolves have recolonised most of their previous range along the Apennine Mountains and the Po lowlands in just 40 years[14]. In fact, their presence has now been recorded in almost all continental European countries[1]. For management purposes, several distinct populations have been defined in Europe, specifically in north-western Iberia, the western-central Alps, the Italian peninsula, the Dinaric Mountain range and Balkans, the Carpathians, the Baltics, Karelia, Scandinavia, European Russia and Central Europe[1,15]. Between 1960 and 2018, the Grey wolf's range increased significantly. Exact percentage changes in spatial distribution could not be calculated from the maps, due to differences in spatial resolution and the types of data used to create them (Figure 1a)[1,3].

In line with expansions in its range, the average rate of change among Grey wolf populations in the Living Planet Index (LPI) database was a 1,871% increase between 1965 and 2016[4]. The decadal rates of change have all been positive, with the most

* *Excluding European Russia.*

** *Percentage change was not calculated from the spatial analysis due to differences in spatial resolution and the types of data used to create the maps.*

positive decadal rate of change occurring during the 2000s (Figure 2)[4]. It should be noted that populations in the LPI database represent a smaller sample of the total species population and small populations in the LPI database can influence the trend when calculated in this way. Further literature similarly highlights an overall increase in the abundance of Grey wolves in Europe, e.g. the quadrupling of wolf numbers in Spain between 1970 and the present[16].

DRIVERS OF RECOVERY

The overall increase of the Grey wolf's distribution and population in Europe can largely be attributed to historical socio-economic changes, such as the abandonment of mountain agricultures, and the subsequent decrease in livestock numbers and human densities in these mountainous and hilly regions[3,5]. Conservation actions have accompanied these socio-ecological and economic changes. Increased public acceptance of Grey wolves has been instrumental in the implementation of legal protection across the Grey wolf's range[22,23]. Such legislation and public tolerance have in turn led to a decrease in poaching and exploitation[22]. Because of its resilience and ability to disperse and adapt, the Grey wolf has been able to exploit the concurrent decrease in persecution and has consequently spread into many types of habitat, expanding from its historical refuges and dispersing over long distances[1,14]. It has also benefitted from the increase in available food resulting from the recoveries observed in wild ungulate populations such as Roe deer (*Capreolus capreolus*), Red deer (*Cervus elaphus*) and Wild boar (*Sus scrofa*)[3,14,16].

BENEFITS OF COMEBACK

The Grey wolf can greatly impact ecosystems both directly and indirectly[14]. Depending on local ecological conditions and the availability of a diverse prey base, they can help to reduce prey densities through direct predation[24]. Furthermore, they can indirectly impact other species through the complex web of relationships linking all species of an ecosystem[3]. For example, Grey wolves in the Białowieża Primeval Forest in Poland have changed the spatial distribution of ungulate browsing, by scaring browsing species away from certain areas. In turn, this can lead to increased tree regeneration at these locations[25].

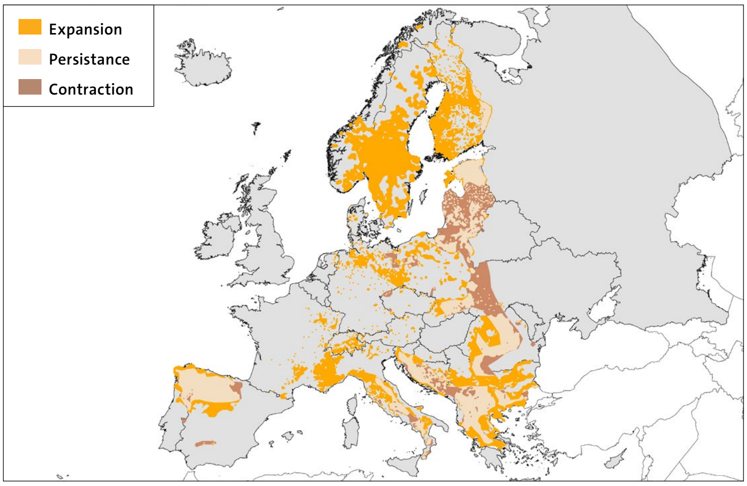


Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Grey wolf in Europe between 1960[3] and 2018[1]. Please note that some of the contraction observed from 1960 to 2018 is likely to be an artefact of the difference in map resolutions and types of data used to create them. The map excludes Russia, Belarus, Moldova, and Ukraine (except for the Carpathians), to match the 2018 map limits, which used the IUCN SIS delineation of Europe.

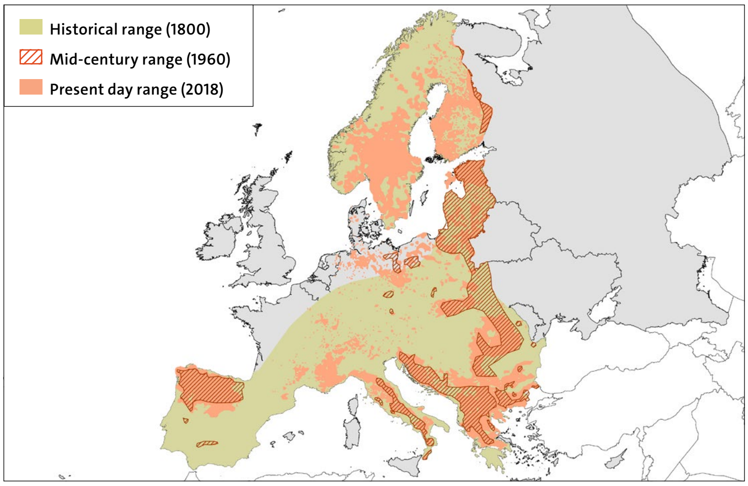


Figure 1b. Distribution of the Grey wolf in 1800[17], 1960[3] and 2018[1]. Please note that the map excludes Russia, Belarus, Moldova, and Ukraine (except for the Carpathians), to match the 2018 map limits, which used the IUCN SIS delineation of Europe.

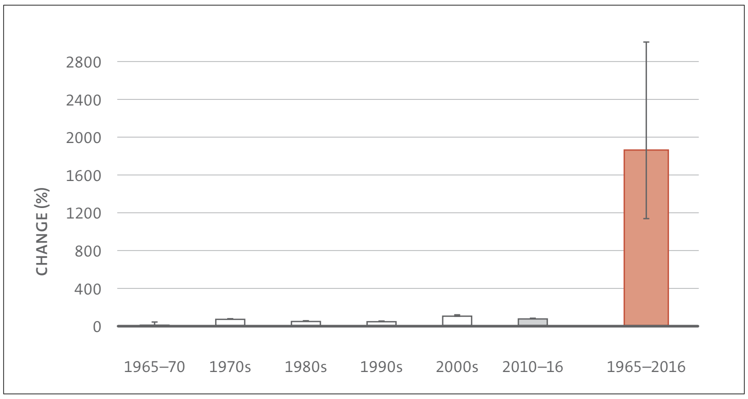


Figure 2. Average rate of change among Grey wolf populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1965 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 32 populations from across the range, representing a minimum of 12,276 individuals, covering 86% of all countries of occurrence. Data were missing from five countries within the species' current range, namely Bosnia and Herzegovina, Macedonia, Montenegro, Russian Federation and Serbia. For any given year the number of populations ranges from 2 to 77 (see Appendix 1 for details on methods and dataset).

THREATS AND PROTECTION	
Legal protection	• EU Habitats Directive (Annex II and IV) – except for some populations in Spain, Greece, Finland and the Baltic States; (Annex V) – only some populations in Spain, Greece, Finland, Bulgaria, Poland, Slovakia and the Baltic States [18] • Bern Convention (Appendix II) [19] • CITES (Appendix II) [20] • EU regulation of trade of fauna and flora (Annex A) – except for some populations in Spain and Greece; (Annex B) – only some populations in Spain and Greece [21] • Many European countries also have national Grey wolf management plans [22]
Current threats (Global) [2]	• Agriculture & aquaculture (livestock farming & ranching) • Biological resource use (hunting & trapping terrestrial animals)
Current threats (Europe) [1]	• Agriculture & aquaculture (livestock farming & ranching) • Transportation & service corridors (roads & railroads) • Biological resource use (hunting & trapping terrestrial animals) • Human intrusions & disturbance (recreational activities) • Climate change & severe weather (habitat shifting & alteration)
Current threats (local)	• Invasive & other problematic species, genes & diseases (introduced genetic material) – e.g., hybridisation with domestic dogs (*C. lupus familiaris*) is impacting some populations at the local scale [3].

OUTLOOK

As the Grey wolf has a large population and widespread range, which will likely continue to expand in the future, it is classified as Least Concern by the IUCN [1]. Furthermore, recent evidence suggests Grey wolf populations are becoming increasingly connected, as several cases of long-distance dispersal of individuals have been recorded [9,26]. Despite this, some populations are still small, fragmented, and threatened. For example, in 2018, the western-central Alpine, Scandinavian, and central European populations were all listed as Vulnerable on the IUCN Red List 1, although they are rapidly moving to lower categories of threat [3].

Despite an increase in public acceptance, hunting and poaching remain as widespread threats to the species, especially in areas where Grey wolves sometimes predate livestock [1]. In Norway, for example, after pressure from hunters and farmers, plans have been proposed to cull 60% of the country's Grey wolf population, which would leave just 3 breeding pairs in the country [27]. The low density of Grey wolf populations makes them particularly vulnerable to hunting and stochastic events [7]. Habitat change and different management schemes for transboundary populations could also be negatively impacting the species [1]. Therefore, to support and manage the species' recovery, several future conservation actions are recommended. Habitat restoration and ensuring suitable prey are available is needed in some locations, to further aid expansion, and to minimise the impact of Grey wolves on livestock [28]. To boost public acceptance of Grey wolves, it is also important to include local stakeholders in management plans [29], and to establish suitable protection and compensation schemes [30]. The species would also benefit from the coordination of management across countries, to allow consistent protection across their territories [29]. Finally, more effective population monitoring is needed to inform management plans [31].

As mentioned before, the increased presence of an apex predator typically leads to backlash amongst local people and stakeholders. Grey wolves can predate livestock, compete with hunters, and occasionally kill hunting dogs [28]. Furthermore, some see Grey wolves as a potential threat to human lives, even if such incidents are extremely rare [28]. As Grey wolf numbers increase, attitudes towards them may become more negative, which could lead to increased conflict [32]. However, Grey wolves are also a powerful symbolic species, with important cultural value [33]. They can attract nature-based tourism, which could boost the local economy. In Spain and Portugal, for example, tourism operators are offering guided walks led by biologists, which focus on the Iberian wolf (Canis lupus signatus) [34]. Furthermore, as predation can reduce herbivore numbers, Grey wolves could benefit local farmers, by reducing the amount of grazing pressure in their area [33]. It is essential that education and awareness campaigns are maintained, to further improve social acceptance of Grey wolves and minimise the likelihood of any human-wolf conflicts, as the species continues to recover [1].

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ARTIODACTYLA CARNIVORA CETACEA CHIROPTERA RODENTIA

Wolverine

Gulo gulo

The Wolverine (*Gulo gulo*), the largest terrestrial member of the Mustelidae family, has a circumpolar distribution[2]. Because Wolverines exist at low densities[7] and have large home ranges, they require vast areas of suitable habitat for viable breeding populations[8]. Wolverines select habitats that promote reproduction and survival through limited negative influence by human activities and relatively high food availability[9]. It is a solitary, generalist species that obtains food by scavenging or hunting, and caching food in summer and winter[10]. Due to special dentition and associated musculature, the Wolverine is able to forage on frozen meat and bone[8]. In Europe, it primarily consumes Reindeer (*Rangifer tarandus*)[10] and, when Reindeer is not available, Eurasian elk (*Alces alces*)[11].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
	VU			+196%	
Forest, Shrubland, Grassland, Wetlands (inland)[1]	Global: Least Concern (2015)[2] Europe: Vulnerable (2018)[1]	Global: Decreasing (2015)[2] Europe: Stable (2018)[1]	Global: Unknown[2,3] Europe: 2,260 (2015)[2]	Increasing, +196% (1989–2016)[4]	Increasing* (1955–2015/2016)[2,5,6]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In the Upper Pleistocene, the Wolverine occurred as far south as the Czech Republic[12] and was widespread through central and eastern European countries including the United Kingdom, Denmark, France, Germany, Switzerland, Estonia, Latvia, Hungary and the Ukraine[13]. With progressive warming, the species retracted northwards into Scandinavia and Russia, but steep declines only began in the mid-1800s through intense human persecution[14]. The species was considered functionally extinct in southern Norway by the 1960s[15] and had declined in Sweden, Finland and Russia by the end of the 20th century[7,8,14].

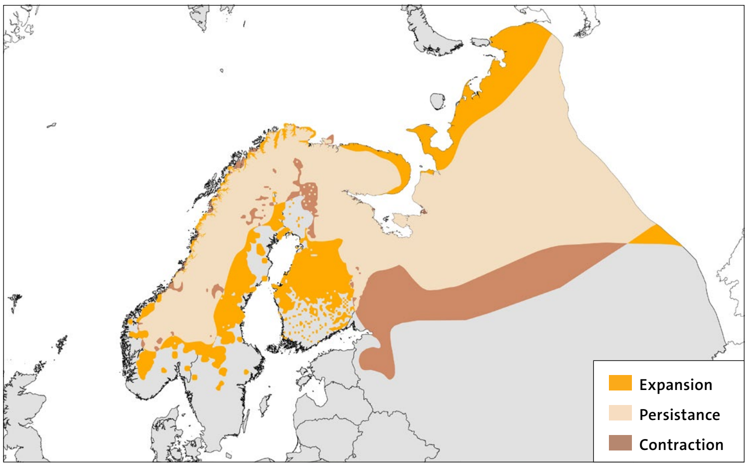


Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Wolverine in Europe between 1955[5] and 2015/2016[2,6]. Please note that differences in spatial resolution between the two maps, caused by a disparity in the accuracy of the methods used, has likely led to over- or underestimations in range change over time.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Following changes in legal protection in Fennoscandia in the late 20th century, the Wolverine's range has naturally expanded[14,16]. In Europe, populations are found in the stronghold of the Scandinavian peninsula and Finland, as well as in Karelia, the Russian Kola peninsula, and more widely in European Russia, west of the Ural Mountain range[1,16,17]. Once thought to be restricted to areas with persistent spring snow cover, the species has been expanding further south in Fennoscandia, into the boreal forest landscape (Figure 1a)[18]. The European populations have a relatively continuous distribution[2]. Exact changes in spatial distribution could not be calculated from the maps, due to differences in spatial resolution caused by a disparity in the accuracy of the methods used[2,5,6].

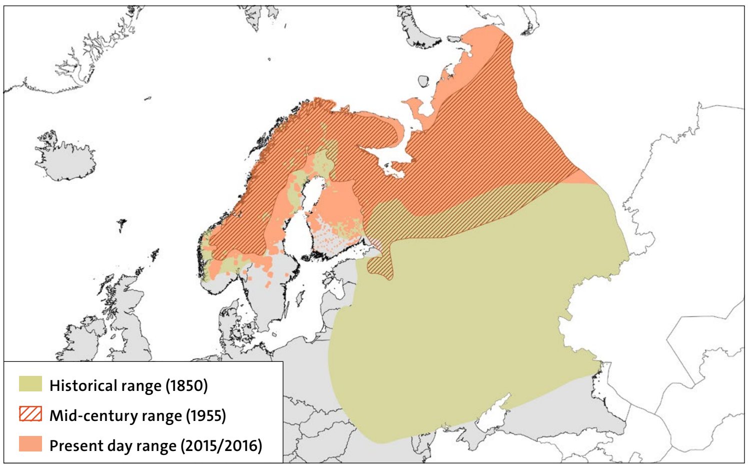
The average rate of change among the Wolverine populations in the Living Planet Index (LPI) database was a 196% increase between 1989 and 2016[4]. The most positive decadal rate of change on average among the populations occurred during the 1990s. However, since this time, these decadal increases have slowed, with the rate of change stabilising between 2010-2016 (Figure 2)[4]. During 2010-2016, 38% of populations in the LPI database increased, 15% remained stable, and 46% declined. Most of the recent declining populations are in

Russia, but reasons for these declines could not be found in the LPI database[4]. Wider literature states that although the Karelian population is slowly increasing, other Russian populations are thought to be declining[2], possibly due to low reindeer density[19], high human density[19] and high levels of poaching for fur[20].

DRIVERS OF RECOVERY

The overall increase in the abundance and distribution of the Wolverine in Europe can initially be attributed to a drastic change in legislation. Much of the historic contraction observed for the Wolverine can be attributed to human persecution due to its depredation of semi-domestic Reindeer and Domestic sheep (*Ovis aries*)[14] which was reinforced by a bounty payment system. Legal protection, which started in Sweden in 1969, and was established in Norway between 1973 and 1983[14,24], and in Finland in 1982[25], as well as a general change in perception towards carnivores in Europe[26], has resulted in increases in populations[14], and allowed the Wolverine to spread naturally into the forested landscapes from which it had been extirpated[18]. Each country has a different management strategy, which has led to differences in the rates of recovery of the species. The recovery remained slow in Sweden, until the Conservation Performance Payment (CPP) scheme was implemented in 1996, which was fully established by 2002[27]. With this scheme, Reindeer herders are paid based on how many documented Wolverine reproductions occurred in their district. Such payments are intended to offset any costs associated with livestock losses, whilst also giving Wolverines a tangible conservation value and encouraging herders to take actions that decrease livestock losses[27]. The programme has been successful, with the Swedish Wolverine population more than doubling in a decade[27]. On the other hand, population recovery remains slow in Norway, where Wolverines continue to be legally culled and national Wolverine target numbers are low[28]. In Finland, compensation schemes and strict protection laws have been implemented, but the country's rate of population increase is still lower than in Sweden[16,27]. The growth of the Finnish population was aided by translocations of individuals to outside of the Reindeer husbandry area between 1979 and 1998, to establish a larger Wolverine breeding population and minimise Human-Wolverine conflict[3,16].

Figure 1b. Distribution of Wolverine in 1850[8], 1955[5] and 2015/2016[2,6]. Please note that there are differences in spatial resolution between the maps, caused by disparities in the accuracy of the methods used, which has likely led to over-or underestimations. For example, the present-day range in Sweden and Norway is thought to be an overestimate as it includes both the resident population, and areas of sporadic occurrence[3].



BENEFITS OF COMEBACK

The Wolverine is a charismatic mesocarnivore which plays a unique role in its ecosystem, interacting with other species as both a predator and a scavenger[29,30]. The species has the intrinsic value of contributing to the integrity of the carnivore community in some northern European ecosystems[31]. Recently, some tourism operators have been offering Wolverine watching, which can help to attract people to the area and boost the local economy[32].

OUTLOOK

Although the species is generally stable or increasing in abundance and has a continuous distribution in Europe, the population size remains small. European Wolverines are therefore classified as Vulnerable by the IUCN[1]. Thus, there remains much potential for further recovery. The differing management plans between countries which share a transboundary population, mentioned previously, is particularly problematic for the species' recovery. For example, the increasing Wolverine abundance in Sweden, leads to more Wolverines dispersing into Norway, where national target numbers are low. Simultaneously, the culling in Norway is slowing the recovery of the species in Sweden[28]. Although collaboration between the two countries has intensified in recent years, especially with regards to monitoring[33] and data sharing[34], the mismatch in conservation actions confounds both countries' conservation efforts. Thus, there is a strong need to further coordinate conservation plans and actions across Fennoscandia, and to avoid harvest levels that are too high and unsustainable[3,28]. Furthermore, the scale of national management plans and landscape protection should be increased[35]. In Sweden, for example, actions focus on the alpine Reindeer husbandry areas. The Wolverine population, however, is expanding further south into boreal forests. Such changes in population extent must be considered and included in management plans, to ensure decisions are not based on incomplete population data[18]. Management should also focus on increasing connectivity amongst populations, particularly between the Scandinavian and Finnish/ Russian populations, to ensure gene flow occurs between these areas[3]. Finally, there is also an overall need to increase research and monitoring of the species, particularly in Russia, although this is often made difficult by its low densities, elusive nature and preference for remote areas[1].

Reindeer husbandry is an important aspect of Sámi culture[36]. As Wolverines predominantly feed on Reindeer, and occasionally Domestic sheep, there is much potential for conflict with indigenous Reindeer herders and Domestic sheep farmers[27]. Wolverines are often viewed as cunning, fierce and dangerous by people living in the Arctic regions[37]. Human intolerance therefore remains a significant threat to Wolverine populations[1]. The CPP scheme in Sweden has helped to give Wolverines a tangible financial value, which has reduced Human-Wolverine conflict in the area. However, such schemes are not in place in other countries within the Wolverine's range, where legal and illegal hunting continues[27]. Improving public support, through CPP and awareness-raising schemes, is therefore essential for the future conservation of the Wolverine in Europe.

THREATS AND PROTECTION	
Legal protection	• EU Habitats Directive (Annexes II and IV) – the population in Finland is listed in Annex IV[21] • Bern Convention (Appendix II)[22] • Sweden, Norway and Finland also have national Wolverine management plans[1]
Current threats (Global)[2]	• Residential & commercial development (housing & urban areas, tourism & recreation areas) • Agriculture & aquaculture (livestock farming & ranching) • Transportation & service corridors (roads & railroads) • Biological resource use (hunting & trapping terrestrial animals, logging & wood harvesting) • Human intrusions & disturbance (recreational activities)
Current threats (Europe)[1]	• Residential & commercial development (tourism & recreation areas) • Agriculture & aquaculture (livestock farming & ranching) • Biological resource use (hunting & trapping terrestrial animals)
Current threats (local)	• Energy production & mining (renewable energy) – e.g. a wind farm in Uljabuouda in Norrbotten, Sweden is potentially reducing the number of Wolverines in the area[23].

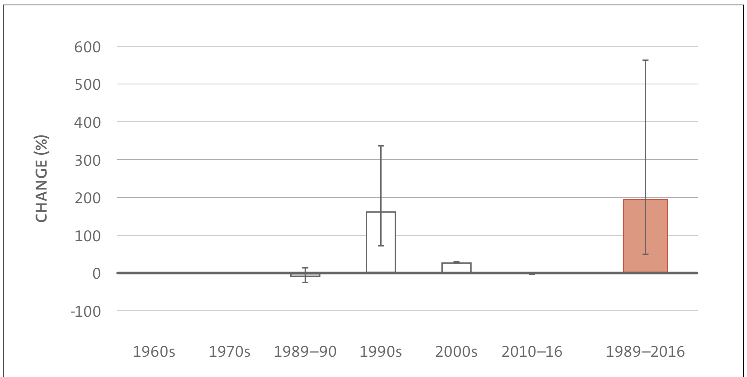


Figure 2. Average rate of change among Wolverine populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1989 and 2016 (coloured-in bar). The percentage change for 2010–16 is -1.82% and not visible on the chart. Decadal change does not sum to overall change. The trend is based on 19 populations from across the range, representing a minimum of 6,127 individuals, covering 100% of all countries of occurrence. This estimate is larger than the European population size estimate because of the inclusion of more recent data in the Living Planet database, collated after the European Red List Assessment was published. For any given year the number of populations ranges from 3 to 17 (see Appendix X for details on methods and dataset).

REVIEWED BY:

Dr Jens Persson

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Grey seal

Halichoerus grypus

The Grey seal (*Halichoerus grypus*, which translates as hooked-nosed sea pig[6]) has two subspecies, the Northwest Atlantic Grey seal (*H. g. grypus* in North America) and the Northeast Atlantic Grey seal (*H. g. macrorynchus* in Europe)[2]. The European subspecies is made up of two populations, East Atlantic and Baltic, that differ in size[7], breeding habitat[8,9] and pupping dates[2]. Some recognise these two populations as different subspecies[2]. Grey seals are generalist feeders[10], and in Europe feed mainly from the seabed (demersally)[11] to depths of 100 m[12]. The species is active day and night[13], and may travel very long distances between haul-out sites (where it rests and moults) and specific breeding colonies[10].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Marine Neritic, Marine Oceanic, Mesopelagic, Marine Intertidal, Marine Coastal/ Supratidal[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2015)[1]	Global: Increasing (2016)[2] Europe: Increasing (2015)[1]	Global: 316,000*(2016)[2] Europe: 133,000* (2019)[3,4]	Increasing, +6,273% (1978–2016)[5]	Increasing**[2,25]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Grey seal historically had a continuous distribution along mainland Europe[14] and permanent breeding grounds as far south as Brittany[15]. Grey seals have been hunted since the Neolithic period[16] and have experienced intense hunting pressure across their European range[15] leading to population decline and local extinctions. Hunting for utilisation resulted in virtual extinction in the Wadden Sea and Dutch North Sea coast as early as the end of the 16th century[17]. Decline and subsequent extinction in the Kattegat-Skagerrak and southwestern Baltic in the early 1900s was attributed to the introduction of bounty systems[14,18]. The Baltic once had the largest European population of grey seals[7], but conflict with fishermen led to bounty systems which reduced grey seal numbers from an estimated 88,000–100,000 in 1900 to 20,000 in 1940[19]. Severe declines in the UK lead to protection as early as 1914 leading to a subsequent increase in population in this region[15].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

While the map shown in Figure 1a shows an area of contraction between 1964 and 2016 in the region between the United Kingdom and Iceland this is likely an artefact of different map resolutions as opposed to a genuine decline in range here. Now, with satellite tracking data, there is a more precise understanding of true Grey seal distribution than in the past[4]. The Grey seal has been able to recover a lot of its European range over the past 50 years. Areas along mainland Europe have been gradually recolonised since the end of the 1970s[14]. The United Kingdom was the source population for the recolonisation of the North Sea[14,17]. The recolonisation in the southwestern Baltic was from the Baltic subpopulation[7]. However, breeding in this region is low compared to the North Sea recolonisations due to multiple possible factors. One is that the Baltic subpopulation prefers to breed on ice and is less adapted to land breeding[18].

The average rate of change among the Grey seal populations in the Living Planet Index (LPI) database was a 6,273% increase between 1978 and 2016 (Figure 2)[5]. This high increase throughout this time period is well documented in the literature and has occurred throughout most of its range. In some areas of recolonisation such as the Wadden Sea this growth has been exponential[20]. The largest increase has occurred in the Netherlands, which now has the largest breeding colony on mainland Europ[e 20]. The United Kingdom's population has grown steadily since monitoring began in 1960 and now has the largest European population estimated

* *Represents number of mature individuals, total population estimate (including all age classes) is approximately double.*

** *Percentage change was not calculated from the spatial analysis due to differences in map resolutions* at 150,000 in 2018 which accounts for 40% of the global population[21]. The only population in the Living Planet database to experience an overall decline in this time period was in Iceland[22], this decline is corroborated by the wider literature[23], where it has been attributed to hunting[24].

DRIVERS OF RECOVERY

As exploitation has been responsible for historic decreases of a once abundant species, protective measures have contributed to the increase in abundance and recolonisation of Grey seals around much of the European continent[14]. The species became protected throughout its European range in the 20th century[14], beginning with the United Kingdom in 1914[15]. The early hunting ban in the United Kingdom resulted in the recovery of the local population, allowing for the subsequent recolonisation of much of the North Sea[17]. Protective measures in place for Grey seals in many countries include limiting harvests, culls, disturbance and by-catch[8]. Many seal conservation areas have also been set up throughout the species' range, and the Grey seal is protected within these sites, e.g. in the United Kingdom in Sites of Special Scientific Interest (SSSIs)[30] and, in the EU, in Special Areas of Conservation (SACs) designated under the EU Habitats Directive[31]. Due to the mobile nature of the species it has also benefitted from international cooperation in species management such as in the Baltic[9] and the Wadden Sea[32]. The historic decline in the Baltic population was partly attributed to environmental pollutants (namely PCBs and DDT) causing infertility in females[19]. Subsequently, a decline in pollutant loads following the ban of these chemicals in the 1970s has led to an increase in Grey seal numbers[33].

BENEFITS OF COMEBACK

As upper-trophic level predators Grey seals are thought to play a key role in the maintenance of healthy marine ecosystems[34]. There is evidence that Grey seal birth rates in the Baltic Sea are indicative of environmental change and status[35]. As a highly mobile species they move nutrients across environments and through the water columns. Like other marine mammals, seals' foraging movements bring nutrients from the sea bed to the surface[36] and from marine to terrestrial environments when they haul out[37], potentially increasing primary productivity. In countries where they occur Grey seals also play an important role in wildlife tourism. In Scotland, for example, they are considered the third largest attraction for this industry[38].

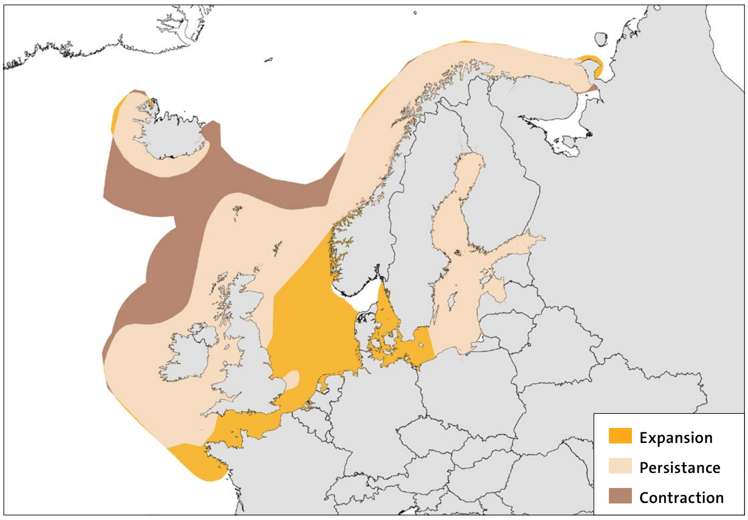

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Grey seal in Europe between 1964[2] and 2016[2,25]. Please note that contraction observed from 1964 to 2016 is likely to be an artefact of the difference in map resolution between the two time periods.

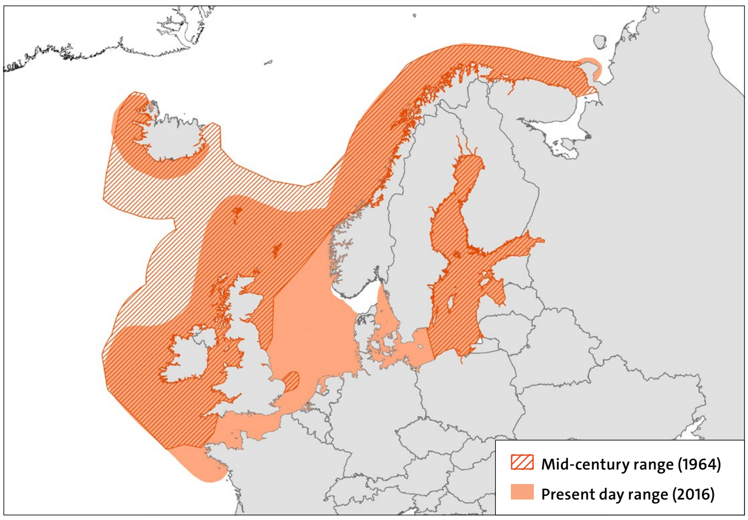

Figure 1b. Map showing the distribution of the Grey seal in 1964[2] and 2016[25]. An accurate historical map prior to 1950 was not available for this species.

THREATS AND PROTECTION

Legal protection	• EU Habitats Directive, Annex II and V [31] • Bern Convention, Appendix III [26] • Baltic population – Bonn Convention, Appendix II [27] • Helsinki Convention [28] • UK – Conservation of Seals Act 1970 [1] • Scotland – Marine Act 2010 [1] • Northern Ireland – The Wildlife Order 1985 [1] • Murmansk Region (Russia) – Red Book of Murmansk [1]
Current threats (Global IUCN Red List) [2]	• Biological resource use (fishing & harvesting aquatic resources) • Pollution (agricultural & forestry effluents) • Climate change & severe weather (habitat shifting & alteration)
Current threats (European IUCN Red List) [1]	• Biological resource use (fishing & harvesting aquatic resources) • Invasive and other problematic species, genes & diseases (viral/ prion-induced diseases) • Pollution (agricultural & forestry effluents)
Current threats (local)	Baltic subpopulation • Pollution (domestic & urban waste water, excess energy) [28] • Climate change & severe weather (habitat shifting & alteration) [28]

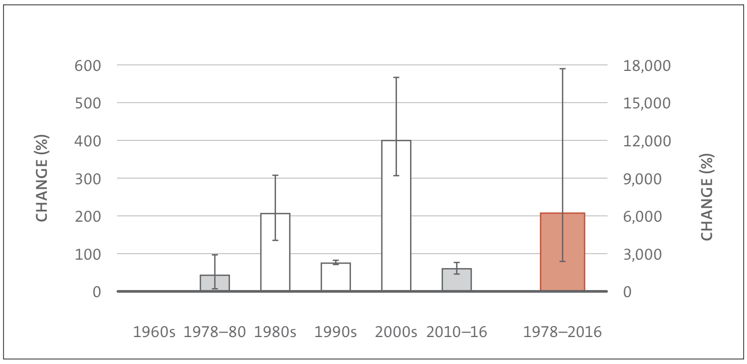

Figure 2. Average rate of change among Grey seal populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall rate of change among populations between 1978 and 2016 (coloured-in bar, secondary y-axis). Decadal change does not sum to overall change. The trend is based on 18 populations from across the range, representing a minimum of 116,863 individuals, or 44% of the total European population of 266,000, covering 82% of all countries of occurrence. Data were missing from three countries within the species' current range, namely Belgium, Faroe Islands and the Russian Federation. For any given year the number of populations ranges from 1 to 13 (see Appendix 1 for details on methods and dataset).

OUTLOOK

The Grey seal has increased dramatically in abundance and range over the last few decades and now inhabits most of its historic range. Overall, the European Grey seal population continues to increase, and growth is still rapid in some areas of recolonisation such as the Wadden Sea [39]. Conversely, in some regions, growth has been levelling off, likely due to numbers reaching carrying capacity, including in the Baltic [40] and United Kingdom (apart from the North Sea region where the population continues to increase steadily) [41]. The Grey seal is thus classified as Least Concern by the IUCN [1]. However, in Iceland it is on the Red List for endangered populations, as it has declined over the last few decades. Even here, the most recent census estimated an increase in population, which has meant that its status has been revised from Endangered to Vulnerable [23].

The increase and reappearance of Grey seals has caused conflict with fisheries [42]. The species is often killed because it feeds on some commercially important fish species and is responsible for damaging nets and traps [1]. This is a controversial and complex topic that is location specific. Research suggests that in some areas the main conflict is driven by the perception of damage to nets rather than resource competition [43]. In some regions spatial overlap between fisheries and seals is not as great as once thought [44]. However, in other regions, spatial overlap has been shown to be high, albeit temporal overlap remains low [45]. There is also variation in economic impact to different commercial fish species [46]. Other threats for the species include pollution [47], development [48], climate change (especially for the Baltic population that breeds on ice) [40] and disturbance [49]. As Grey seals continue to increase so do both conflict and benefits (such as tourism), so it is important to understand the mechanisms behind these interactions, in order to come up with solutions whilst maintaining a healthy marine ecosystem. Examples include creating codes of conduct for ecotourists to reduce disturbance [49] and the development of non-lethal deterrents for fishing nets [50].

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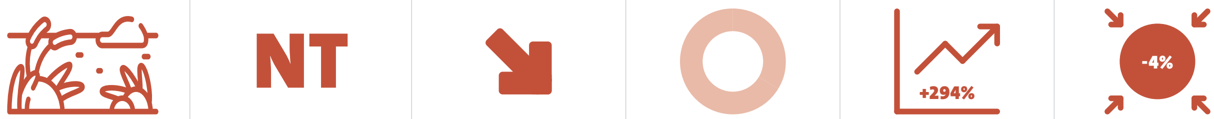
Eurasian otter

Lutra lutra

The Eurasian otter (*Lutra lutra*) is a typically solitary, territorial, and nocturnal mustelid, with an extraordinarily wide distribution, ranging from Europe and North Africa to Asia[7]. In Europe, the species occupies linear ranges along rivers and in surrounding wetlands, as well as in some coastal habitats[3,8]. Riparian vegetation belts and rock crevices are important for their holts and dens[9]. Eurasian otters are usually piscivorous apex predators, but their diet can change depending on which prey items are available, extending to crustaceans and amphibians, and, to a lesser extent reptiles, birds and mammals[3,10].



HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Wetlands (inland); Marine Neritic; Marine Intertidal; Marine Coastal/Supratidal[1]	Global: Near Threatened (2020)[2] Europe: Near Threatened (2006)[1]	Global: Decreasing (2020)[2] Europe: Unknown (2006)[1]	Global: 57,880–361,140 (2020)[2] Europe: Unknown (2006)[1,3]	Increasing, +294% (1977–2016)[4]	Decreasing, -4%, (1955–2020)*[2,3,5,6]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The earliest fossil records of Eurasian otters in Europe are from the late glacial period. It is likely that during the Last Glacial Maximum, the species was restricted to just one glacial refuge in the central or western Mediterranean region[11]. During the older and mid-Holocene, Eurasian otters colonised Scandinavia, the British Isles, and the eastern Mediterranean region[11]. Subsequently, the species became widespread throughout Europe. In the eighteenth and nineteenth centuries, Eurasian otters were increasingly persecuted, mostly either for sport, for their fur, or to protect fisheries[12,13]. Despite this, they generally remained abundant, to the extent that in Flanders, Belgium, Eurasian otter density was so high that an eradication campaign was introduced in 1889[13]. It was not until the first half of the twentieth century that their numbers began to noticeably decline in multiple countries. In Finland, for example, the numbers reported in hunting bags during this period decreased by tenfold in just a couple of decades, whilst in Luxembourg and much of France, the species became locally extinct[13].

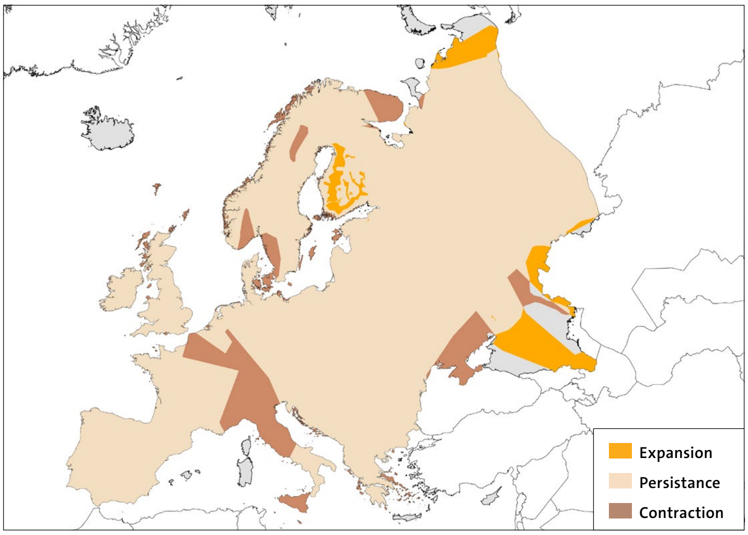


Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Eurasian otter in Europe between 1955[5,6] and 2020[2,3].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Overall, the range of the Eurasian otter decreased by approximately 4% between 1955 and 2020 (Figure 1a)[2,3,5,6]. The species' distribution, however, has greatly changed during this period. In the late 1950s, the Eurasian otter population in the United Kingdom unexpectedly crashed, with similar declines occurring elsewhere in Europe throughout the 1970s and 1990s[13]. These sudden reductions in distribution and abundance have been attributed to the introduction of the organochlorine groups of insecticides, as well as polychlorinated biphenyls (PCBs) and mercury, into waterways[7]. Following strict protection (especially EU Habitat Directive 43/92/EEC) and legislation

* *The range of the Eurasian otter initially decreased up until the 1990s but has been expanding rapidly since this time. This change in distribution trend was not detected when looking at the net change between 1955 and 2020.*

which banned such water pollutants in the 1990s, the species has slowly recovered and returned to much of its historic range in Europe[7]. Currently the Eurasian otter occurs in most European countries (Figure 1b), but they remain very rare in much of Italy, Switzerland, Belgium, western Germany, and eastern France, and are locally extinct in Luxembourg[2].

The average rate of change among the Eurasian otter populations in the Living Planet Index (LPI) database was a 294% increase between 1977 and 2016[4]. As expected, the rate of change has fluctuated over the decades, with a negative rate occurring in the 1990s, followed by much larger positive rates of change in the 2000s and between 2010 and 2016 (Figure 2)[4]. Further literature also highlights that Eurasian otter abundance has been increasing in the past two decades[2,7]. It should be noted that populations in the LPI database represent a smaller sample of the total species population, and that small populations influence the trend when calculated in this way.

DRIVERS OF RECOVERY

Numerous conservation actions have contributed to the recent recovery of Eurasian otters in Europe. Initially, strict legal protection and the banning of water pollutants in the 1970s and 1990s allowed many populations to increase in both abundance and distribution[7,20]. Specifically, populations have been able to recover naturally following the improvement of habitat and water quality, and habitat connectivity, as well as the sustainable management of activities such fishing, hunting and water abstraction[7]. A European breeding programme was also initiated in 1985 and these captive-bred individuals have sometimes been used in reintroduction projects[21]. Successful reintroduction initiatives, such as those in Czechia, Sweden, Netherlands, Spain and the United Kingdom, have likely boosted Eurasian otter numbers in parts of Europe, although some question their overall usefulness and efficiency[2,7,22,23]. Recovery centres have also been set up in the United Kingdom, Germany and Italy to aid orphaned or wounded individuals, although these likely had limited impacts on the recovery of Eurasian otter populations overall[7].

Furthermore, the ecological flexibility of Eurasian otters, in terms of their ability to widen their diet when their preferred prey is not available, has likely helped them to survive and thrive in novel areas, as they naturally recolonise habitats[10].

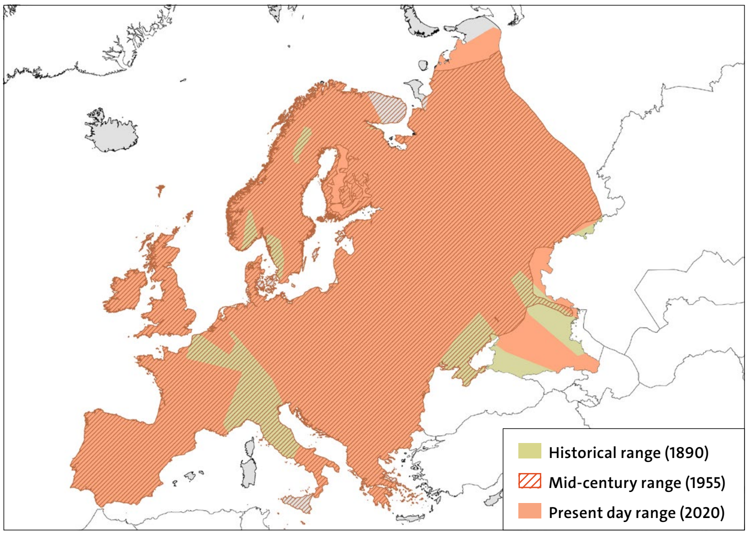
BENEFITS OF COMEBACK

The Eurasian otter is an enigmatic, flagship species for freshwater ecosystem conservation[24–26]. Otters are top predators, which play a key role in local food webs in both terrestrial and aquatic ecosystems[27]. As the Eurasian otter is particularly sensitive to environmental pollutants and has a flexible diet, both its presence and an analysis of its dietary niche could be used as environmental indicators[28,29]. Specifically, the comeback of Eurasian otters would likely indicate that the wider ecosystem is also recovering. In some areas, Eurasian otters preferentially predate on invasive freshwater species, such as the Red swamp crayfish (*Procambarus clakii*) in the Mediterranean[30]. Therefore, the species can also help with biocontrol in vulnerable ecosystems.

OUTLOOK

Although the Eurasian otter has recovered in much of Europe, it continues to decline or remain locally extinct in some areas. In fact, it is listed as

Figure 1b. Distribution of the Eurasian otter in 1890[13], 1955[5,6] and 2020[2,3].



THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix I)[14] • EU Habitats Directive (Annex II and IV)[15] • CITES (Appendix I)[16] • EU regulation of trade of fauna and flora (Annex A)[17] • Helsinki Convention[18] • Action plans for the Eurasian otter have been implemented in Italy, Latvia, Ireland, Czechia, Belgium, Luxembourg, France, and for some United Kingdom counties (Cheshire, Pembrokeshire, Somerset)[2,3]
Current threats (Global IUCN Red List)[2]	• Residential & commercial development (housing & urban areas; commercial & industrial areas) • Agriculture & aquaculture (annual & perennial non-timber crops; marine & freshwater aquaculture) • Transportation & service corridors (roads & railroads) • Biological resource use (hunting & trapping terrestrial animals; fishing & harvesting aquatic resources) • Natural system modifications (dams & water management/use) • Pollution (domestic & urban wastewater; industrial & military effluents; agricultural & forestry effluents)
Current threats (European IUCN Red List)[1]	• Residential & commercial development (housing & urban areas; commercial & industrial areas; tourism & recreation areas) • Agriculture & aquaculture (marine & freshwater aquaculture) • Biological resource use (hunting & trapping terrestrial animals; gathering terrestrial plants; fishing & harvesting aquatic resources) • Human intrusions & disturbance (recreational activities) • Natural system modifications (dams & water management/use) • Pollution (domestic & urban wastewater; industrial & military effluents; agricultural & forestry effluents; air-borne pollutants)
Current threats (local)	• Agriculture & aquaculture (livestock farming & ranching) – e.g. in England, livestock have overgrazed river banks and increased siltation of waterways used by otters[19].

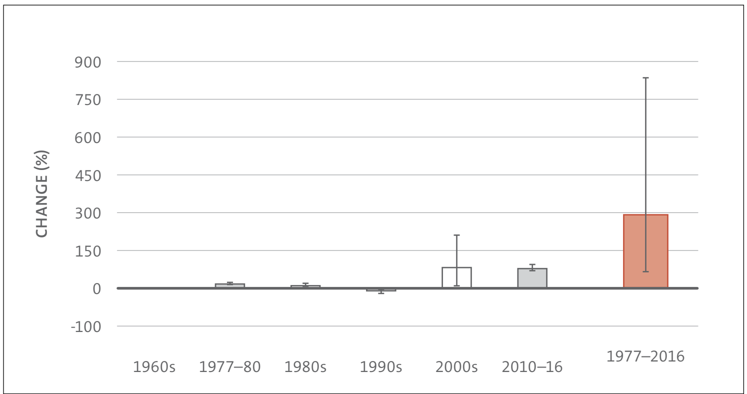


Figure 2. Average rate of change among Eurasian otter populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1977 and 2016 (coloured-in bar)[4]. Decadal change does not sum to overall change. The trend is based on 31 populations from across the range, representing a minimum of 9,132 individuals, covering 32% of all countries of occurrence. Data were missing from 26 countries within the species' current range: Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Estonia, Germany, Gibraltar, Greece, Latvia, Lithuania, Luxembourg, Moldova, Montenegro, North Macedonia, Norway, Portugal, Romania, the Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Sweden and Ukraine. For any given year the number of populations ranges from 2 to 20 (see Appendix 1 for details on methods and dataset).

Vulnerable, Endangered or Critically Endangered on the National Red Lists of Sweden, Denmark, Italy, Greece, Bulgaria and Romania[2]. Despite legislation banning water pollutants in Europe, the species remains threatened by new sources of pollution in some regions, particularly in western and central Europe[2,7]. For example, perfluorinated chemicals (PFASs) have increasingly been found in Scandinavian Eurasian otters[31]. In some parts of Europe, Eurasian otters are also threatened by human persecution, entanglement in fishing gear and traps, road collisions, and habitat modification, such as the canalisation of rivers[7]. Climate change will also likely have an impact on the species and its distribution in the near future, for example, by altering precipitation patterns and increasing the risk of flooding[25]. Therefore, to prevent any future decline of the Eurasian otter in Europe, some further conservation actions have been recommended. More riparian habitats should be protected, taking into account climate change projections, as a means to aid population expansion and increase connectivity between populations[7,25]. Downstream sections of rivers and coastal marine waters between river basins should be prioritised for protection, as they may be important dispersal pathways for Eurasian otters[3]. Similarly, the protection of existing populations should be prioritised, to form source populations for future natural recolonisation[7]. An assessment of the effect of novel pollutants and other novel threats, such as the cumulative impact of small hydroelectric power stations on Eurasian otters, is also needed to help rapidly identify suitable mitigation methods[7].

Eurasian otters have been known to predate on stocked fish species where available, as such prey items are typically a constant and easily accessible food source. This behaviour, however, could bring them into conflict with fish farmers and anglers[32]. It has become a political issue in some countries, with some stakeholders petitioning governing bodies for licenses to hunt Eurasian otters which impact their fisheries[2]. It is therefore essential that suitable compensation and awareness-raising schemes are put in place where appropriate[32]. On the other hand, the Eurasian otter is a charismatic species, frequently used in successful fundraising campaigns and to promote the conservation of riparian and aquatic habitats throughout Europe[26]. The species has been shown to elicit a particularly positive response from the general public[33] and therefore could attract ecotourists to areas, which in turn would generate extra income for local communities[26].

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Eurasian lynx

Lynx lynx

The Eurasian lynx (*Lynx lynx*) is the largest European felid and the most widely distributed species of the *Lynx* genera [6]. Adults are solitary and primarily nocturnal, being most active when hunting at dawn and dusk [6]. As their preferred prey are medium-sized ungulates such as Roe deer (*Capreolus capreolus*), the most suitable areas of habitat for Eurasian lynx are large forests which support substantial populations of these herbivores [6].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest, Shrubland, Grassland [1]	Global: Least Concern (2014) [2] Europe: Least Concern (2018) [1]	Global: Stable (2014) [2] Europe: Stable (2018) [1]	Global: ~70,000 (2014) [2] Europe: 17,000–18,000 (2016)* [1]	Increasing, +524% (1963–2016) [3]	Increasing, +156% (1950s–2016) [4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Eurasian lynx first appeared in Europe during the late Pleistocene [7], where it was widely distributed up to the Black Sea region [8]. During the past 500 years, the species has been in decline in Europe, likely due to deforestation and hunting pressure on both it and its prey species [8]. This initially led to a retreat of the species into mountainous areas, after persecution in more populous lowlands during the 16th and 17th centuries, followed by further declines in mountainous areas during the 18th century [8]. By the end of the 19th century, the species was close to extinction, with only small, fragmented populations surviving in remote areas, e.g. parts of Scandinavia and the Baltic states, the Carpathians, and the border regions of North Macedonia and Albania [8].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Since lows in the mid-20th century, the Eurasian lynx has benefited from considerable conservation attention and has seen significant recovery in range size and abundance. This recovery started with expansion of existing populations in Scandinavia and the north-western Carpathians [9], and was further facilitated by reintroductions in Switzerland, Slovenia, and Austria [10]. The Eurasian lynx is now found throughout Fennoscandia and into the northern Baltic countries, as well as populations in mountainous regions across central Europe, although these remain fragmented (Figure 1) [11]. In terms of abundance, there have also been significant increases since the middle of the 20th century – the average rate of change among Eurasian lynx populations in the Living Planet Index (LPI) database was a 524% increase between 1963 and 2016 (Figure 2) [3]. However, these monitored populations have also exhibited a slowing in the rate of increase in more recent years, and even negative rates of change, on average, between 2010 and 2016. While declines seen in this data are likely driven by changes in individual populations within European Russia and Norway [3], wider surveys also suggest that Eurasian lynx numbers have declined or stagnated in some regions in the past decade, e.g. in Scandinavia, Bulgaria, Ukraine and the Balkan population [11].

* *This estimate includes the population in European Russia – excluding this leaves a European population of 8,000 – 9,000 individuals.*

DRIVERS OF RECOVERY

Initial recovery in the strongholds of Scandinavia and the Carpathians during the mid-20th century was likely caused by a combination of factors. A reduction in deforestation and subsequent increased habitat availability, an increase in prey species (particularly medium sized ungulates such as Roe deer (*Capreolus capreolus*)), and reduced human persecution due to the introduction of legal protection, are all likely to have contributed to observed increases in range and abundance [9,16]. Since 1970, there have also been numerous attempts across central and western Europe to reintroduce Eurasian lynx into areas where they were historically located [17]. Some of these have been successful, for example, the establishment and continuing increase of a population across both the French and Swiss sides of the Jura Mountains following reintroductions into Switzerland in 1974 and 1975 [18,19]. However, the long- term success of some reintroductions has been questioned as result of genetic analyses which have suggested that small numbers of founders have limited the genetic diversity of some reintroduced populations, and so genetic reinforcement through further translocations may be needed to remedy this [17,20,21].

BENEFITS OF COMEBACK

As one of the few remaining large carnivores in Europe, Eurasian lynx play a key role in providing top-down regulation of native ecosystems, influencing population dynamics of both mesocarnivores and herbivores, and potentially initiating cascading influences throughout these assemblages [22]. For example, in Finland, Eurasian lynx have been shown to influence the number of Red foxes (*Vulpes vulpes*) and therefore also influence populations dynamics of Mountain hares (*Lepus timidus*) [23]. Finally, due to their large home range size requirements and preference for extensive wooded areas with low human disturbance, Eurasian lynx can act as umbrella species. Conservation actions aimed at increasing Eurasian lynx numbers, especially in terms of habitat protection and connectivity, can therefore benefit many other species which require similar conditions [24,25].

OUTLOOK

While the overall European Red List assessment lists the Eurasian lynx as Least Concern [1], the fragmented nature of the species' distribution across the continent and the lack of migration and gene flow between isolated populations means that the status of individual Eurasian lynx populations varies significantly by location [26,27]. All reintroduced populations are still listed as either Critically Endangered (Bohemian/Bavarian/Austrian, Harz, Vosges) or Endangered (Alpine, Dinaric, Jura) due to small population sizes [11]. The native population in the Balkans, recognised as subspecies *L. l. balcanicus*, is also listed as Critically Endangered and is considered a conservation priority [11,28,29]. While there remain significant areas of unoccupied habitat potentially suited to Eurasian lynx, i.e. densely forested regions, these areas are often fragmented and separated by barriers such as roads, which prevent natural dispersion of individuals

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix III; ssp. *L. l. balcanicus* listed under Appendix II) [12] • EU Habitats Directive (Annexes II and IV; exception from Annex II in Finland and Latvia; listed under Annex V and excepted from Annex II in Estonia) [13] • CITES (Appendix II) [14] • Protected and hunting prohibited in most range countries; listed as game species in Estonia, Norway and in some regions of European Russia where it is abundant; protected but some hunting under derogations in Sweden, Finland, Romania and Latvia. [1]
Current threats (Global) [2]	• Agriculture & aquaculture (annual & perennial non-timber crops; wood & pulp plantations; livestock farming & ranching • Energy production & mining (mining & quarrying) • Transportation & service corridors (roads & railroads) • Biological resource use (hunting & collecting terrestrial animals) • Invasive and other problematic species, genes & diseases (invasive non-native/alien species/diseases)
Current threats (Europe) [1]	• Agriculture & aquaculture (livestock farming & ranching) • Transportation & service corridors (roads & railroads) • Biological resource use (hunting & collecting terrestrial animals; logging & wood harvesting)
Current threats (local)	N/A

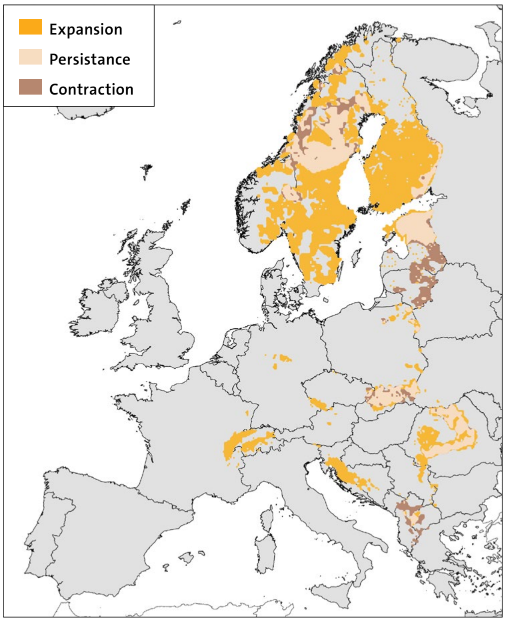

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Eurasian lynx in Europe between 1950[4] and 2016[5]. Note that European Russia, Moldova, Belarus, and Ukraine (aside from the Carpathians) are excluded from these distribution maps due to lack of available data.

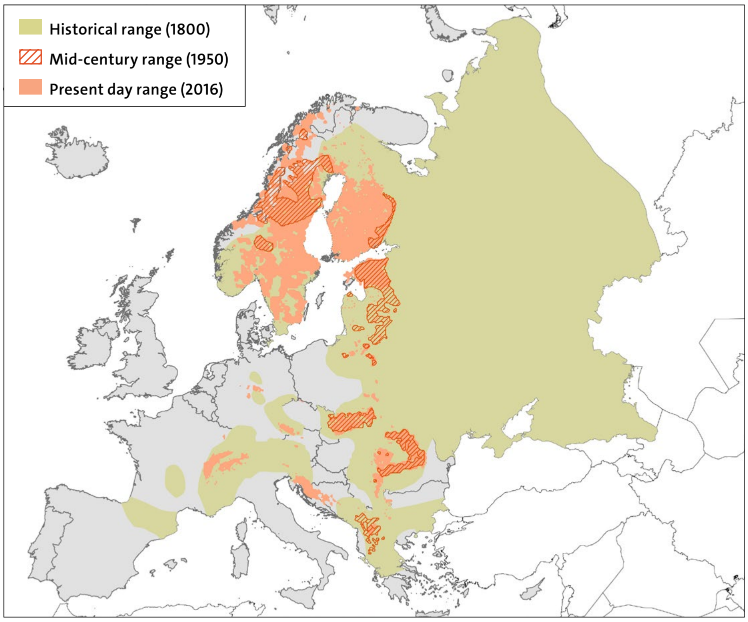

Figure 1b. Distribution of the Eurasian lynx in 1800[8], 1950[4] and 2016[5]. Note that the historical map does not exclude the countries mentioned in Figure 1a, and therefore reduction in distribution from these areas represents a change in map extent rather than a change in range.

and subsequent range expansion[10,26,30]. Further programmes of reintroductions are still occurring, such as in the Palatinate Forest in Germany[31], but establishing stepping-stone populations to join up existing populations may be required[32–34]. This should be paired with genetic monitoring to reduce the risk of inbreeding within metapopulations, and the use of assisted dispersal to increase gene flow if required[35]. Maintaining habitat connectivity between suitable patches is also an important consideration for landscape scale conservation planning for this species[33,35].

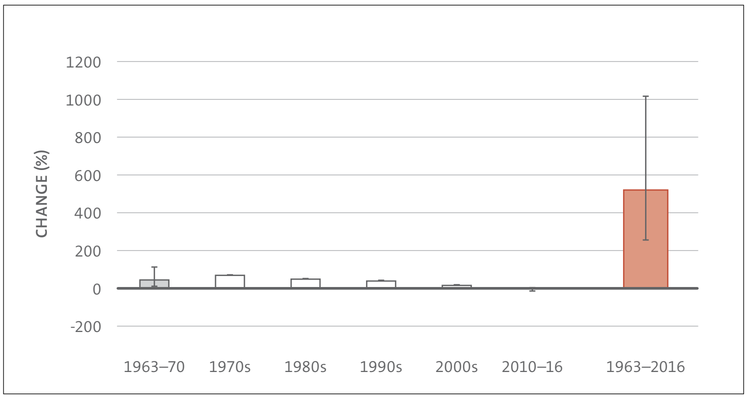

Figure 2. Average rate of change among Eurasian lynx populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1963 and 2016 (coloured-in bar). The percentage change for 2010–16 is -5.11% and not visible on the chart. Decadal change does not sum to overall change. The trend is based on 75 populations from across the range, representing a minimum of 14880 individuals, or 83% of the total European population of 2018, covering 70% of all countries of occurrence. Data were missing from 9 countries within the species' current range: Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Moldova, Montenegro, Slovenia, and Spain. For any given year the number of populations ranges from 2 to 61 (see Appendix 1 for details on methods and dataset).

Despite the charismatic nature and ecological importance of this felid, as with all large carnivores there is the potential for human-wildlife conflict, particularly when reintroduced to areas where they have been absent for extended periods of time[4]. It is therefore key that conservation interventions to promote recovery of this species, such as reintroductions or reinforcement of populations, are paired with participatory approaches including relevant actors like farmers and hunters[28,36]. Other actions to reduce conflict which have been successfully implemented in some regions include sustainable management of wild ungulate prey species; funding for smallholders to introduce husbandry practices which reduce vulnerability of livestock to large carnivores (e.g. improved fencing, use of overnight enclosures), and if necessary, reimbursement for livestock damage; and taking Eurasian lynx presence into account in hunting ground leases[28,36]. Mitigating conflict with local people while carrying out reintroductions and reinforcements that have been considered at a transnational scale[20,35] could help to facilitate further expansion of the Eurasian lynx in Europe.

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Manuela von Arx

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Iberian lynx

Lynx pardinus

The Iberian lynx (*Lynx pardinus*) is a solitary[7], territorial[8] apex predator, and one of the most endangered carnivore species globally[1]. It is a habitat and feeding specialist, occupying shrublands in the Iberian Peninsula and feeding almost exclusively on European rabbits (*Oryctolagus cuniculus*)[1], which make up approximately 90% of its diet[9].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Shrubland[1]	Global: Endangered (2014)[1]	Global: Increasing (2014)[1]	Global: 1,111 (2020)[2]	Increasing, +252% (1988–2016)[3]	Decreasing (1960–2018)*[4,5]
	Europe: Endangered (2014)[1]	Europe: Increasing (2014)[1]	Europe: 1,111 (2020)[2]		

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Iberian lynx was sympatric with the Eurasian lynx in southern France and Iberia during the Pleistocene[10]. The species was subsequently widespread throughout the Iberian Peninsula, which acted as a Pleistocene refuge for the European rabbit[11]. However, during the last five centuries, the Iberian lynx became increasingly rare in the north and was mostly restricted to the south-western quarter of the peninsula[6,12]. By the mid-1960s, just a few south-western populations still persisted, and the species had an increasingly fragmented distribution[4,12]. Human persecution, habitat loss and fragmentation, and a decrease in European rabbit numbers due to disease are all thought to have contributed to this precipitous population decline and range restriction[12,13].

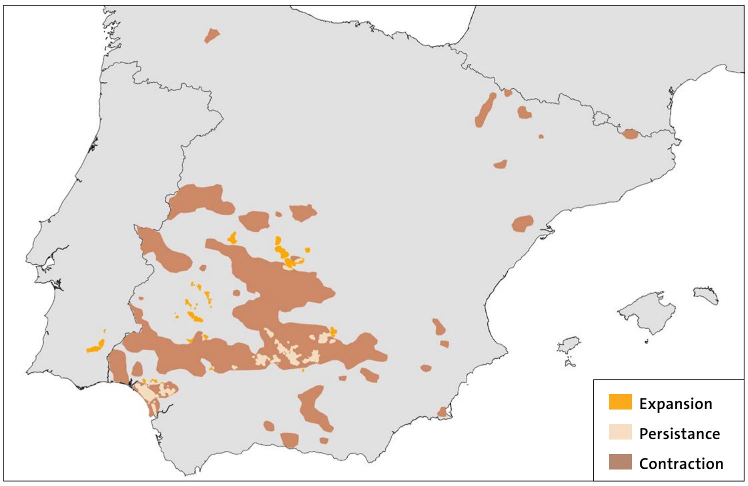


Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Iberian lynx in Europe between 1960[4] and 2018[5]. Please note that contraction observed from 1960 to 2018 could be slightly overestimated, due to the difference in map resolution between the two time periods.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The latter half of the 20th century saw a drastic range reduction (Figure 1a)[12,15]. At this point, the Iberian lynx occupied just over 1% of its historical range in Europe. This decline is comparable to figures reported elsewhere, which quote a range loss of approximately 80% between 1960 and 1985[4,16], and approximately 90% between 1985 and 2001[14,15]. The Iberian lynx distribution remained restricted to the south-western part of the Iberian Peninsula even into the early 2010s, having existed in just two populations since the early 2000s, at Andújar-Cardeña and Doñana[14,15]. The decrease in the Iberian lynx's distribution between the 1960 and 2018 maps could be somewhat overestimated due to the difference in spatial resolution between the maps, with the 1960 map being coarser[4,5]. Despite this overall decline in distribution, between 2008 and 2018 the species' range has expanded[1,5,17]. Following several reintroduction projects over the last 10 years, seven populations currently exist in Spain, with one population now occurring Portugal, where the species had previously been extinct[18,19].

The average rate of change among Iberian lynx populations in the Living Planet Index (LPI) database was a 252% increase between 1987 and 2016 (Figure 2)[3]. Although the LPI dataset showed a slight decadal decrease in the average rate of change amongst populations during

* *Percentage change was not calculated from the spatial analysis due to differences in map resolutions. It should be noted that the distribution has been increasing during the last 20 years[6].*

the 1990s, there was a positive rate of change during the 2000s, which further increased between 2010–2016 [3]. This increase in population abundance is again likely attributed to successful conservation efforts, including captive breeding programmes and reintroductions [19,20], as well as habitat management and the natural recovery of European rabbit populations over the last decade [6]. Progress in recent years led to the species being downlisted from Critically Endangered in 2008 to Endangered in 2014 [1].

DRIVERS OF RECOVERY

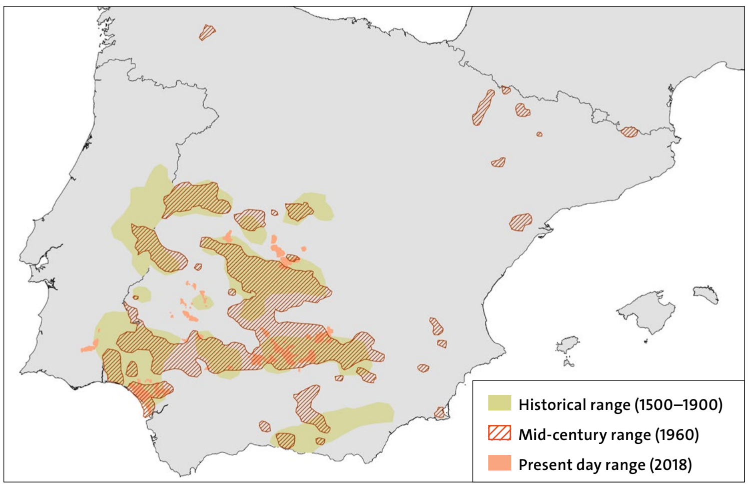
As discussed above, the initial decline observed in the latter half of the 20th century has been attributed to a combination of prey base depletion through disease, habitat loss and fragmentation, and non-natural mortality [13,16].

After the species was declared Critically Endangered in 2002, management strategies were intensified within the framework of several EU LIFE projects [27]. These included a variety of conservation measures such as habitat quality improvements, monitoring, disease prevention and addressing both natural and human-caused mortality [27]. The latter focuses on public outreach, patrols for illegal poaching and increased road safety (e.g. under/overpasses, reduced speed zones, fencing, reflective lighting) [27], and these actions are argued to have greatly decreased mortality [28]. Stakeholder engagement has led to some landowners signing agreements with relevant administrations in order to, for example, suspend European rabbit hunting [28]. There is also thought to be less illegal hunting of Iberian lynx due to increased awareness-raising and more frequent monitoring for illegal traps [20]. However, it should be noted that the species still often gets caught in traps set for other species, such as Red foxes (*Vulpes vulpes*) [29]. The involvement of landowners is important, as the majority of Iberian lynx occur on private property [27].

There are currently several captive breeding centres [30] from which individuals, along with other wild individuals, have been used for reintroductions [31]. Since 2009, populations have been reintroduced to Guadalmellato, Guarrizas, Vale do Guadiana, Matachel, Montes de Toledo and Sierra Morena Oriental [18]. Individuals have also been translocated to boost the genetic diversity of small populations [1]. Intensive habitat and prey restoration practices, such as creating artificial cavities for breeding dens and European rabbit restocking efforts, are also thought to have helped sustain these recovering populations [27].

Overall, the conservation status of the Iberian lynx has enjoyed significant improvements over the past two decades, with much of this being attributed to habitat management and reintroductions. In fact, Bolam *et al.* (2021) [32] showed that without conservation actions, there was a relatively high probability that the Iberian lynx would have gone extinct by 2020.

Figure 1b. Distribution of the Iberian Lynx in 1500–1900 [6,21], 1960 [4] and 2018 [5].



THREATS AND PROTECTION	
Legal protection	• EU Habitats Directive (Annex II* and IV)[22] • Bern Convention (Appendix II)[23] • CITES (Appendix I)[24] • EU regulation of trade of fauna and flora (Annex A)[25] • Nationally protected in Spain and Portugal[26]
Current threats (Global IUCN Red List)[1]	• Residential & commercial development (housing & urban areas) • Agriculture & aquaculture (annual & perennial non-timber crops; wood & pulp plantations) • Transportation & service corridors (roads & railroads) • Biological resource use (hunting & trapping terrestrial animals) • Invasive and other problematic species, genes & diseases (viral/prion-induced diseases) • Climate change & severe weather (habitat shifting & alteration)
Current threats (European IUCN Red List)[1]	• Residential & commercial development (housing &urban areas) • Agriculture & aquaculture (annual &perennial non-timber crops; Wood &pulp plantations) • Transportation & service corridors (roads &railroads) • Biological resource use (hunting &trapping terrestrial animals) • Invasive and other problematic species, genes &diseases (viral/prion-induced diseases) • Climate change & severe weather (habitat shifting & alteration)
Current threats (local)	N/A

Figure 2. Average rate of change in Iberian lynx populations by decade (hollow bars, grey fill represents incomplete decade) and overall change between 1988 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 7 populations from across the range, representing a minimum of 156 individuals, or 14% of the total European population of 2020, covering 100% of all countries of occurrence. For any given year the number of populations ranges from 1 to 5 (see Appendix 1 for details on methods and dataset).

BENEFITS OF COMEBACK

The Iberian Lynx is an apex predator and is considered a keystone species[33]. Its reintroduction can positively impact lower trophic levels, by reducing the abundance of mesocarnivores such as Egyptian mongooses (*Herpestes ichneumon*) and Red foxes (*Vulpes vulpes*)[34]. The reduction of mesocarnivores has been shown to result in approximately a 56% reduction in rabbit consumption by all carnivores, meaning more rabbits – which have a high socio-economic value as a small game species – are present in the ecosystem[34]. The species is also regarded as an umbrella species, as the protected status of the Iberian lynx facilitates the protection of Mediterranean shrublands and other species which occur within these habitats[35].

OUTLOOK

Recent conservation actions have led to the Iberian lynx making an impressive recovery, from just 94 wild individuals across two populations in 2002, to 1,111 wild individuals distributed across eight populations in 2020[2,33]. Cubs are successfully being born in the wild and evidence also suggests individuals are dispersing further into new territories[19]. However, the species' populations remain largely isolated and small, with infrastructure expansion and unsuitable habitat often creating barriers to potential movement and dispersal[1,18]. Thus, future conservation efforts should focus on boosting current population sizes, reducing non-natural mortality rates and establishing a metapopulation, by reintroducing more populations and restoring suitable habitats and corridors[1,18,36]. Conservation efforts should particularly focus on continuing to expand the Iberian lynx's range north, as climate projections suggest the southern regions may not be suitable for the species in the future[37].

The reintroduction of apex predators typically creates some backlash from local people who share land with the species, particularly those who may incur some costs through loss of livestock or game[38]. Previously, the Iberian lynx was often removed during general predator control[13]. However, the Iberian lynx can be beneficial to landowners. The reduction in mesopredators, and subsequent increase in small game species means the Iberian lynx's reintroduction can lead to more game being available for landowners and managers[34]. Additionally, Iberian lynx typically predate on European rabbits and rarely on livestock, with only a few recent reports of poultry being lost to Iberian lynxes[38]. Thus, generally, conflicts with farmers are likely to be uncommon[6]. Several targeted campaigns amongst stakeholders have led to increased awareness and general acceptance of the species, reducing the potential for human-wildlife conflict[35]. Furthermore, the Iberian lynx is a rare and charismatic species, which would likely be a significant positive addition to the growing nature tourism industry in the Iberian Peninsula[39].

REVIEWED BY:

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ARTIODACTYLA | **CARNIVORA** | CETACEA | CHIROPTERA | RODENTIA

PINE MARTEN

Martes martes

The Pine marten (*Martes martes*) is a generalist mesocarnivore with a broad distribution across most of central and northern Europe[1], also extending into Asia Minor, the Caucasus and western Russia. This medium-sized mustelid is primarily associated with both deciduous and coniferous forests, although in Mediterranean regions it can also be found in more open shrubland and maquis habitats[7,8].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest, Shrubland[2]	Global: Least Concern (2015)[1] Europe: Least Concern (2006)[2]	Global: Stable (2015)[1] Europe: Stable (2006)[2]	Global: Unknown[1] Europe: Unknown[2]	Increasing, +21% (1986–2016)[3]	Increasing, +6% (1955[4–6]–2016[1])

HISTORICAL DISTRIBUTION AND ABUNDANCE

Genetic evidence suggests that the Pine marten first appeared in the Pleistocene when it diverged from its sister species the Sable (*Martes zibellina*)[9,10]. The distribution of the Pine marten was likely limited by both climate and the presence of suitable forest habitats, with the species therefore restricted to appropriate refugia in the Mediterranean region and east of the Carpathians during the Last Glacial Maximum[11–13]. The warming climate after this event allowed expansion out of these areas and across most of Europe, spreading north into Fennoscandia and Great Britain[12]. Throughout its coexistence with humans, the Pine marten has been targeted for its pelt, with the first records of hunting and skinning coming from the Mesolithic era[14]. This exploitation, alongside habitat fragmentation due to deforestation for agriculture, meant that the species had already experienced significant declines by the 1600s, at which point it was considered rare in Scandinavia[15,16]. These declines continued, with additional pressure from persecution due to their role as predators of game species, and by the 1930s the Pine marten was regionally extinct in much of England, Wales, Ireland, Norway and Sweden[15–17]. Legal protection was then introduced in Norway and Sweden to prevent harvesting, and subsequently numbers recovered here in the 1940s and 1950s[16]. Post-war recovery was also recorded in Latvia, again due to limitations on harvesting, as well as increased habitat availability as a result of increases in forest cover[18].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

While some populations of this species are well monitored at a local scale (e.g. Scotland[19], Ireland[17,20] and the Białowieza Forest, Eastern Poland[21]), across the species' range in Europe there is little reliable data on abundance and distribution, and therefore it is difficult to demonstrate trends at a regional or global level[22]. However, based on monitored populations and the impacts of conservation interventions, it is likely that both the range and abundance of this species has increased in recent years, with individuals recolonising areas from which they were lost[17] and adapting to exploit novel habitats[23]. The range occupied by this species has therefore likely increased since the middle of the last century (Figure 1). This recovery is reflected in the trends seen in the abundance data for this species included in the Living Planet Index database, with the average rate of change among Pine marten populations calculated as a 21% increase between 1986 and 2016 (Figure 2)[3]. Despite this overall positive change, the average trend over the most recent period for which data is available (2010–2016) is negative, although this trend may be influenced by the small number of populations which were recorded for this time period and therefore may not indicate an overall decrease in the population more generally.

DRIVERS OF RECOVERY

Various possible factors may have contributed to the increases in abundance and range seen. As a species which relies on forest stands for denning (with dens used for resting and breeding), afforestation as a result of landscape management has been identified as a reason for recovery in Ireland and Scotland[17,26]. The return of more sustainable farming practices, and therefore increased food availability for Pine martens, has also been suggested as facilitating expansion into agricultural landscapes that were previously avoided[23]. Reductions in direct exploitation due to legal protection[17,26] and decreases in the price of fur[18], alongside bans on the use of strychnine as a pest-control poison in many European countries, are also likely to have contributed to recovery[27]. Finally, in parts of the United Kingdom active conservation interventions have been carried out to restore populations to areas of historical range, for example reintroductions in Gloucestershire[28,29], and the reinforcement of populations in Wales with translocated individuals from Scotland[30,31].

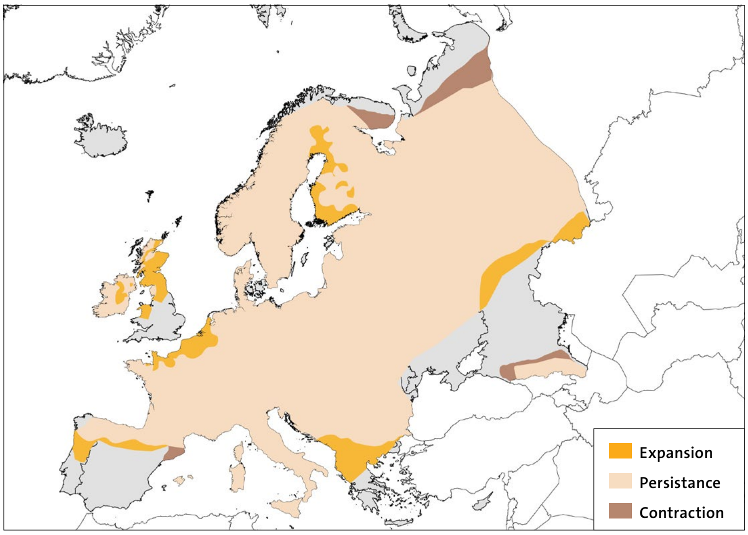

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Pine marten in Europe between 1955[4-6] and 2016[1].

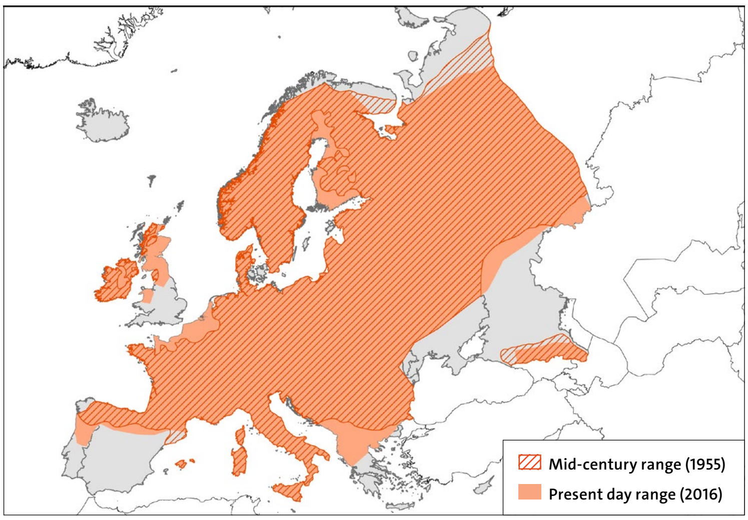

Figure 1b. Distribution of the Pine marten in 1955[4-6] and 2016[1]. Note a map of historical distribution could not be constructed due to lack of accurate information from this period.

BENEFITS OF COMEBACK

As generalist, opportunistic omnivores, Pine martens can influence dynamics in a variety of other species and so they are an important component of native woodland ecosystems[32]. They commonly consume berries from numerous different plant species, and therefore play an important role in seed dispersal[32–34]. In addition,

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix II)[24] • EU Habitats Directive (Annex V)[25]
Current threats (Global IUCN Red List)[1]	• Biological resource use (hunting & trapping terrestrial animals)
Current threats (European IUCN Red List)[2]	• Biological resource use (hunting & trapping terrestrial animals); natural system modifications (other ecosystem modifications)
Current threats (local)	N/A

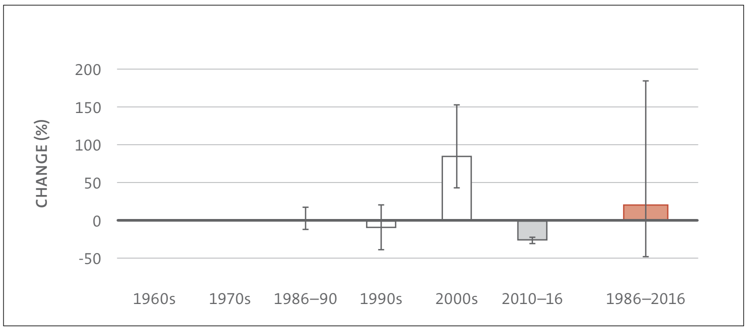

Figure 2. Average rate of change among Pine marten populations by decade (hollow bars, grey fill represents incomplete decades) and overall rate of change among populations between 1986 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 25 populations from across the range, representing a minimum of 2,068 individuals and covering 21% of all countries of occurrence. Data were missing from 30 countries within the species' current range: Albania, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Denmark, Estonia, Germany, Greece, Hungary, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Moldova, Montenegro, Netherlands, North Macedonia, Norway, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Switzerland and Ukraine. For any given year the number of populations ranges from 3 to 17 (see Appendix 1 for details on methods and dataset).

there is evidence that the recovery of Pine marten numbers in Ireland and Scotland has helped to suppress populations of invasive Grey squirrels (*Sciurus carolinensis*) which has subsequently facilitated the recovery of native Red squirrels (*Sciurus vulgaris*)[35,36]. Finally, the return of this charismatic species presents opportunities for rural communities in the form of ecotourism, as sightings of this species can be a key attraction for visitors[30,37].

OUTLOOK

There is potential for this species to expand further, especially as recent studies have suggested that the diet and habitat requirements of the Pine marten are more flexible than previously established[7,8,23,32]. Therefore, increasing abundance in currently occupied regions may promote expansion into novel locations, although this is likely dependent on the presence of linear habitats such as riparian corridors, as Pine martens tend to avoid large stretches of open space[23]. In the United Kingdom, further recovery is expected due to natural range expansion migration from Scotland into Northern England, but specific conservation interventions in the form of translocations may be required to re-establish populations further south[31]. In addition, given this species' reliance on wooded areas, further logging or forest clearance may limit recovery in future[38].

Due to its role as a generalist predator, perceptions of the Pine marten are not always positive, and therefore there may be conflict associated with its recovery. For some stakeholders, their presence may be unpopular due to potential impacts on game birds, particularly pheasant chicks[39,40]. There may also be impacts on native ground nesting birds, for example in Scotland, where there are concerns about the effects of increasing pine marten numbers on the locally endangered Western capercaillie (*Tetrao urogallus*)[41]. The Western capercaillie is also a woodland specialist, and Pine marten predation on Western capercaillie eggs has been recorded, although there is no conclusive evidence this is influencing overall population dynamics and there are many other factors contributing to the Western capercaillie's low breeding success[19,41]. Despite these issues, efforts to reintroduce Pine martens into Wales and England enjoy broad public support[39,42].

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ARTIODACTYLA | **CARNIVORA** | CETACEA | CHIROPTERA | RODENTIA

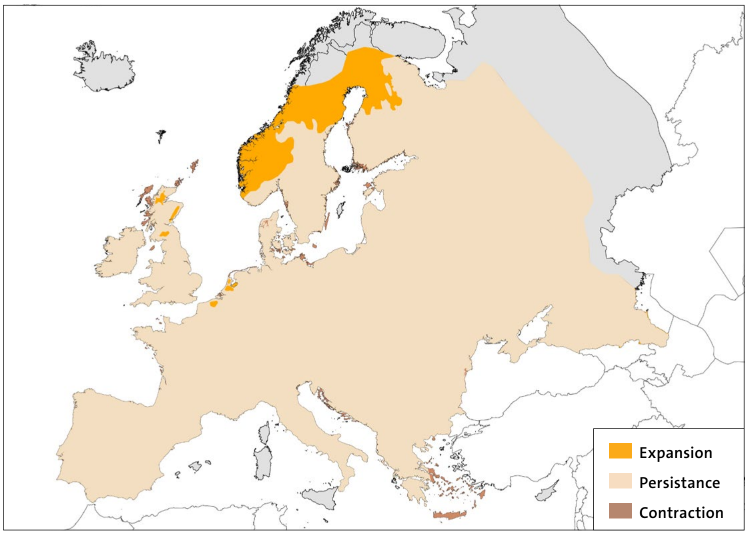
European badger

Meles meles

The European badger (*Meles meles*) is a semi-fossorial mesocarnivore, which is widely found throughout continental Europe and the British Isles[2,8]. Three European subspecies have been identified, namely *M. m. meles*, *M. m. taxus*, and *M. m. milleri*[9]. It occurs in a variety of habitats, from forested and mountainous regions to agricultural fields and urban areas[9]. Their diet is equally variable, with European badgers consuming species such as European rabbits (*Oryctolagus cuniculus*), earthworms and even olives (*Olea europaea*), depending on the area and seasonal availability of such food sources[10]. European badgers excavate vast burrows, known as setts, which can span up to 970 m² in some cases[8]. They reach their highest densities in southwest Britain, where they may occur in large social groups of over 20 individuals[7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest, Shrubland, Artificial/Terrestrial[1]	Global: Least Concern (2015)[2] Europe: Least Concern (2006)[1]	Global: Stable (2015)[2] Europe: Stable (2006)[1]	Global: Unknown[2] Europe: at least 1,500,000 (2010)[3]	Increasing, +110% (1960–2016)[4]	Increasing, +5% (1955–2015)*[2,5–7]

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the European badger in Europe between 1955[5–7] and 2015[2,7]. Please note, the contracted ranges on offshore islands and peninsulas are most likely due to discrepancies between the 1955 and 2015 map, rather than genuine contraction.



HISTORICAL DISTRIBUTION AND ABUNDANCE

Several glacial refugia for the European badger have been identified across the continent, including the Iberian Peninsula, central Mediterranean Europe, the Balkans, and possibly Moldova and the Crimean Peninsula[11]. Subfossils of the species have been found at numerous late palaeolithic sites, suggesting European badgers were widely distributed in Europe during the late glacial period[11]. It is likely that the spread of European badgers after the Last Glacial Maximum was associated with the afforestation of Europe[11].

The species remained abundant throughout the continent until the 19th and 20th centuries, when numbers began to locally decline in some countries[12–15]. In the United Kingdom, for example, European badgers were persecuted for pest control or for sport, such as badger baiting, which led to the species being noted as uncommon during the 1800s[12]. Similarly, European badger populations strongly declined in the Netherlands and Belgium during the early 1900s, where they were hunted as pests or for their fur and fat[13,14]. Trends are not known for much of Europe during this time, but European badger populations likely remained relatively stable in many regions where the species was not a major hunting target, such as in the Baltics[14,15].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

In the 1960s and 1970s, the European badger's distribution and abundance drastically declined across Europe, primarily due to a rabies (*Rabies lyssavirus*) outbreak and the subsequent European badger eradication programme, which involved

* *The percentage change in distribution may be over- or under-estimated, as the 1955 map is suspected to contain part of the Asian badger's (Meles leucurus) and Southwest Asian badger's (Meles canescens) range in eastern Europe, the latter species awaiting official sanction, and it is difficult to determine exactly where these two species' ranges overlapped with M. meles[7].*

gassing their setts[15,16]. Hunting for pest control, sport, meat and fur, as well as an increase in road traffic and collisions, also likely contributed to this period of decline[17,18]. However, following the introduction of rabies vaccinations for Red foxes (*Vulpes vulpes*) to replace the eradication programme[14,19], as well as other conservation actions, such as the initiation of European badger reintroduction programmes in some regions[8,9,14], the European badger returned to much of its historical range. It is now present throughout Europe, from the British Isles to the west of the Volga River in Russia[2,9]. The species' range is even expanding further north into Scandinavia[20,21]. Between 1955 and 2020, the European badger's range increased by approximately 5%, mostly in its northern extent (Figure 1a)[2,5–7]. It should be noted that the eastern part of its range could overlap with part of the Asian badger's (*Meles leucurus*) and Southwest Asian badger's (*Meles canescens*) range, both of which were only recently described as separate species, with the latter awaiting official sanction[7,22,23].

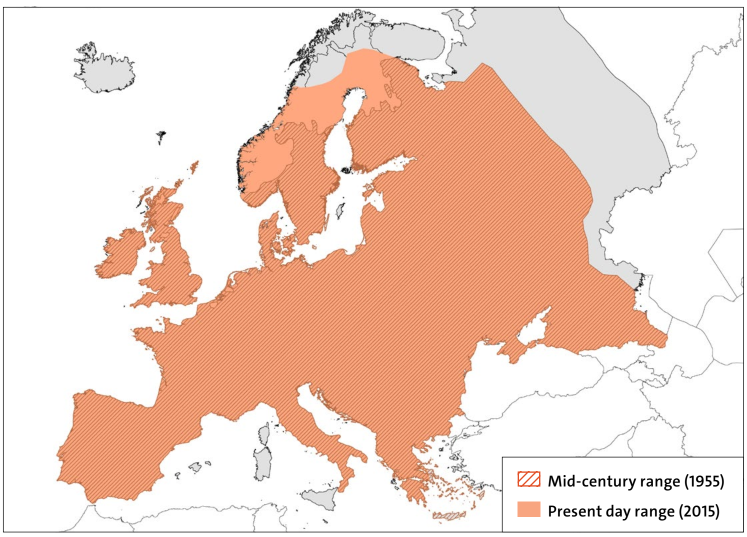
The average rate of change among the European badger populations in the Living Planet Index (LPI) database was an 110% increase between 1960 and 2016 (Figure 2)[4]. Following a negative rate of change amongst populations in the 1970s, the most positive rate of change occurred during the 1980s. However, since this time, average rates of increase have slowed each decade. According to the LPI database, between 2010–2016 the average rate of change among populations was negative[4]. This negative rate was mostly driven by strong declines in the abundance of a few populations in European Russia[4]. It should be noted that populations in the LPI database represent a smaller sample of the total species population and small populations in the LPI database can influence the trend when calculated in this way. Between 2010–2016, 39.7% of populations were declining in abundance, 22.4% were stable and 37.9% were increasing. Reasons for these recent population declines could not be identified in the LPI database[4]. The literature suggests that European badger populations throughout most of Europe have remained stable or increased in recent years, with relatively few populations thought to be locally declining, predominantly due to hunting, deliberate persecution and road traffic mortality[7,9]. Less is known about their status in several eastern European countries[7].

DRIVERS OF RECOVERY

A variety of conservation actions and other factors have aided the increase in abundance of the European badger. Legislation has encouraged recovery by suspending or restricting the hunting of badgers in several countries[8]. For example, the Protection of Badgers Act (1992) in the United Kingdom bans any sett disturbance or killing of badgers without a licence[12]. Policy changes have also led to the replacement of using chemicals to fumigate dens for rabies control with a Red fox vaccination scheme, which has greatly benefitted the species[8,14]. Other conservation actions which have boosted the European badger's recovery have included reintroductions and translocations, for example in northern Italy[25] and the Netherlands[26], which have established new populations and enhanced existing ones.

Road mortality mitigation techniques, including tunnels and fences, have been utilised in the Netherlands to reduce road mortality and encourage range expansion and connectivity between populations[13,18]. In addition to such targeted management actions, the warming

Figure 1b. Distribution of the European badger in 1955[5–7] and 2015[2,7]. An accurate historical map prior to 1950 was not available for this species.



THREATS AND PROTECTION

Legal protection	• Bern Convention (Appendix III)[24] • Nationally protected in 11 European countries, e.g. Protection of Badgers Act (United Kingdom)[8]
Current threats (Global IUCN Red List)[2]	• Biological resource use (hunting & trapping terrestrial animals)
Current threats (European IUCN Red List)[1]	N/A
Current threats (local)	• Transportation & service corridors (roads & railroads) – e.g. traffic collisions are the most common cause of death amongst badgers in the United Kingdom and Denmark[9].

Figure 2. Average rate of change among European badger populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1960 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 69 populations from across the species' range, representing a minimum of 134,790 individuals, covering 29% of all countries of occurrence. Data were missing from 27 countries within the species' current range: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Finland, Greece, Hungary, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Macedonia, Moldova, Montenegro, Norway, Portugal, Romania, Serbia, Slovakia, Slovenia, Sweden, Switzerland and Ukraine. For any given year the number of populations ranges from 2 to 58 (see Appendix 1 for details on methods and dataset).

climate, sustaining a longer snow-free period and growing season, is likely facilitating the northwards expansion of the species' distribution in Scandinavia[20,21]. With longer summers and more food availability, European badgers can accumulate more fat deposits, and therefore are more likely to survive the winter in these northern regions[21]. Furthermore, the ecological flexibility of the European badger, in terms of its ability to successfully adapt to urban and agricultural landscapes, has likely allowed them to expand their range into increasingly human-modified habitats in Europe[27].

BENEFITS OF COMEBACK

The European badger is considered an important ecosystem engineer[8]. Although more of a forager than a hunter, as a predator it may play an important role in trophic interactions, e.g. in mechanisms of mesopredator release[8,28]. They may also influence the abundance of other predators, such as Red foxes, through competition for key resources[29]. European badgers also efficiently disperse the seeds of some plants, by consuming large fleshy fruits[8,30]. Topsoil disturbance from digging behaviour at setts can change the physical and chemical properties of soil, which creates a locally altered environment within the wider landscape, creating ideal conditions for different plant and animal species to colonise[31]. Furthermore, the excavated soil and organic bedding material gathered by European badgers to furnish their setts creates valuable microhabitats for many invertebrate species[8,32,33]. The areas around setts therefore often have higher diversities of plants and invertebrates compared to their surroundings. The setts themselves can also provide shelter or breeding dens for other species[8], such as the Eurasian lynx (*Lynx lynx*)[34] and the Greek tortoise (*Testudo hermanni*)[35].

OUTLOOK

As the European badger is generally abundant and widely distributed, with a stable population trend in Europe, it is listed as Least Concern on the IUCN Red List[1,2]. Despite this, the species is declining in abundance in some countries[9] and continues to be legally hunted across 69.3% of the continent[8]. Even legal protection does not guarantee the cessation of hunting, as some countries, such as Spain, have hunting traditions which mean European badgers continue to be poached despite legal protection, whilst the United Kingdom, Ireland and France have derogations in which European badgers can be culled as part of efforts to control the spread of Bovine tuberculosis (*Mycobacterium bovis*) to livestock, where they are deemed to increase transmission risk[8,14]. Badger baiting and digging up setts also continues at the very local scale[9].

However, vehicle collisions are the most significant cause of death for European badgers in many countries[9,36]. Moreover, road construction and habitat loss have led to further habitat fragmentation[9]. It is therefore recommended that future conservation initiatives seek to increase the number of road tunnels and fences to allow European badgers to cross roads safely and boost habitat connectivity[13,18]. Where hunting legally continues, it has also been suggested that legislation is introduced which bans the destruction of large setts, to ensure some level of protection for the species in these areas[8]. Further research and monitoring of European badgers in eastern Europe is needed, as less is known about the trends and statuses of these populations[9]. More research on the potential impacts of climate change throughout its range is also required[9].

In recent decades there has been concern over the European badger's ability to host and spread zoonotic diseases to livestock, particularly Bovine tuberculosis (bTB). In England, for example, the loss of cattle to bTB has led to culling schemes which aim to control the disease by reducing European badger populations in licensed areas by approximately 70% [12]. In 2021, 33,687 badgers were culled in the United Kingdom [37]. A more holistic and sustainable approach to control bTB, including the vaccination of European badgers and cattle (*Bos taurus*), has been advocated to reduce the amount of culling in these areas [38].

There have also been concerns that European badgers could damage crops or lawns, and that setts excavated near infrastructure could become safety hazards. In such cases, fencing can be used to exclude European badgers or, on rare occasions, individuals or groups may be translocated [3,14]. Despite these concerns, studies have shown that the general public is highly tolerant of European badgers [14]. Strong, vocal campaigns against the culling of European badgers [39], and the existence of numerous local European badger protection groups [14], have demonstrated that people commonly have positive attitudes towards this charismatic species.

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ARTIODACTYLA | **CARNIVORA** | CETACEA | CHIROPTERA | RODENTIA

Harbour seal

Phoca vitulina

With the widest distribution of any pinniped species, Harbour seals (*Phoca vitulina*) occur across the Northern Hemisphere [5,6]. They can utilise a range of coastal and intertidal habitats for breeding and as haulout sites (including beaches, rocky areas, sand bars and mudflats), while also venturing further offshore to forage [1,5]. In part due to this primarily nearshore distribution, the Harbour seal has been exposed to numerous anthropogenic activities throughout the past 500 years, which have influenced this species' abundance and distribution [5,7]. Three subspecies are currently recognised [8]. All populations found in European waters are classified as *P. v. vitulina*, as are the those across the rest of the North-Atlantic distribution [9]; *P. v. richardii* occurs across the North Pacific, while *P. v. mellonae* is restricted to the lakes and rivers of the Ungava Peninsula in Canada [5,9].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Wetlands (inland), Marine Neritic, Marine Intertidal [2]	Global: Least Concern (2016) [1] Europe: Least Concern (2007) [2]	Global: Unknown (2016) [1] Europe: Unknown (2007) [2]	Global: 315,000 (2016)* [1] Europe: 65,000 (2016) [1]	Increasing, +91% (1960–2016) [3]	Stable (1955 [4]–2016 [1])**

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Harbour seal has had a dynamic past in Europe, with a long history of human exploitation – evidence of large-scale hunting of Harbour seals across the North Sea has been noted from at least the 16th century [7]. The perception that Harbour seals negatively impacted fisheries catch led to intensive hunting campaigns, often encouraged by government bounties [5,10]. These bounty schemes started as early as the 16th century (e.g in the Netherlands [10]) and continued into the 20th century in Scandinavia [7,11,12], Iceland [13] and the Netherlands [10]. This persecution resulted in steady declines, with the most dramatic decrease occurring in the early 20th century as a result of increased hunting pressure [14]. In some cases, the complete extermination of this species as a result of human activity has been recorded, as occurred in the Faroe Islands in the mid-19th century [15].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The current distribution of the Harbour seal ranges from Svalbard in the north [16] to the southern limit along the north coast of France [17] (Figure 1). Expansion back into the southerly areas of the distribution has been relatively recent – breeding populations in France had been lost by 1960, but the total protection of the species after legislation in the 1990s led to recolonisation, and there are now multiple haulout sites along the northern coastline [17,18]. In terms of contraction, the species' range may have decreased in the south-eastern Baltic since the middle of the 20th century, as there were observations of the species around islands off the east coast of Sweden (Gotland and Oland) at the beginning of this period, where the Harbour seal is no longer found [19]. In addition, the species is no longer seen along the Polish Baltic coast, but its disappearance from this area may have occurred earlier in the 20th century [20].

In terms of population numbers, the Harbour seal has broadly been recovering since the 1970s, primarily as a result of reduced hunting pressure [5,12,14,21], although population dynamics have been influenced by outbreaks of *Phocine morbillivirus*, formerly known as Phocine Distemper Virus (PDV) in some areas. These occurred in 1988 and again in 2002 [22,23], with an estimated mortality of 23,000 individuals in the first epidemic and 30,000 in 2002 [23]. Figure 2 does not show negative trends in the 1980s or 2000s, but this may be due to masking

* *Number listed refers to mature individuals only, Europe estimate refers to Eastern Atlantic subspecies P. v. vitulina.*

** *Percentage change not calculated due to differences in mapping approach between periods.*

of declines by increases in unaffected populations, or significant annual increases at other points in these decades, giving an overall positive average rate of change, especially as populations recovered very rapidly after these outbreaks. There have also been other recent declines which are not linked to disease outbreaks. Populations in Iceland were not affected by PDV but have declined significantly between the 1970s and 2006, possibly due to overharvesting, fisheries bycatch, anthropogenic disturbance or other environmental changes [13,24]. While the Icelandic population may now be showing signs of recovery, the population is still well below the 1970 level [13]. For most other populations of the Harbour seal, the population trend is now either increasing or stable, but there are concerning signs of recent declines in some Management Units in Scotland and south-east England, the causes of which are currently unknown [5,25].

DRIVERS OF RECOVERY

One of the major drivers of recovery for this species was increased legal protection implemented from the late 1970s in response to precipitous declines seen in Harbour seal populations. Legislation at both a national and European scale (e.g. bans on hunting implemented in Sweden in 1967 and Denmark in 1977 [12], the introduction of the Conservation of Seals Act in the UK [31,35] and protection under the Habitats Directive in 1993 in response to the PDV outbreak in 1988 [28]), led to reductions in hunting pressure which undoubtedly helped the Harbour seal recover in number and range. For example, in the Wadden Sea, the species increased from 3,000 individuals in 1974 to more than 35,500 in 2011 due to reduced exploitation and increased habitat protection [36], made possible by collaborative management between the Netherlands, Germany and Denmark [37,38]. The banning of PCBs under the Stockholm Convention in 2001 [39] also likely contributed to recovery, as high levels of these pollutants can cause reproductive failure in seals [40].

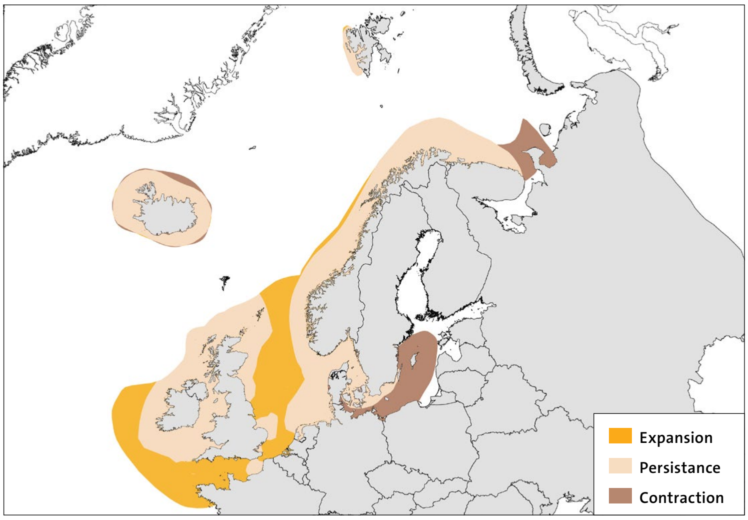

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Harbour seal in Europe between 1955 [4] and 2016 [1]. Note that while this implies an expansion of the species' at sea distribution, this is an artefact of differing estimates of offshore foraging distance and may not reflect a true change in range [26]. Because of this, the expansion shown is likely an overestimate.

BENEFITS OF COMEBACK

As a top-level predator, the Harbour seal can play an important role in marine ecosystems, and given the complexity of marine trophic webs, maintaining the balance between predator and prey species is an important aspect of ecosystem health [41,42]. Aside from their ecological value, marine mammal watching can also be a major source of income for coastal communities, with wildlife tourism a growing sector in the Scottish economy [43] and pinniped tourism becoming increasingly popular [44].

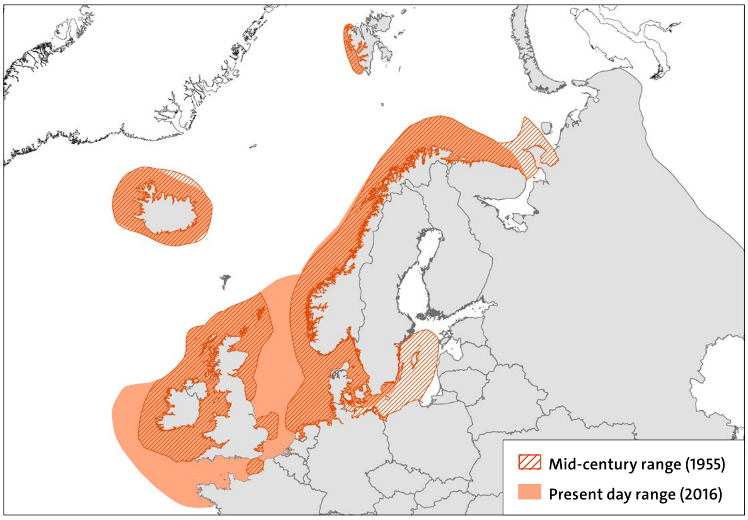

Figure 1b. Distribution of Harbour seal in 1955 [4] and 2016 [1]. Note that a map of historical distribution prior to 1950 could not be produced for this species as accurate data was not available.

THREATS AND PROTECTION

Legal protection	• Bern Convention (Appendix III)[27] • EU Habitats Directive (Annexes II and V)[28] • CMS (Appendix II) - Baltic and Wadden Sea populations only[29] • Agreement on the Conservation of Seals in the Wadden Sea[30] • National level protection in France[5]; Iceland[5]; Denmark[7]; Sweden[5]; Greenland[5]; Svalbard[5]; England and Wales (Conservation of Seals Act 1970[31]); Scotland (Marine Act 2010[32]); Northern Ireland (The Wildlife Order 1985[33])
Current threats (Global IUCN Red List)[2]	• Residential & commercial development (commercial & industrial areas) • Biological resource use (fishing & harvesting aquatic resources) • Human intrusions & disturbance (work & other activities) • Natural system modifications (dams & water management/use) • Pollution (domestic & urban wastewater; industrial & military effluents; agricultural & forestry effluents)
Current threats (European IUCN Red List)[1]	None listed
Current threats (local)	• Biological resource use (fishing and harvesting aquatic resources) – bycatch in fishing equipment has been identified as a threat in some areas including Iceland[13] and Ireland[34].

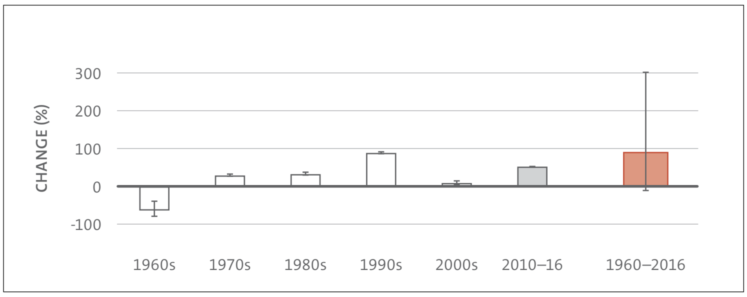

Figure 2. Average rate of change among Harbour seal populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1960 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 32 populations from across the range, representing a minimum of 61,060 individuals, or 94% of the total European population in 2007 (this percentage may be an overestimate, as total population refers to mature individuals only which may not be the case for the estimate of minimum individuals represented). Populations included cover 63% of all countries of occurrence, while data were missing from 6 countries within the species' current range: Belgium, Finland, Portugal, Russian Federation, Spain, and Svalbard and Jan Mayen. For any given year the number of populations ranges from 4 to 24 (see Appendix 1 for details on methods and dataset).

OUTLOOK

There is potential for further future recovery in this species, particularly in the southern reaches of its range where numbers are increasing[17,45,46]. Populations in the Kattegat and Southern Baltic have also shown positive trends in the past couple of decades, but there are now indications that these populations are close to carrying capacity so further growth is unlikely[47,48].

However, despite these reasons for optimism, there remain a number of threats to the Harbour seal. Past threats, such as the impact of pollution, human disturbance and conflict with fisheries remain an issue[11,20], with bycatch from fishing activity a significant cause of mortality[13]. Recovering populations may also be viewed negatively by local fisherman given the perception that Harbour seal predation can reduce available fish take[42,49]. In addition, there are ongoing threats due to the impact of human disturbance, in the form of boat traffic[50], tourism[44] and potential impacts linked to the construction of offshore windfarms[51,52]. There are also emerging threats with relatively unknown implications for Harbour seal populations, such as the impact of toxic algal blooms[53] and competition with (and even predation by[54]) Grey seals (*Halichoerus gryphus*)[55].

Finally, as with other high latitude marine species, Harbour seals are likely to be impacted by the effects of climate change[5]. While warming temperatures may facilitate expansion northwards, they are also likely to negatively affect populations at the southern edges of the species' range, due to the danger of hyperthermia, and therefore an overall northwards range shift may occur. This may also negatively influence overall population trends due to competition with existing Arctic species[5,56]. In addition, warmer sea and air temperatures may increase the risk of disease outbreaks in this species, especially given the susceptibility of populations to mass mortality events in the past[5].

Therefore, while there are reasons for optimism for the future of this important marine mammal, monitoring programmes and conservation actions may still be required to maintain healthy population levels across its range.

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Ringed seal

Pusa hispida

The Ringed seal (*Pusa hispida*) is the smallest of the true seals. It is extremely ice dependent, because it builds its breeding lairs in snow caves on top of land-fast ice[7]. The species consists of five subspecies, four of which occur in Europe. These include the Arctic Ringed seal (*P. h. hispida*); the Baltic Ringed seal (*P. h. botnica*); the Ladoga Ringed seal (*P. h. ladogensis*); and the Saimaa Ringed seal (*P. h. saimensis*)[8]. Although predominantly a marine species, the latter two European subspecies are restricted to two freshwater lakes[3,4]. The Ringed seal's story is not one of straightforward recovery but of some recent positive trends tempered by projected future declines due to climate change.

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Wetlands, Marine Neritic, Marine Oceanic, Mesopelagic[1]	Global: Least Concern (2016)[1] Europe: N/A	Global: Unknown (2016)[5] Europe: Increasing (2015)[5]	Global: Unknown[5] Europe: Unknown[5]	Increasing, +142% (1971–2016)[6]	Declining*[5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Ringed seals are predominantly an Arctic species. They require ice to breed[7] and so their range includes the most northerly latitudes of Europe. During the Last Glacial Maximum, Ringed seals migrated into the Baltic Basin[9]. The two freshwater lake subspecies, the Ladoga Ringed seal in Lake Ladoga (Russia) and the Saimaa Ringed seal in Lake Saimaa (Finland), separated from the rest of the Baltic population circa 8,000–9,000 years ago[8]. Historically, another subspecies, the Arctic Ringed seal, has been an important human food resource throughout most of its range and has been hunted by coastal communities for a long time. However, little is known about population abundance and trends of this Arctic subspecies[10,11]. The Baltic, Saimaa and Ladoga Ringed seal subspecies all experienced severe population declines in the first half of the 20th century, mainly due to overhunting[12,13]. It is estimated that there was a minimum of 180,000 Baltic Ringed seals at the start of the 20th century[14] which had declined to around 25,000 by 1940 due to culling because of perceived conflicts with fisheries[15]. In Finland and Sweden, 16,000 Ringed seals were killed annually in the 1910s[16].

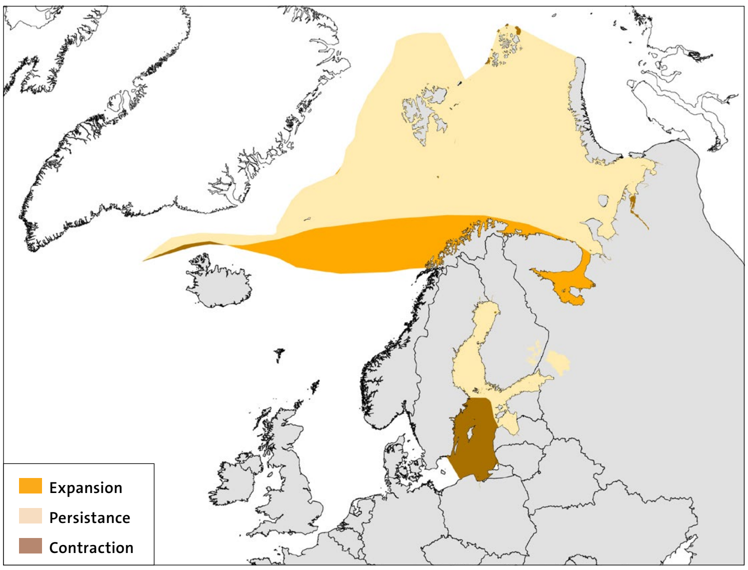


Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Ringed seal in Europe between 1964[10] and 2016[1]. Please note that contraction and expansion observed from 1964 to 2016 is likely to be an artefact of the difference in map resolution between the two time periods.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

While the map shown in Figure 1 shows an area of contraction and expansion between 1964 and 2016, this is likely an artefact of different map resolutions as opposed to a genuine change in range. On a continental scale, the range of the Ringed seal has largely remained unchanged between these time periods. However, breeding habitat has been drastically reduced due to ice cover declining[5,17]. Distribution has certainly declined for the Saimaa Ringed seal, as it once had a continuous distri-

* *Percentage change was not calculated from the spatial analysis due to map resolution being too low.*

bution throughout Lake Saimaa. By the end of the 20th century, it was reduced to highly fragmented patches that cumulatively summed to 30–40% of their former range[13].

The average rate of change among the Ringed seal populations in the Living Planet Index (LPI) database was a 142% increase between 1971 and 2016[6]. However, population estimates and trends are difficult to assess accurately for this species[10]. Ringed seals are difficult to survey as they spend little time on the surface of the ice, except for a brief period during moulting. Estimates and trends are especially difficult for the Arctic subspecies due to their remoteness and wide distribution[10]. In Svalbard, the number of Ringed seals and demographic parameters seemed to be quite stable from early 1980s–2010s[18]. However, a recent collapse in sea ice is likely to have had serious consequences for Ringed seal numbers in this area in the coming decades[19,20] and has already affected Ringed seal migration and foraging behaviour, which is leading to more energy expenditure[21].

The LPI database shows a negative trend in the 1970s and a small increase in the 1980s (Figure 2). Both the Baltic[14] and Saimaa[22] subspecies declined until the mid 1980s. The decline in these decades in the Baltic subspecies was attributed to pollution, primarily DDT and PCBs, causing reproductive failure[14]. Pollution (mainly mercury) also affected the Ladoga and Saimaa Ringed seal populations at this time, with bycatch and human disturbance also having negative impacts[13]. However, as shown in both the literature and LPI database (Figure 2) the three southern subspecies have recently shown some increases[10,13,23,24].

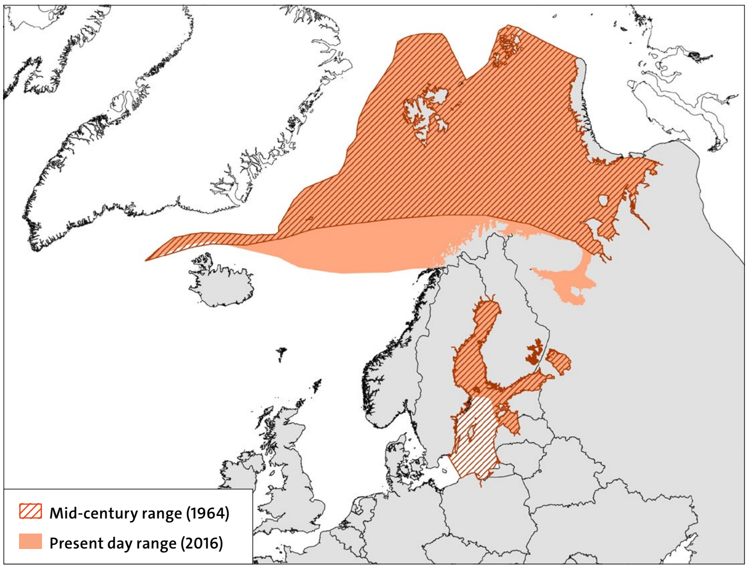
DRIVERS OF RECOVERY

Whilst some positive abundance trends for the Ringed seal have been documented in the last few decades, linked to a reduction in some threats, this species is still at risk. Hunting caused large historical declines for three of the four European subspecies. Legal protection was implemented for Baltic Ringed seals in the 1980s[28], the Saimaa Ringed seal in 1955 and the Ladoga Ringed seal in 1980[29]. These protective measures have contributed to population increases. Pollution as a threat to Ringed seal populations has decreased in recent decades. Since DDT and PCBs have been banned, the pregnancy rate of the Baltic subspecies has increased dramatically and is now over double what it was in the 1980s[30]. For the Ladoga and Saimaa subspecies, mercury loads decreased in the 1990s[13]. Conservation action has also contributed to the recovery of the Saimaa Ringed seal. Whilst legal protection was first established in 1955, little recovery occurred until the 1990s when water fluctuations and quality improved and regulations in fishing were created to tackle bycatch of seal pups[31,32]. It has been estimated that the springtime gill net fishing ban that was introduced in the 1990s resulted in a 20% population increase in the following 20 years[33]. In recent years interventions to combat the effects of climate change include the creation of artificial lair (birthing caves) structures in Lake Saimaa in years of low snowfall[32].

BENEFITS OF COMEBACK

Ringed seals play an important role in Arctic food chains as higher trophic level consumers that are also the main prey species for Polar bears (Ursus maritimus)[21,34]. Their importance within Arctic food webs means they are often selected as being

Figure 1b. Distribution of the Ringed seal in 1964[10] and 2016[1]. Note a historical map prior to 1960 could not be constructed for this species due to lack of information.



THREATS AND PROTECTION

Legal protection	• Bern Convention (Saimaa and Ladoga *ssp* Appendix II, Arctic and Baltic *ssp* Appendix III)[25] • EU Habitats Directive (Saimaa *ssp* Annex II and IV, Baltic *ssp* Annex II and V and Arctic *ssp* Annex V)[26] • Red Data Book of the Russian Federation (Ladoga *ssp* Status 1, Conservation Priority I)[23]
Current threats (Global IUCN Red List)[1]	• Transportation & service corridors (shipping lanes) • Biological resource use (fishing & harvesting aquatic resources) • Human intrusions & disturbance (recreational activities) • Pollution (domestic & urban waste water; industrial & military effluents; agricultural & forestry effluents) • Climate change & severe weather (habitat shifting & alteration)
Current threats (European IUCN Red List)[2–4,25]	• Biological resource use (fishing & harvesting aquatic resources) • Pollution (agricultural & forestry effluents) • Climate change & severe weather (habitat shifting & alteration)
Current threats (local)	• Residential & commercial development (commercial & industrial areas, Baltic[2] & Saimaa *ssp*[3]; housing & urban areas, Saimaa *ssp*[3]; tourism & recreation areas, Ladoga[4] & Saimaa *ssp*[3]) • Agriculture & aquaculture (annual & perennial non-timber crops; wood & pulp plantations; livestock farming & ranching; marine & freshwater aquaculture) – Baltic *ssp*[2] • Energy production & mining (mining & quarrying) – Baltic *ssp*[2] • Biological resource use (hunting & trapping terrestrial animals) – Baltic *ssp*[2] • Pollution (excess energy) – Baltic *ssp*[2]

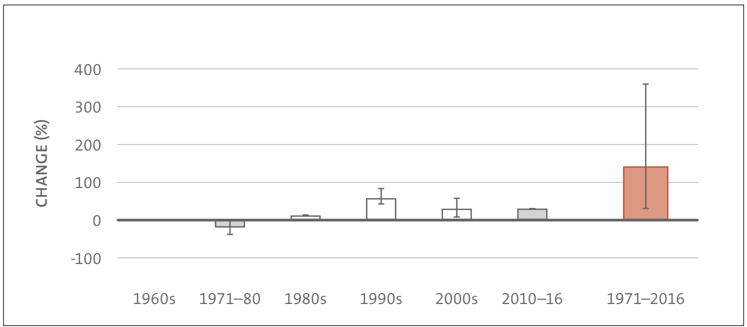


Figure 2. Average rate of change among Ringed seal populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1971 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 12 populations from across the range, covering 100% of all countries of occurrence. For any given year the number of populations ranges from 1 to 6 (see Appendix 1 for details on methods and dataset).

an important species to monitor, for example for the Conservation of Arctic Flora and Fauna (CAFF) programme[35]. They are also an important subsistence food source for Arctic communities[7]. Ringed seals also hold important cultural significance. For example, the Saimaa Ringed seal is the only endemic Finnish mammal[36] and it has become a symbol of national and local identity. The Ringed seal is featured as the logo for the Finnish Association of Nature Conservation, and it is used extensively in iconography throughout the local area[31].

OUTLOOK

In its southern European range the Ringed seal has been perceived to be in competition with fisheries, consuming some commercially important fish species and damaging nets[24,37,38]. The Saimaa Ringed seal used to be viewed as a pest, although in recent decades this has changed to it being viewed by locals as more of a celebrated 'pet'[31].

Although the IUCN classified Ringed seals as a species of Least Concern in 2016, the assessment highlighted how climate change was adversely impacting all subspecies, even though at that time the species did not meet IUCN criteria for threatened status[1]. However, the Saimaa and Ladoga Ringed seal subspecies were classified as Endangered and Vulnerable respectively[3,4]. Although currently increasing slightly in abundance, the Saimaa Ringed seal subspecies remains classified as Endangered due to its small population size and ongoing threats such as bycatch, reproductive failure and climate change[3]. With only a population of a few hundred animals it has much lower genetic diversity than the other subspecies, putting it at risk of demographic stochasticity and inbreeding[10]. Similarly, the Ladoga Ringed seal subspecies remains classified as Vulnerable due to its small population size[4], and threats from climate change, bycatch and human disturbance[24]. The Baltic Ringed seal subspecies is increasing in the Gulf of Bothnia, but HELCOM has assigned it "not good" status because the population growth rate is below the threshold value[23]. Models suggest that this subspecies is likely to increase in abundance until the late 2060s, at which time it will peak and then decrease due to climate change[39]. Threats to the Baltic subspecies have changed over time, from exploitation to persecution to pollution and now to climate change.

Climate change is the biggest current threat to Ringed seals in Europe (and globally) because the species requires ice for most of its life cycle and crucially, relatively deep snow on ice for breeding[7]. Sea ice breaking up early can lead to mothers being separated from their pups. Changes in temperature and increased ocean acidity are also thought to be reducing Ringed seal prey densities, for example Arctic cod (*Boreogadus saida*), which is the dominant prey species for Arctic Ringed seals in Europe[10]. By incorporating estimated impacts of climate change on the species, population modelling has predicted declines in abundance ranging from 50% to 99% by the year 2100[40].

REVIEWED BY:

Prof Kit M. Kovacs

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ARTIODACTYLA | **CARNIVORA** | CETACEA | CHIROPTERA | RODENTIA

Brown bear

Ursus arctos

The Brown bear (*Ursus arctos*) is the largest terrestrial mammalian predator in mainland Europe, and the most widespread bear in the world[7]. This omnivorous species is adaptable, historically occurring in a wide variety of habitats and environmental conditions in Europe[1,7]. However, due to habitat alteration by humans, it is now predominantly found in forested, mountainous areas with low human activity[1,7]. Brown bears have large home ranges to, for example, secure access to mates, sufficient food, and suitable winter den sites, the latter needed for when they hibernate[1,7].

	LC			+44%	
HABITAT	**RED LIST STATUS**	**RED LIST POPULATION TREND**	**POPULATION SIZE**	**CHANGES IN RELATIVE ABUNDANCE (LPI)**	**CHANGES IN DISTRIBUTION**
Forest, Shrubland, Grassland, Wetlands (inland), Artificial/Terrestrial[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2018)[1]	Global: Stable (2016)[2] Europe: Stable (2018)[1]	Global: 110,000 (2016)[2] Europe: 50,000–55,000 (2018)[1]	Increasing, +44% (1960–2016)[3]	Increasing (1955–2017)*[2,4–6]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Brown bears were first present in Europe in the late Pleistocene and were one of the first species to repopulate the region in the Holocene following the Last Glacial Maximum, when they occurred at high densities[8]. Climate change throughout the Holocene likely led to gradual population declines throughout Europe, with increasingly warmer winters reducing the species' reproductive rate and enabling human land use[9]. The first major reduction in Brown bear numbers started during the times of the Roman Empire[9]. Brown bears continued to range over the entirety of the European continent except large islands such as Iceland, Gotland, Corsica and Sardinia, and until recently (c. 1850) had a wide distribution[7,10]. During the 19th century, populations declined dramatically in most European countries due to widespread deforestation and increased persecution[11]. Many populations have since become extinct, particularly in lowland regions with high levels of human-bear conflict. As a result, the remaining European Brown bear populations are separated and occur in forested, mountainous areas[7].


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RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Between 1955 and 2017, the Brown bear's range increased slightly, with significant range expansion in Fennoscandia (Figure 1a)[2,4–6]. The percentage change in distribution could not be calculated for these maps, due to differences in spatial resolution. Populations are currently found in several regions in Europe, specifically the Cantabrian Mountains, the Pyrenees, the Alps, the central Apennine Mountains, the Dinarids and Pindus Mountains, the Carpathian Mountains, the eastern Balkans, Scandinavia, the Baltics, Karelia (together c. 15,000–20,000 bears)[12], and European Russia (c. 35,000–40,000)[1,5,12]. The European Russian population represents an important stronghold of the Brown

* *Percentage change was not calculated from the spatial analysis due to the differences in spatial resolution and the types of data used to create the maps.*

bear, maintaining both the largest population and widest distribution, much of which was, until recently, unfragmented[1,13]. It is also interconnected with the Karelian and Baltic populations, as well as the larger Siberian population to the east[14]. Most of the populations in the rest of Europe are smaller and more fragmented[1].

The average rate of change among the Brown bear populations in the Living Planet Index (LPI) database was a 44% increase between 1960 and 2016[3]. The most positive decadal rate of change amongst the populations occurred during the 1970s. However, since this time these rates have declined in the LPI database, with increasingly negative trends in the 1990s, 2000s, and 2010–2016 (Figure 2)[3]. The most negative decadal rate of change amongst populations, which occurred between 2010–2016, was likely driven by strong declines in the abundance of four very small Brown bear populations in European Russia[3]. Although, as the data from European Russia is based on sign surveys, Brown bear population abundance may be overestimated in these areas[12]. For this time period, 33.3% of populations were declining in abundance in the database, 20.8% were stable and 45.8% were increasing[3]. Please note, small populations in the LPI database, such as those in European Russia, can influence the trend when calculated in this way. According to the LPI database, these recent population declines are likely attributed to exploitation and habitat degradation[3]. Further literature and monitoring data highlights that the European populations of Brown bears have generally remained stable or increased over the past few decades[1,15,16]. For example, the Large Carnivore Initiative for Europe (LCIE) showed that, between 2012–2016, the Dinaric-Pindos, Alpine and Cantabrian populations increased in abundance, whilst the Karelian, Baltic, Carpathian, eastern Balkan, central Apennine, and Pyrenean populations remained stable, and the Scandinavian population decreased[18]. The Scandinavian population, which had rapidly increased in size between 1990–2008, is being actively managed to decrease its Brown bear abundance[12,17]. This status report, however, does not include the population trends for European Russia[18].

DRIVERS OF RECOVERY

The overall increase in abundance and distribution of Brown bears in Europe can be attributed to changes in public attitudes towards nature resulting in several conservation actions. Legal protection and its reinforcement, and the subsequent control of hunting, has likely been one of the greatest factors in its initial recovery[5,16]. In Spain, for example, a dramatic reduction in poaching

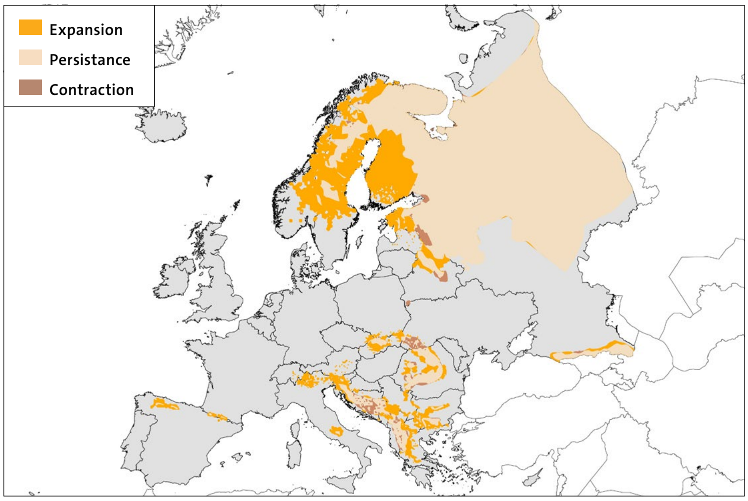

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Brown bear in Europe between 1955[4,5] and 2017[2,6]. Please note, the contraction seen in Ukraine and the Dinaric Mountains is likely an artefact of the different methods used to create these maps.

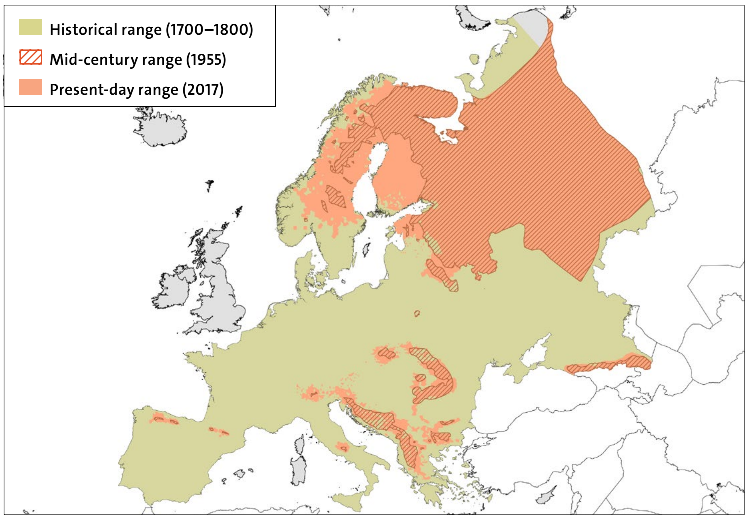

Figure 1b. Distribution of the Brown bear in 1700–1800[10,19], 1955[4,5] and 2017[2,6]. Please note, the historical map has a lower resolution than the other maps, and therefore it likely overestimates the Brown bears' distribution at this timepoint.

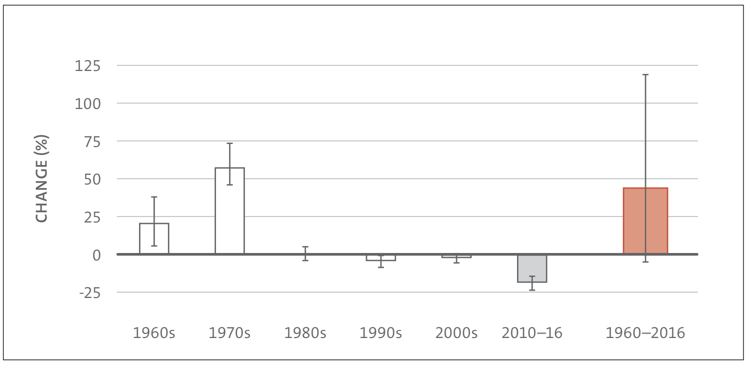

Figure 2. Average rate of change among Brown bear populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1960 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 67 populations from across the range, representing a minimum of 76,948 individuals, covering 68% of all countries of occurrence. Please note, unlike the population estimate for Europe cited earlier, this minimum number includes both young and mature individuals. Within the Living Planet Index data were missing from eight countries within the species' current range: Andorra, Bosnia and Herzegovina, Czech Republic, Latvia, Macedonia, Montenegro, Serbia, and Slovenia. However, population estimates for these countries are available elsewhere[15]. For any given year the number of populations ranges from 3 to 53 (see Appendix 1 for details on methods and dataset).

THREATS AND PROTECTION	
Legal protection	• CITES Appendix I and II [20] • EU regulation of trade of fauna and flora: Annex A [21] • Bern Convention: Appendix II [22] • EU Habitats Directive: Annex II (except Estonian, Finnish and Swedish populations) and Annex IV [23] • Most European range states have national Brown bear management plans [1,15]
Current threats (Global) [2]	• Residential & commercial development (housing & urban areas; commercial & industrial areas; tourism & recreation areas) • Agriculture & aquaculture (annual & perennial non-timber crops; livestock farming & ranching) • Energy production & mining (oil & gas drilling; mining & quarrying; renewable energy) • Transportation & service corridors (roads & railroads; utility & service lines) • Biological resource use (hunting & trapping terrestrial animals; logging & wood harvesting) • Human intrusions & disturbance (recreational activities; work & other activities) • Natural system modifications (fire & fire suppression) • Pollution (garbage & solid waste; excess energy)
Current threats (Europe) [1]	• Residential & commercial development (housing & urban areas; commercial & industrial areas; tourism & recreation areas) • Agriculture & aquaculture (annual & perennial non-timber crops; livestock farming & ranching) • Transportation & service corridors (roads & railroads; utility & service lines) • Biological resource use (hunting & trapping terrestrial animals; gathering terrestrial plants; logging & wood harvesting) • Human intrusions & disturbance (recreational activities; work & other activities) • Natural system modifications (fire & fire suppression; dams & water management/use) • Pollution (domestic & urban waste water; garbage & solid waste; air-borne pollutants; excess energy) • Climate change & severe weather (habitat shifting & alteration; temperature extremes)
Current threats (local)	• Biological resource use (hunting & trapping terrestrial animals) – e.g. poaching in Albania and Austria [15,24]

in the 1990s has contributed to the growth of the Cantabrian population [25]. Other key conservation actions include extensive research and monitoring programmes [15,16,19], increasing public awareness and education, engaging stakeholders in the development of management plans, establishing compensation schemes and providing anti-predation measures [5,19,26], habitat restoration [25,27], and, occasionally, supplementary feeding [26]. Across Europe, the management of Brown bears is highly varied, with the species being legally hunted in some countries outside the EU as well as some countries within it, e.g. in Sweden, Croatia and Slovenia (under Article 16 derogations from the Habitats Directive [23,28]), while the species has been reintroduced and is strictly protected in other areas, e.g. in Italy [26]. There have been successful reintroductions of the species in the Pyrenees [26] as well as the Italian Alps [29], where 10 Brown bears were released between 1999–2001, boosting population growth. However, some reintroduction attempts have failed, e.g. in Austria and north-east Poland, due to conflicts with people, and illegal hunting [29,30]. It should also be noted that although the species is stable in population size overall, certain populations remain threatened, particularly those in southern and western Europe [1]. This is linked to continued pressures on small, fragmented and isolated populations, illegal hunting, negative public opinions and other human-bear conflict [1].

BENEFITS OF COMEBACK

The Brown bear is a culturally important and emblematic species, with which many people have positive associations [12,31]. Brown bears are omnivores and as such can consume a wide variety of food items, including berries and flowering plants [1,7]. As a result, they play an important role as a seed disperser in European alpine forests [32]. Brown bears have also been shown to promote the germination of bilberries (*Vaccinium myrtillus*), an important plant in boreal forests [33]. Furthermore, they are considered an umbrella species, as Brown bears typically require large unfragmented forests and mountain habitats, the protection of which also benefits other species [31].

OUTLOOK

As the Brown bear has a large population and widespread range, with a generally strong core in northern and eastern Europe and an overall relatively stable population trend, it is regionally classified as Least Concern by the IUCN [1]. Despite this, some populations, mostly in western and southern Europe, remain small, fragmented, and are sometimes declining. For example, the Alpine, central Apennine and Pyrenean populations are listed as Critically Endangered on the IUCN Red List [1]. In some cases, the Brown bear remains threatened by habitat loss due to infrastructure development, disturbance, poor management structures, accidental mortality and occasionally poaching [15]. Future management recommendations therefore include: increasing connectivity between populations by protecting key Protected Areas and corridors [1]; ensuring coordinated management approaches for transboundary populations [15]; increased monitoring and research to inform decision making [1,17]; and enforcing national and international legislation to reduce persecution [1]. Furthermore, it has been suggested that some isolated populations, such as the

Apennine subspecies *U. a. marsicanus*, should be managed as a separate unit, so that the subspecies' unique genetic material is not lost[34]. That could, however, lead to increasing loss of genetic diversity and inbreeding within this population[35].

As the largest terrestrial carnivore in mainland Europe, there is much potential for conflict with humans[7]. Brown bears have been known to damage livestock, beehives, orchards and crops, which can be economically costly to farmers in the area[29]. Predation on wild ungulates, e.g. Eurasian elk (*Alces alces*) calves in Fennoscandia[36], can also bring them into competition with hunters[29]. Just their presence has also been shown to have emotional impacts on the local community, whether positive (e.g. linked to their cultural importance) or negative (e.g. fear of attack or injury from bears)[31]. There have been cases of Brown bears injuring or killing people, which can greatly impact tolerance, although such incidents remain rare[13,31]. On the other hand, as a symbolic species which is strongly associated with wilderness, they can attract nature-based tourists wanting to catch a glimpse of Brown bears, which in turn can support the local economy[37]. One study highlighted that the economic benefits of bear-watching and associated activities greatly outweigh any financial costs, such as damages to farms and property[38]. It is therefore essential that social tolerance is boosted in areas where Brown bears and humans coexist, through education and awareness campaigns, reimbursements and anti-predation measures[1,29].

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Humpback whale

Megaptera novaeangliae

The Humpback whale (*Megaptera novaeangliae*) has a global distribution, occurring in all major oceans[5]. Within distinct populations, Humpback whales typically undertake extraordinarily long migrations, travelling between winter breeding grounds in warm tropical and subtropical waters, and summer feeding grounds in subpolar regions[6]. The species is a generalist, mostly feeding on crustaceans and small schooling pelagic fish[7]. Humpback whales use a unique hunting method amongst large whales, trapping schools of fish in bubble nets[8]. It should be noted that although this account will focus primarily on the European feeding groups, because these groups are a subgroup of the much larger North Atlantic population, the general North Atlantic population may also be referred to.

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Marine Neritic, Marine Oceanic[1]	Global: Least Concern (2018)[2] Europe: Least Concern (2007)[1]	Global: Increasing (2018)[2] Europe: Increasing (2007)[1]	Global: 135,000 (2018)[2] Europe: 25,791* (2014–2018)[3]	Increasing, +37% (1997–2009)[4]	N/A*

HISTORICAL DISTRIBUTION AND ABUNDANCE

Historically, the Humpback whale was much more abundant than it is currently, with the North Atlantic pre-exploitation population numbering an estimated 240,000 individuals[9]. There is debate over the accuracy of this estimate, due to uncertainties surrounding catch records, timescales, and genetic estimates[9,10]. Evidence from whaling records indicates that the Humpback whale's historical distribution was similar to its current distribution, with the species being previously found in north-western European waters[11].

Humpback whales have been targeted by the pelagic whaling industry since at least the 17th century, starting with non-mechanized shore whaling and small-scale operations, and peaking in the 19th century, following the introduction of more intense, mechanised whaling practices[12]. The species was typically caught for subsistence, or exploited commercially for its oil, meat and baleen[13]. In European waters, Humpback whales were frequently caught near Norway, Iceland and other parts of northern Europe, to the extent that the species was almost completely exterminated from the eastern North Atlantic by the early 1900s[14]. In total, an estimated 30,842 humpbacks have been removed from the North Atlantic population since the 1600s[12]. Although, there is also evidence for the occurrence of large numbers of illegal or unreported takes of Humpback whales in Europe. For example, it has been stated that up until the mid-1900s, a large but unknown quantity of Humpback whales were caught off the Canary Islands[15], and that Soviet whaling fleets often hunted the species as they left the Suez Canal and passed through the Mediterranean[16]. Therefore, pre-exploitation population numbers and total catch numbers for the North Atlantic populations should be treated with caution[15].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

As there is no mid-century distribution map available for the Humpback whale, calculating a reliable estimate for any change in its spatial distribution since this timepoint is difficult. Currently, in the wider North Atlantic population, Humpback whales predominantly breed in either the West Indies or Cape Verde Islands and migrate either to specific feeding grounds in Greenland

* *This estimate includes the summer populations in Iceland and the Faroe Islands, Norway, and East and West Greenland, the latter regions being outside the definition of European waters used in this report. This estimate does not include individuals located in the United Kingdom, Ireland, or southern European waters, as accurate estimates for these regions were not available.*

** *Percentage change was not calculated as there is no known mid-century or historical distribution map for the species.*

and the northwest Atlantic, or parts of north-western Europe[5]. In Europe, Humpback whales are mostly located in feeding grounds around Iceland and Jan Mayen, and from Norway to the Barents Sea (Figure 1)[15]. The precise north-eastern Atlantic subpopulation breeding grounds are not well known. However, it is thought that some of these individuals travel along the coastal waters of western Europe, and winter somewhere around Cape Verde[17]. Other European Humpback whales have been known to winter in the West Indies[17]. Genetic analyses also suggest the existence of a third breeding site with an unknown location[18].

Outside of their main European feeding grounds, there has been an increase in Humpback whale sightings and strandings in the southern North Sea since the 1990s[7]. The species is now considered an annual visitor to this area rather than a vagrant. Similarly, since the 1980s, Humpback whale sightings have risen on the west and north coasts of the British Isles, and both west and south of Ireland[11,19]. Furthermore, sightings of the species in the Mediterranean have also become more frequent since the 1980s, although the mean observation rate is still low at 0.1 subjects/year[20].

The average rate of change among the Humpback whale populations in the Living Planet Index (LPI) database was a 37% increase between 1997 and 2009[4]. It should be mentioned that the populations in the LPI database represent a smaller sample of the total species population, and that there is limited population abundance data available for this species across its range. Due to this lack of data, precise decadal trends were not calculated for Humpback whales. Further literature also suggests that there has been an increase in the species' abundance in the North Atlantic since the mid-1900s[10,15]. However, this literature similarly emphasises that a general lack of available data means that the true extent of the abundance increase from this timepoint cannot be determined[10,21]. This highlights the need for more monitoring of Humpback whale population abundance.

THREATS AND PROTECTION

Legal protection	• EU Habitats Directive (Annex IV)[22] • Bonn Convention (Appendix I)[23] • Bern Convention (Appendix II)[24] • ACCOBAMS[25] • CITES (Appendix I)[26] • EU regulation of trade of fauna and flora (Annex A)[27] • SPA/BD Protocol (Annex II)[28]
Current threats (Global IUCN Red List)[2]	• Energy production & mining (oil & gas drilling) • Transportation & service corridors (shipping lanes) • Biological resource use (fishing & harvesting aquatic resources) • Pollution (excess energy)
Current threats (European IUCN Red List)[1]	• Pollution (excess energy)
Current threats (local)	N/A

DRIVERS OF RECOVERY

The overall increase in abundance of the Humpback whale in Europe can be attributed to a major positive change in public attitudes towards the conservation of the species, resulting in gradual changes in legislation[29]. As mentioned previously, much of the earlier reduction in Humpback whale abundance in Europe was caused by human exploitation. In the North Atlantic, hunting in United States' waters was halted following legislation brought in by the International Whaling Commission (IWC) in 1955, which banned commercial whaling in the area[15,17]. This was followed by a global ban on hunting Humpback whales in 1966[15,17]. Small subsistence takes of the species were continued around Greenland by indigenous communities until 1985[15,17]. Since this time, there have been relatively few threats to the species across the North Atlantic, allowing the population to recover naturally[30].

Humpback whales have also likely benefitted from recent recoveries of some European prey populations, such as the Atlantic herring (*Clupea harengus*) in the North Sea[29]. Other than legislation, no specific conservation measures are in place for Humpback whales, although they have been recorded in marine protected areas and marine mammal sanctuaries in Europe[19,31].

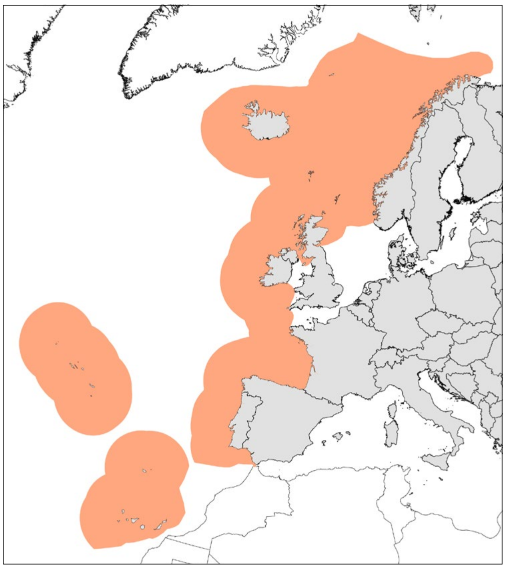
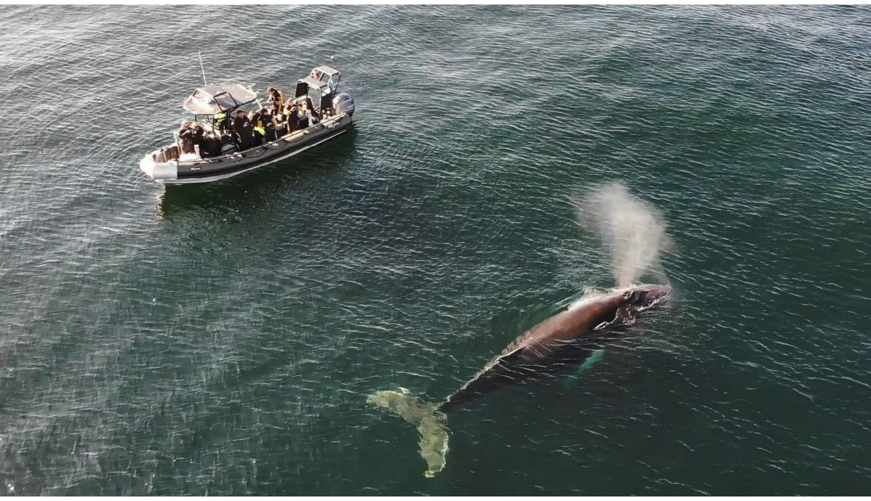


Figure 1. Map highlighting the present-day (2020) primary range of the Humpback whale in Europe[18]. Please note that the species is not confined to this region and can be recorded anywhere in the Irish and North Seas and in the western Baltic. Range change and past distribution maps have not been presented for this species, due to a lack of available historical or mid-century distribution data.

BENEFITS OF COMEBACK

The Humpback whale is considered an ecosystem engineer[32]. Humpback whales are thought to aid the cycling of nutrients in marine ecosystems, by acting as a 'whale pump'[32]. Individuals feed in deep water, before returning to the surface, where they excrete. Whale excrement contains nutrients which fertilise phytoplankton, microorganisms which efficiently release oxygen and remove carbon from the atmosphere[33]. The long migrations of Humpback whales also mean such nutrients are transferred between feeding and breeding grounds. The species is an effective carbon store in marine ecosystems[32]. During a Humpback whale's lifetime, a large amount of carbon is stored in its body. When a whale dies, it sinks, storing this carbon on the ocean floor. Thus, Humpback whales can help to reduce the amount of carbon dioxide in the atmosphere, reducing the rate of global climate change[32,33]. A sunken, deceased whale, also known as a whale fall, can also provide a valuable nutrient-rich habitat island in the deep–sea, often supporting evolutionarily distinct species[34].



FRANCESCO ROVEDO / SKUA NATURE

OUTLOOK

As the Humpback whale faces reduced threats and has a large population which is increasing in abundance, it has been downlisted to Least Concern in both the European and Global assessments of the IUCN Red List[1,2]. Despite this, in Europe, the species is increasingly threatened by entanglement in fishing gear, exposure to underwater noise disturbance, such as seismic surveys, and occasionally disturbance from whale watching vessels or physical injuries from collisions with ships[30,35]. For example, between 2012 and 2015, 7.5% of Humpback whale sighting records in Scottish waters involved entanglements with fishing gear[36]. Furthermore, approximately 25% of Humpback whales in Icelandic waters had scarring which suggested they had been entangled in fishing gear[37]. It has been suggested that acoustic 'pingers' could be used to divert whales away from fishing gear and ships[37]. In general, more research and monitoring of Humpback whales' abundance and distribution in Europe is needed[37]. Such information could be used to quantify local threats, estimate trends more accurately, and determine optimal mitigation strategies to aid further recovery. Any additional protection of Humpback whales from future potential threats should be considered at the ocean basin level, as the species has a transboundary distribution[38].

Collisions with ships or fishing gear entanglement can also be costly to stakeholders in the area. For example, it has been estimated that damage to equipment in Iceland costs up to 55,000,000 ISK per incident[37]. As Humpback whale abundance increases, such incidences are also likely to increase. Thus, researching and developing mitigation strategies would likely benefit both fishing communities and whales[37]. On the other hand, the increase in Humpback whale abundance and distribution in Europe could boost local economies, through the expansion of whale watching opportunities. In 2017, for example, one in five visitors to Iceland went whale watching, where Humpback whales were one of the main cetaceans to be spotted[39]. Whale-watching tours need to be regulated and some voluntary codes of conduct have been introduced to limit disturbance to the species[29,39]. As discussed previously, Humpback whales are also an important carbon store, and thus benefit the climate and environment globally. This service, which is expensive to recreate artificially, is therefore also incredibly valuable to people. Indeed, the monetary value of each Humpback whale has been estimated at approximately US$2 million[33].

REVIEWED BY:

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ARTIODACTYLA | CARNIVORA | CETACEA | **CHIROPTERA** | RODENTIA

Geoffroy's bat

Myotis emarginatus

Geoffroy's bat (*Myotis emarginatus*) is a small- to medium-sized bat which is distributed across the Mediterranean region and further north into Germany and the Netherlands[5]. As the species primarily forages by gleaning insects from vegetation, it is mainly found along forest edges and other areas of cluttered vegetation, although in some regions it has also been observed foraging on the wing in cowsheds and stables[6–8]. In terms of roosting sites, this species can use a range of habitats including residential and farmland buildings, caves and artificial underground sites[9].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Shrubland, Grassland, Caves and Subterranean Habitats, Artificial/Terrestrial[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2006)[1]	Global: Stable (2016)[2] Europe: Stable (2006)[1]	Global: Unknown[2] Europe: Unknown[1]	Increasing, +5,392% (1974–2016)[3]	Increasing (1955–2016)*[2]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The early evolutionary history of this species is unresolved, but fossil remains suggest that it was distributed through parts of central Europe in the late Pleistocene[9,10]. Given that there are no earlier records, it is therefore likely that this species colonised Europe from Africa sometime in the Pleistocene[11]. Genetic evidence also corroborates this, suggesting a post-glacial expansion of this species in the early Holocene[12], perhaps related to the post-glacial reforestation of Europe, given that this species utilises woodland habitats for foraging[5,9]. It is difficult to determine trends in abundance and distribution, but as a thermophilic bat, warmer temperatures and the use of buildings for roosting may have facilitated expansion northwards in more recent periods, although the main concentration of the species remained in the central and southern areas of the continent[9].

IMAGEBROKER / ALAMY STOCK PHOTO

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

In common with other European chiropterans, Geoffroy's bats suffered significant declines between the 1960s and 1990s particularly at the north-western edge of its distribution, e.g. in France[9,13,14]. Causes of this decline have not been fully established, but multiple possible factors have been identified. These include loss of forest habitats due to changes in agricultural practices, and the use of toxic substances, such as organochlorides, for treating wood in older buildings where the species roosts, as well as disturbances to roosting sites more generally[14–16]. More recently, the species appears to be recovering (Figure 1), with expansion north and westward implied by sightings in areas previously believed to be uninhabited, including western areas of the Netherlands[17], and in England (although these may just be vagrant individuals)[18]. Long term monitoring data based on numbers

* *Percentage change in area not calculated due to missing data from mid-century map.*

of individuals recorded at winter hibernacula across Europe also suggests this species has been increasing in numbers since the late 20th century[14]. This recovery is echoed in the trends in populations of this species included in the Living Planet Index database[3], with an average rate of change of 5,392% between 1976 and 2016 among these populations (Figure 2). Note that while the bar chart implies a strong increasing trend in the 1980s, this is primarily driven by data for populations in the Netherlands, which declined earlier in the 20th century (i.e. in the 1940s and 1950s) but also experienced an earlier recovery (from the 1960s onward) than the European population more generally[17,19].

DRIVERS OF RECOVERY

As with the causes of decline, drivers of recovery in this species have been hard to definitively identify. The recognition of large-scale declines across bat species led to the creation of international legislation aiming to protect these species in the 1990s, including the listing of all bat species under Annex IV of the EU Habitats Directive[23] and the formation of the Agreement on the Conservation of Bats in Europe[25]. This then enabled national level conservation actions, such as protection of roosting sites from tourists to prevent disturbance of cave-roosting colonies, which may have contributed to population recovery[27]. Restrictions in the use of organic compounds such as DDT and DDE as pesticides are also likely to have contributed to increases in bat populations[28].

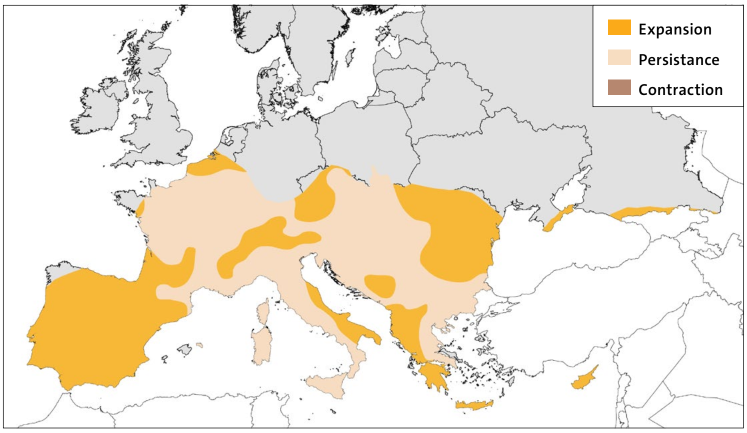

Figure 1a. Map highlighting areas of range expansion, persistence and contraction of Geoffroy's bat in Europe between 1955[4] and 2016[2]. Note that the 1955 distribution is likely a significant underestimate of the species' range in this period, with areas of absence likely reflecting lack of surveys rather than that the species was not present. For example, Geoffroy's bat was likely present across the Iberian Peninsula as there are records in Portugal from the 1920s[20] and Spain from the 1960s[21], but there was insufficient monitoring of this region at the time to determine the occupied range. The comparison of the two maps therefore implies greater expansion in range than has likely occurred between these time points.

BENEFITS OF COMEBACK

Bats are an important part of many ecosystems, and contribute to a significant number of ecosystem services[29]. As an insectivorous species frequently found close to agricultural land[8], Geoffroy's bat likely provides pest suppression services[30]. Due to their sensitivity to environmental conditions, relatively long lifespan and position higher in the trophic chain, bats are valuable bioindicator species[31]. Therefore, recovery of this species likely reflects positive trends for ecosystem health more broadly – for example, the presence of Geoffroy's bat was found to be correlated with higher riparian ecosystem function in central Italy[32].

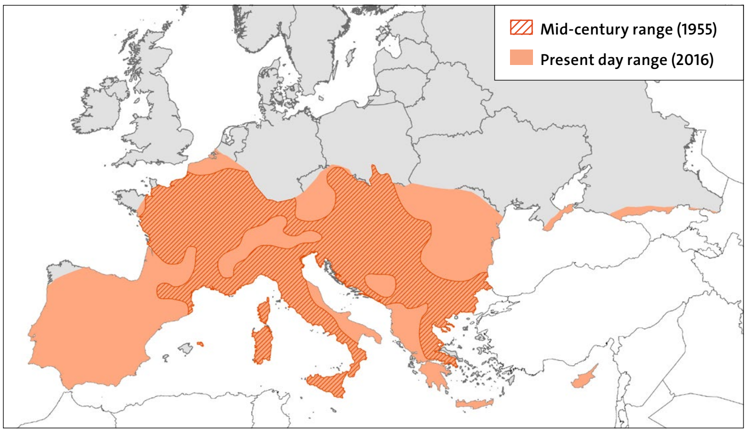

Figure 1b. Distribution of Geoffroy's bat in 1955[4] and 2016[2]. Note that a historical map prior to 1950 could not be produced for this species due to lack of information before this period.

OUTLOOK

While populations appear to have increased in recent decades, numbers are unlikely to have been restored to the level of the early 20th century[14]. Therefore, further recovery in population size may be possible, especially as the slow life history of

THREATS AND PROTECTION	
Legal protection	• Bern Convention (Appendix II) [22] • EU Habitats Directive (Annex II and IV) [23] • Bonn Convention (Appendix II) [24] • Protected under Agreement on the Conservation of Bats in Europe [25]
Current threats (Global) [2]	• Biological resource use (hunting & trapping terrestrial animals) • Human intrusions & disturbance (recreational activities, work & other activities) • Natural system modifications (fire & fire suppression; other ecosystem modifications)
Current threats (Europe) [1]	• Biological resource use (hunting & trapping terrestrial animals) • Human intrusions & disturbance (recreational activities, work & other activities) • Natural system modifications (other ecosystem modifications)
Current threats (local)	• Residential & commercial development (housing & urban areas, commercial & industrial areas) – renovation of attics and other spaces used by building-dwelling colonies reduces the availability of roosting sites [26] • Pollution (agricultural & forestry effluents) – pesticides used for treatment of wood frames can be toxic to individuals using the space to roost [16]

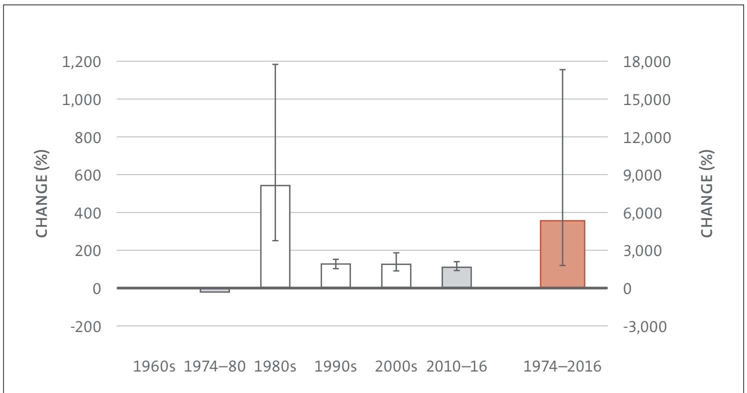

Figure 2. Average rate of change among Geoffroy's bat populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall rate of change among populations between 1974 and 2016 (coloured-in bar, secondary y-axis). Note that overall change is shown on the secondary axis on the right-hand side of the plot. Decadal change does not sum to overall change. The trend is based on 12 populations from across the range, representing a minimum of 827 individuals, and covering 27% of all countries of occurrence. Data were missing from 22 countries within the species' current range: Albania, Andorra, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Greece, Hungary, Italy, Kazakhstan, Montenegro, North Macedonia, Poland, Portugal, Romania, Russian Federation, Serbia, Slovenia, Switzerland, Turkey and Ukraine. For any given year the number of populations ranges from 1 to 11 (see Appendix 1 for details on methods and dataset).

this species may mean that the positive impacts of ongoing conservation actions are not yet reflected in population trends [14]. There may also be potential for expansion into novel areas of northwest Europe, due to the influence of climate change, particularly milder winters [9,33].

However, while the species is listed as Least Concern at both a European and Global level, it is still considered Vulnerable at a national scale in some countries (e.g. in Spain [15,34] and the Netherlands [35]), and its conservation status is classified by the European Commission as 'unfavourable-inadequate' in all biogeographical regions other than the Pannonian region [9]. Even with the progress made on some of the factors negatively impacting this species, there are still multiple existing and emerging threats [9,16]. For example, despite legislative restrictions on their use, high levels of pesticides were still found in Geoffroy's bats' faeces at roosts in the Netherlands [36]. Concerns have also been raised about the impact of wind turbines on bat populations if located close to hunting or roosting areas [16]. In addition, renovations to buildings and other anthropogenic disturbance at roosting sites remains an issue, which could potentially be resolved by designation of these major roosting sites and hibernacula as Natura2000 sites, thereby placing them under EU legislative protection [9]. Finally, Geoffroy's bat is highly impacted by ongoing habitat fragmentation and degradation, through the loss of linear habitats like hedgerows and riparian vegetation corridors due to agricultural intensification and the construction of large roads [7–9]. Europe-wide focus on conservation via the EUROBATS programme has highlighted both the need for, and the benefits associated with, transboundary conservation activity, which is particularly important for this species as individuals may roost or hibernate in one location or country and have hunting grounds in others [7,12].

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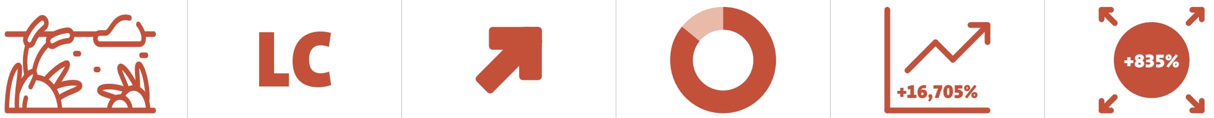
EURASIAN BEAVER

Castor fiber

The Eurasian beaver (*Castor fiber*) is a semi-aquatic species, which uses a variety of freshwater systems, with a preference for those surrounded by woodland[8]. It may also occur in agricultural land and urban areas[8]. It is described as a keystone species and ecological engineer due to its dam-building behaviour[9].



HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
Forest. Wetlands (inland)[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2006)[1]	Global: Increasing (2016)[2] Europe: Increasing (2006)[1]	Global: 1,479,863 (2021)[3] Europe: 1,272,187 (2021)[3]	Increasing, +16,705% (1960–2016)[4]	Increasing, +835% (1955–2020)*[3,5–7]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Once distributed continuously across Eurasia from Great Britain to eastern Siberia and from the far north of Norway to Iran, Greece and southern Spain[2], the beaver had decreased in number and range by medieval times in most countries, with the introduction of steel traps and firearms in the 17th century causing the local extinction of many remnant populations[2]. By the beginning of the 20th century, around 1,200 individuals remained[8] in five isolated European sites – in Rhône (France), Elbe (Germany), Telemark (Norway), Pripet (Belarus, Ukraine, Russia) and Voronezh (Russia)[3]. Causes for this decline included over-exploitation for fur, meat and castoreum (prized as a medicine and perfume base) coupled with habitat loss[8].

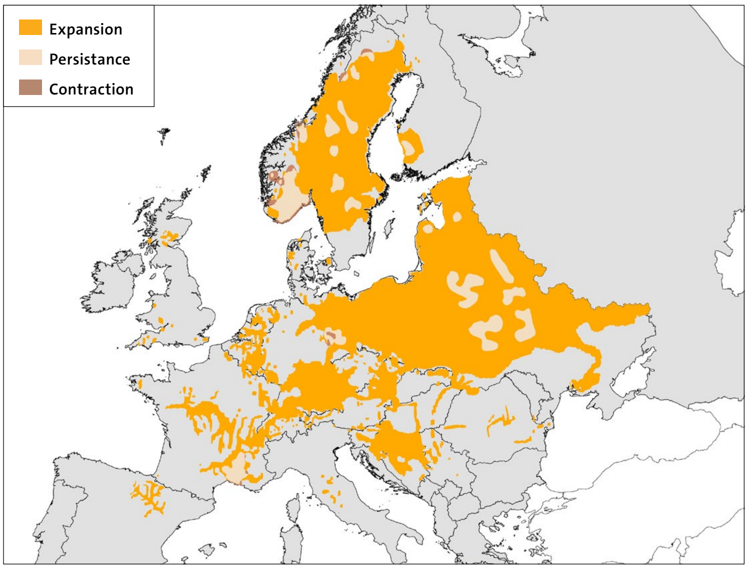


Figure 1a. Map highlighting areas of range expansion, persistence and contraction of the Eurasian beaver in Europe between 1955[5,6] and 2020[3,7]. Please note, European Russia has not been included in the maps, due to lack of available mid-century data.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

By 1955, outside of European Russia, the Eurasian beaver had staged an initial recovery, occurring in over 25 distinct populations in eastern Germany, the south of France, central Europe, and Scandinavia. Since then, populations have been established in all countries within the beaver's former natural range in Europe except for Portugal, and most of Spain, Italy and the southern Balkans[3,8]. Much of central and western continental Europe is currently experiencing a significant increase in Eurasian beaver ranges, which will likely continue in the future[3]. With few barriers to its spread, expansion has been particularly rapid in the Danube basin, which spans 19 countries[3]. However, in north-central Europe and the Nordic countries, range expansion is slowing, as populations reach carrying capacity[3]. Overall, between 1955 and 2020, the Eurasian beaver's range has increased by approximately 835% (Figure 1a)[3,5–7]. It should be noted that European Russia has been excluded from this calculation, due to the lack of available mid-century data. Furthermore, the apparent loss of range recorded in southern France, eastern Germany, Norway, and northern Sweden is likely to be due to differences in map resolution (Figure 1a).

The large-scale expansion in the species' range between 1955 and the present day is reflected in the change in population size over the same period. The average rate of change among the Eurasian beaver populations in the Living Planet Index

* *Please note that European Russia has not been included in the maps, due to lack of available data.*

(LPI) database was a 16,705% increase between 1960 and 2016[4]. Although the positive decadal rates of change among populations have generally remained high, the increase between 2010–2016 was much lower (Figure 2). This, however, is likely due to the data in the decade being incomplete in the database[4]. Overall, these trends represent a remarkable recovery in numbers over a mere 56-year period, which can be attributed to conservation successes in the underlying populations monitored.

DRIVERS OF RECOVERY

The most important drivers of recovery have been legal protection and the restriction or management of hunting, reintroductions and translocations, and natural recolonisation following initial recovery[1,8].

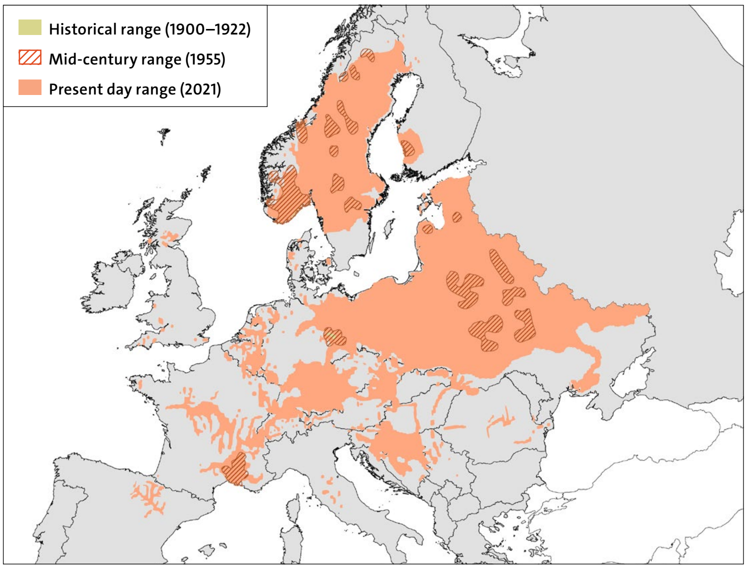
Legal protection of the five populations remaining at the beginning of the 20th century[8] was key in enabling the species to persist and expand in Europe. These populations were the source for extensive reintroduction and translocation programmes in at least 25 European countries[8]. In Sweden, the first major reintroductions were initiated in 1922, explicitly for conservation purposes[6]. However, in European Russia and eastern Europe, reintroductions were initially motivated by the fur trade but gradually became more conservation-focused and better researched, particularly as the ecosystem benefits were realised[8,14]. There have also been several 'unofficial' releases of the species, for example, into three central Italian rivers, apparently in 2019 and 2020[6,15]. The species is robust and can expand easily within and often between watersheds, e.g. onto the islands of Saaremaa and Hiiumaa from mainland Estonia[8], into Slovenia, Bosnia and Herzegovina, Hungary, and Austria from Croatian watersheds[3] and more recently, into Moldova from the Romanian Danube[6].

Habitat protection and restoration have also played a role in its resurgence. Unsuitable habitat is believed to be the reason for reintroduction failures in Switzerland, and poor habitat quality is limiting reproductive output in the Biesbosch National Park in the Netherlands[8,16]. Conservation and regeneration of riparian zones around rivers for flood control has created suitable beaver habitat around the continent[8,16], contributing to the observed recoveries. The species' resilience and ability to spread swiftly following introduction or colonisation, was also beneficial[17].

BENEFITS OF COMEBACK

Beaver dams change the flow and nutrient cycling of a watershed, leading to the creation of wetlands and ponds, as well as more open areas near waterways. Such ecosystem changes can alter invertebrate communities, and attract new species of birds,

Figure 1b. Distribution of Eurasian beaver in 1900–1922[3,7], 1955[5,6] and 2020[3,7]. Please note, European Russia has not been included in the maps, due to lack of available mid-century data. The 1900-1922 timepoint represents the time when, historically, the species range was most restricted.



THREATS AND PROTECTION	
Legal protection	• EU Habitats Directive (Annex V for the Swedish. Finnish, Latvian, Lithuanian, Estonian and Polish populations, Annex II for all other and the Polish populations & IV for all other populations)[10] • Bern Convention (Appendix III)[11] • National level protection in at least 10 European countries[3]
Current threats (Global)[2]	• Biological resource use (hunting & trapping terrestrial animals; logging & wood harvesting) • Natural system modifications (dams & water management/use; other ecosystem modifications) • Pollution (industrial & military effluents)
Current threats (Europe)[1]	N/A
Current threats (local)	• Transportation & service corridors (roads & railroads) – e.g. in Switzerland, traffic accidents are the leading cause of Eurasian beaver deaths[12] • Invasive & other problematic species, genes & diseases (invasive non-native/alien species/diseases) – e.g. in Finland, the invasive North American beaver (*Castor canadensis*) is outcompeting it[3,13]

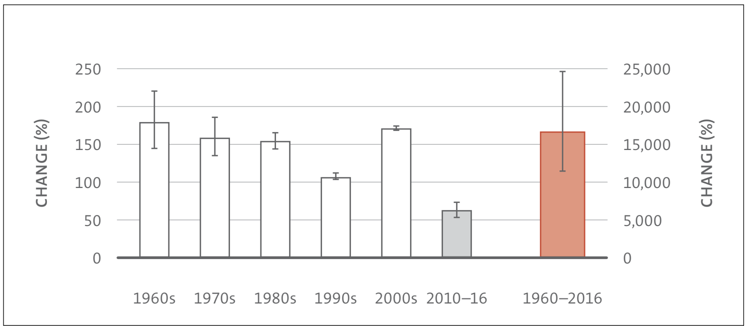


Figure 2. Average rate of change among Eurasian beaver populations by decade (hollow bars, primary y-axis, grey fill represents incomplete decade) and overall rate of change among populations between 1960 and 2016 (coloured-in bar, secondary Y-axis). Decadal change does not sum to overall change. The trend is based on 98 populations from across the range, representing a minimum of 838,730 individuals, or 53% of the total European population of 2020, covering 52% of all countries of occurrence. Data were missing from sixteen countries within the species' current range, namely: France, Hungary, Italy, Liechtenstein, Luxembourg, Montenegro, Norway, Serbia, Slovakia, Slovenia, Spain, Ukraine, United Kingdom. For any given year the number of populations ranges from 5 to 49 (see Appendix 1 for details on methods and dataset).

fish and amphibians through the provision of a suitable water table[9,18]. Various studies show higher numbers of dragonflies, fish, amphibians, birds and mammals (e.g. otters and bats) in beaver-influenced habitat[9]. Through their water regulation behaviour, Eurasian beavers can support the necessary restoration of waterways undertaken in response to climate change and mitigate extreme weather events, such as increased flooding[18,19].

OUTLOOK

As both its population size and range extent have increased significantly in the past century, the Eurasian beaver is listed as Least Concern on the IUCN Red List, both in Europe and globally[1,2]. Despite this impressive recovery, Eurasian beaver density is still low in some locations, and large areas of suitable habitat remain unused[3], suggesting potential for further spread. Considerable growth in range and numbers is expected, particularly in western Europe and the lower Danube watershed[3]. Reintroduction efforts are continuing in the Danube basin, whilst other successful recent reintroduction projects (and natural spread) have been occurring in the Netherlands, Belgium, Scotland and England[3]. There are also proposals to re-establish the beaver in Wales[20]. Natural and artificial barriers, which can hinder expansion, will need to be considered in these efforts[8]. It should also be noted that interspecific competition with the non-native North American beaver (*Castor canadensis*) could impact Eurasian beaver recovery in parts of Finland[3]. Therefore, it has been recommended that this invasive beaver species is controlled or exterminated in these regions, to minimise the potential negative effects on Eurasian beavers[3].

Any future increase in the distribution or number of Eurasian beavers is also likely to entail greater potential for conflict with humans. While public opinion towards the Eurasian beaver and its reintroduction is often positive[21], those more directly affected, such as farmers and foresters, may display greater scepticism[22,23]. Eurasian beavers can impact land use through activities such as damming small waterways, burrowing, felling commercial trees and foraging on crops[22]. Level of acceptance depends primarily on social factors, which will need to be addressed to mitigate potential conflict[21,24]. On the other hand, there are also opportunities to boost the local economy through wildlife tourism, where early provision of interpretation and public viewing opportunities may help foster positive attitudes[8,25]. Beavers also provide valuable ecosystem services which would be costly to recreate artificially. For example, through their dam-building behaviour and subsequent wetland creation, they can increase water filtration and greenhouse gas sequestration, and reduce erosion in waterways[23]. Because of expected further increases and the species' patterns of dispersal, management will need to be implemented at the watershed scale[23,26]. The associated benefits of waterway restoration and potential for tourism will likely outweigh the cost of any beaver-related damage; however, potential conflict will have to be managed in some countries to allow for peaceful coexistence and mutual benefit of beavers and people[23].

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Reptile accounts

TESTUDINES

TESTUDINES

Loggerhead turtle

Caretta caretta

The Loggerhead turtle (*Caretta caretta*) is the most widely distributed of the seven sea turtle species, nesting on sandy beaches in both tropical and temperate zones and foraging across all tropical and temperate ocean basins[5,6]. Due to the complexity of turtle population structure and habitat use, management and research at a regional level is most commonly defined using the Regional Management Unit (RMU) framework[7]. Most Loggerhead turtles in European waters live within the Mediterranean RMU, and these individuals, which feed throughout the Mediterranean Sea, nest primarily along the eastern Mediterranean coast[3,5]. However, individuals from North Atlantic RMUs also migrate into the Mediterranean to feed, as well as using the shallower waters along the coastlines of France and Portugal, and the coastal waters around the island groups of the Canaries and the Azores[1,5]. Given the difficulty in defining a European range, this account deals mainly with the wider Mediterranean RMU, with a focus on nesting sites in European countries where possible.

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN RELATIVE ABUNDANCE (LPI)	CHANGES IN DISTRIBUTION
	LC			+68%	
Marine Neritic, Marine Oceanic, Marine Intertidal[1]	Global: Vulnerable (2015)[1] Europe (Mediterranean subpopulation): Least Concern (2015)[2]	Global: Decreasing (2015)[1] Europe (Mediterranean subpopulation): Increasing[2]	Global: 200,000 nests yr^{-1} (2013)[1] Europe (Mediterranean subpopulation*): 8,179 nests yr^{-1} (2018)[3]	Increasing, +68% (1984–2016)[4]	Stable**

HISTORICAL DISTRIBUTION AND ABUNDANCE

The early historical distribution of the loggerhead turtle (i.e. during the Pleistocene) was likely primarily determined by climatic conditions, as lower temperatures in northern latitudes during glacial periods would have prevented nesting in the Mediterranean and reduced use of the North Atlantic ocean[8,9]. Warmer inter-glacials would have allowed feeding and nesting at higher latitudes, and genetic analysis suggests the Mediterranean was colonised approximately 65,000 years ago, with populations retreating to refugia and then expanding across the basin after the Last Glacial Maximum[10]. Past historical trends are difficult to determine for this species as there is a significant lack of information, as ecological research and monitoring of this species did not really commence until the 1970s[3,11]. While past human exploitation in the Mediterranean was primarily focused on Green turtles (*Chelonia mydas*), Loggerhead turtles were also collected for meat and eggs[3,11,12]. This harvesting may have had negative effects on the population in the early 20th century but this hypothesis is based only on anecdotal evidence. Novel threats such as beach development and commercial fisheries which became an issue in the second half of the 20th century are likely responsible for more significant impacts[3,11,13].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

At present, the main European nesting sites of the Loggerhead turtle are located in the eastern Mediterranean (Figure 1), primarily in Greece, Turkey, Cyprus and Libya, although smaller numbers of nests have also been recorded in Italy, Israel, Egypt, Syria and Tunisia[12,14,15]. More recently, nesting activity has also been recorded in Albania[16] and into the western Mediterranean including Spain, Italy, France and Malta which may be novel colonisation in response to warming waters resulting from climate change[15,17–19].

* *This population estimate also includes nests which are located in Mediterranean countries outside of Europe such as those on the North African coast.*

** *While the at sea foraging distribution has likely remained stable in recent decades, the distribution of nesting sites in the Mediterranean has expanded westward.*

At sea, this species is found throughout the Mediterranean region, and this distribution has likely remained relatively stable, although areas of higher density may have fluctuated over time [15,20]. In terms of abundance, severe declines likely occurred in the 1980s, primarily as a result of tourism and associated beachfront development which negatively impacted nesting site quality, alongside at-sea impacts from fishing and increased boat traffic [21,22].

Intensive efforts from a network of conservation organisations across the Mediterranean from the late 1980s onwards have contributed to what appears to be a recovery in this species over the past couple of decades, although this has been gradual given the long generation time of Loggerhead turtles [3,12,13]. This recent recovery is reflected in the monitored populations included in the Living Planet Index Database, with the average rate of change among these populations calculated as 68% between 1984 and 2016 [4] (Figure 2). However, abundance trends are hard to determine accurately due to the limitations of estimating populations using nest counts, and the lack of monitoring in some areas of the Mediterranean [3].

DRIVERS OF RECOVERY

While the Loggerhead turtle has been protected under legislation at both an international (e.g. CITES [30], the Barcelona Convention [31]) and national (e.g. presidential decrees in Greece [21]) level since the 1980s, this has often been poorly enforced due to conflict with other stakeholders [22,32]. Instead, local intervention by NGOs has been most responsible for recovery, with conservation measures enacted to aid turtles both in the terrestrial and marine stages of their lifecycle [31,33]. Nest protection (to prevent predation) and relocation (where nests are in danger of flooding) appear to have improved nesting and hatchling success, likely facilitating population growth, with these measures implemented across numerous nesting sites [3,34]. Other beneficial interventions include erecting shading at night to reduce light pollution on key nesting beaches, and education programmes for local residents and fishermen to raise awareness about the threats to sea turtles and encourage positive behaviour change [12]. Finally, a number of sea turtle rescue centres across the Mediterranean have been set up, with the first opening in the 1990s [35,36]. These centres help to provide medical treatment and rehabilitation for turtles reducing adult


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mortality from injuries sustained through boat strikes or entanglement with fishing equipment, both of which remain major issues in the Mediterranean [3,35,37,38]. While the medical attention offered by these centres is unlikely to have had a significant impact on overall population dynamics, given the small number of animals treated and uncertainty surrounding the efficacy of rehabilitation, in terms of public education and environmental awareness they are very effective tools [35]. They have therefore assisted sea turtle conservation by promoting behaviour change such as improved sea turtle handling by fishermen, which also reduces mortality associated with incidental capture [35,39].

BENEFITS OF COMEBACK

Loggerhead turtles are considered a keystone species due to the range of ecological functions they contribute to marine ecosystems [6]. As generalist consumers they are important parts of the marine trophic web, acting as both predators and prey for a range of species, and through feeding habits such as crushing the shells of benthic prey, they increase availability of calcium to other organisms and contribute to sea floor bioturbation [6,40,41]. In addition, by laying their eggs on shore but primarily feeding at sea, they contribute to nutrient cycling and energy transfer between marine and terrestrial ecosystems [42]. Another important ecological contribution is their relationship with various epibiotic taxa which live on their shells (most commonly these include algae, sponges, crustaceans and some molluscs), which may use the Loggerhead turtle solely as a raft, or benefit from increased nutrient availability, both from Loggerhead turtle faeces and from sediment disturbances caused when Loggerhead turtles feed [6,43,44]. In addition, turtle presence can have socio-economic benefits for coastal communities through ecotourism opportunities as turtle-watching is a popular visitor attraction [45].

OUTLOOK

While the Mediterranean subpopulation of the Loggerhead turtle is listed as Least Concern on the IUCN Red List, this status remains highly dependent on conservation actions [2,3]. There is potential for further recovery, if current conservation efforts continue successfully, and if other recommendations are enforced [3]. Given the success of initiatives and interventions to reduce the impact of threats on nesting environments, there is an increasing focus on strategies to mitigate mortality at sea [12]. For example, there are various changes to fishing equipment that can be made to

THREATS AND PROTECTION	
Legal protection	• CITES (Appendix I) [23] • Bonn Convention (Appendices I and II) [24] • Barcelona Convention (Annex II) [25] • Bern Convention (Appendix II) [26] • EU Habitats Directive (Annexes II and IV) [27] • EU regulation of trade of fauna and flora (Annex A) [28] • OSPAR Convention (Annex V) [29] • Also protected under national law for many countries around the Mediterranean [2]
Current threats (Global) [1]	• Residential & commercial development (housing & urban areas; commercial & industrial areas; tourism & recreation areas) • Biological resource use (fishing & harvesting aquatic resources) • Human intrusions & disturbance (recreational activities; work & other activities) • Invasive and other problematic species, genes & diseases (viral/prion-induced diseases) • Pollution (garbage & solid waste; excess energy) • Climate change & severe weather (habitat shifting & alteration; temperature extremes; storms & flooding)
Current threats (Europe)* [2]	• Residential & commercial development (housing & urban areas; commercial & industrial areas; tourism & recreation areas) • Biological resource use (fishing & harvesting aquatic resources) • Human intrusions & disturbance (recreational activities; work & other activities) • Climate change & severe weather (habitat shifting & alteration; temperature extremes; storms & flooding)
Current threats (local)	N/A

* *This assessment refers to the whole Mediterranean RMU, so threats are also relevant to nesting sites outside of Europe but within this RMU.*

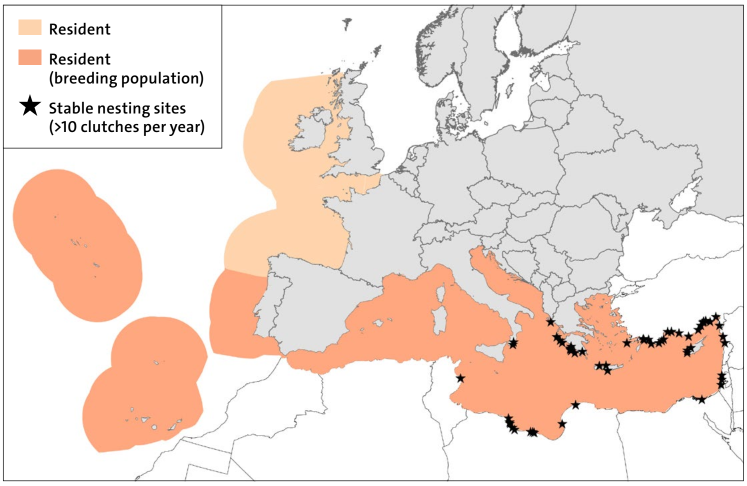

Figure 1. Map showing distribution and stable nesting sites of the Loggerhead turtle in 2020 [1,3,12]. Note that for this species, the mapped area has been expanded to the whole Mediterranean region, and therefore some countries outside of the study area are included. The mapping boundaries here are therefore broader than for other species included in the report. It was not possible to include maps of either past or historical distribution for this species due to lack of accurate information.

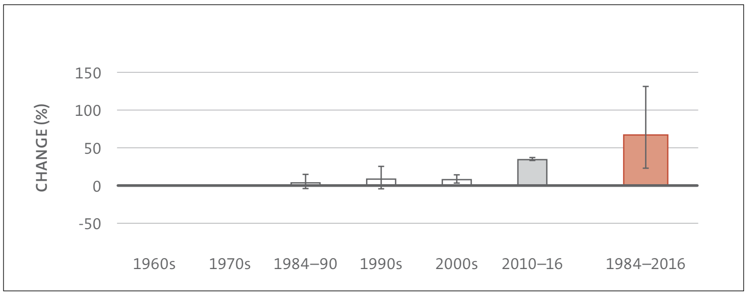

Figure 2. Average rate of change among Loggerhead turtle populations by decade (hollow bars, grey fill represents incomplete decade) and overall rate of change among populations between 1984 and 2016 (coloured-in bar). Decadal change does not sum to overall change. The trend is based on 14 populations from across the range, and while data was available for some key nesting areas in Greece and Cyprus, further data is required to ensure this trend is representative of other locations. For any given year the number of populations ranges from 2 to 14 (see Appendix 1 for details on methods and dataset).

reduce turtle bycatch such as installation of Turtle Excluder Devices in bottom trawlers [46] and changes to the style of hook used when longline fishing [47,48]. In order to encourage the use of these technologies, economic incentives and awareness initiatives may be required, since they could be important tools for reducingthe mortality caused to juveniles and adults through fisheries bycatch [3,37,48]. Given the wide-ranging behaviour of this species, transnational cooperation is also a key aspect of successful conservation management. This is currently facilitated by a number of initiatives, including the EU LIFE projects EuroTurtles and MedTurtles which provide an operational network to link together organisations working on sea turtle conservation across the Mediterranean [49,50].

Despite this positive potential, there are still many other ongoing threats to the Loggerhead turtle. There remains significant conflict between the tourist industry and turtle conservation, given the overlap between the peak summer tourist season in the Mediterranean region and Loggerhead turtle nesting season. Tourist activity can negatively interfere with nesting in a multitude of ways, ranging from the compaction of sand and disturbance of laid clutches (due to driving and/or heavy foot traffic on beaches) to light pollution (from beachside bars and developments), with this latter issue disturbing nesting females and disorientating hatchlings [3]. It is therefore important to prioritise the protection of key nesting sites through legislation and education programmes to encourage local support for turtle conservation [3,51,52]. Alongside tourism, all turtles are also facing increasing impacts from climate change [53]. Given their thermal sensitivity, warming is likely to influence sex ratios and potentially reduce hatchling success, as well as altering distribution and migrations due to changes to ocean currents [53,54]. In the Mediterranean, changes to nesting phenology have already been recorded, likely in response to warming temperatures, and there are concerns that foraging availability will also be affected, leading to reduced reproductive fitness [55]. Given the precarious nature of the Loggerhead turtle's recovery in this region, and the pressures facing the species, it is vital that the current conservation focus is continued. Further research and monitoring are also required to ensure conservation efforts are effective, as there are still many aspects of Loggerhead turtle distribution and ecology that remain undetermined [3].

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FRANCESCO ROVEDO / SKUA NATURE

Bird accounts

White-headed duck

Oxyura leucocephala

The White-headed duck (*Oxyura leucocephala*) is a partially migratory duck, and the only species in its family indigenous to the Palearctic. It is known for the males' unique appearance, having a white head with a black cap and blue bill. The species is highly aquatic and is very rarely seen on land. It is a diving duck which feeds both day and night on invertebrates, particularly midge larvae, but also on aquatic plants and seeds. It nests in reedbeds and other emergent vegetation on small and enclosed freshwater, brackish or eutrophic lakes with dense vegetation around the fringes, often preferring areas of extensive shallow water. It can also use old nests constructed by other duck or coot species. During the non-breeding season, the species may congregate at selected sites, depending on the environmental conditions; in winter, it may move to larger and deeper lakes or lagoons, or even estuaries and the sheltered coastal waters of inland seas[1,5–7].

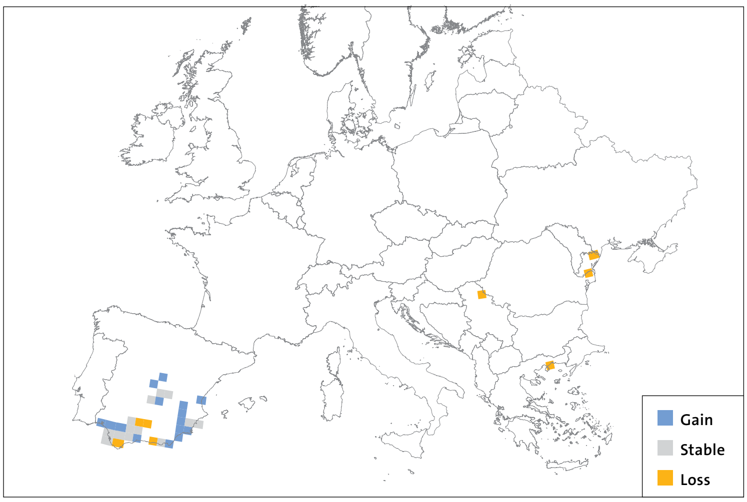
HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
	VU			+124%	-20%
Wetlands (inland), Marine Coastal/ Supratidal, Artificial/ Aquatic & Marine[1]	Global: Endangered (2017)[2] Europe: Vulnerable (2020)[1]	Global: Decreasing (2017)[2] Europe: Decreasing (2020)[1]	Global: 6,800* (2017)[2] Europe: 1,300* (2020)[1,3]	Increasing, +124% 1990–2018**	Decreasing, -20% 1980s–2010s[3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In Europe, there are two distinct populations: one non-migratory population that is present all year round in Spain, and one population that breeds in Russia, Turkey and the Caucasus before wintering in the eastern Mediterranean region, the Middle East and central Asia[2,5,6].

Historically, the White-headed duck had a much larger range in the region. The species suffered steep declines in the 20th century, at both European and global levels, likely as a result of wetlands being drained for agriculture and infrastructure development. In the 19th century it went extinct in Greece, then in Albania and Romania in the first half of the 20th century, and in Hungary, Serbia, Croatia, France, Italy and Ukraine in the 1960s and 1970s. It is estimated that in the 20th century alone, half of the area of suitable breeding habitat across the species' range was lost, and that hunting and egg collection in these countries were likely the final causes of local extinctions. In Spain, the species declined from approximately 400 individuals in the 1950s to a low of 22 individuals in 1977, due to hunting, egg collecting and habitat loss, and during the late 1970s and early 1980s, it was restricted to just one wetland in Cordoba. In addition to this, the accidental introduction of the non-native Ruddy duck (*Oxyura jamaicensis*), first to the United Kingdom in the 1950s, from where it spread to the rest of Europe, has posed a great threat to the White-headed duck. Male Ruddy ducks and hybrids of White-headed and Ruddy ducks have social dominance over the native species; as a result, White-headed ducks have a greatly reduced chance of breeding success where Ruddy ducks or Ruddy duck hybrids are present[5–9].

Figure 1a. Change in range of the White-headed duck between the 1980s[11] and 2010s[4] as per the EBBA2.



* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The species' current distribution is highly fragmented (Figure 1b). In Europe, the non-migratory population in Spain is split from the migratory population which breeds mainly in Russia, Turkey and the Caucasus, and it is feared that the reduced genetic diversity in the western population may limit its adaptability to environmental change[1,5,6].

Nevertheless, since the 1970s, the population in Spain has increased by two orders of magnitude (Figure 2) thanks to successful conservation actions, reaching approximately 2,000 individuals in 2012 and maintaining a stable population since then. This increase has been accompanied by a considerable expansion of its distribution in the country (Figure 1a)[1,5,6].

On the other hand, in Russia and Turkey, where extensive key breeding sites are still available, the population has been declining since the 1980s, driving the overall decline in Europe. In Turkey, heavy declines of at least 90% have been observed, including at the key wintering site of Burdur Gölü. Similar observations have been recently reported from Greece (contrasting with a previously increasing trend). Large declines have also been observed in Bulgaria over the past two decades, although since 2019 the species has started increasing again at Lake Burgas, where the total number of individuals reached 2,270 in 2021[1,5,6,10].

The current breeding population of White-headed duck in Europe is estimated at around 640 pairs and is decreasing, while the wintering population is approximately 9,500 individuals with a stable trend[1].

DRIVERS OF RECOVERY

White-headed ducks are legally protected in all the European countries in which they are found, both during the breeding and the non-breeding seasons, and this protection was the most important factor for the species' recovery in Spain. However, enforcement in other countries, particularly in south-eastern Europe, is not effective and needs to be improved, although notably sport hunting has been banned on two of the species' primary wintering lakes in Turkey (Burdur Gölü and Yarisli Gölü), where hunting from speedboats was threatening the White-headed duck[1,5,6].

Habitat protection, for example through the designation of Important Bird Areas (IBAs), and habitat management and restoration, including the control of pollution, vegetation management and removal of introduced fish species, have also contributed to this species' survival. A European Action Plan for the conservation of the species

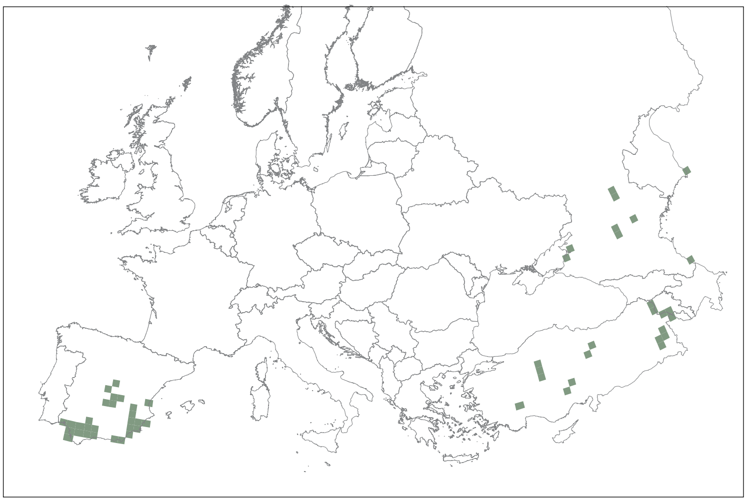


Figure 1b. Current distribution of the White-headed duck across Europe (2010s)[4].

was published in 2006 and has been revised as part of the LIFE EuroSAP project, helping to advise and coordinate conservation actions across the species' range [5,6,16].

In addition, in 2010, an international Action Plan was produced for the elimination of Ruddy ducks in the Western Palearctic, which, after considerable efforts, is proving successful in western Europe (e.g. no pairs reported in the United Kingdom in 2021, and substantial parallel decreases in records of the species in Spain). Reintroduction programmes are ongoing in Mallorca (Spain), France and Italy, but should only be carried out if all Ruddy ducks have been eradicated from those areas. In addition, in 2001 lead shot was banned from use in protected wetlands in Spain, aiming to reduce pollution and other negative impacts associated with lead poisoning [1,5–7,17,18].

Legal tools which have supported these drivers of recovery include the species' inclusion in Annex I of the EU Birds Directive, in Appendix II of CITES, Annex II of the Bern Convention and Annex I of the Convention on Migratory Species (CMS). These have all now been in place for some decades, helping to explain the long-term increase in this species' population, and the West Mediterranean population (Spain and Morocco) is also classified in Column A of the African-Eurasian Waterbird Agreement (AEWA) Action Plan.

BENEFITS OF COMEBACK

The White-headed duck is very rare and distinctive in Europe and can be a powerful draw for bird enthusiasts and ecotourists to regions where it is present. This could directly and indirectly generate socio-economic benefits to local areas.

The species is also very selective about its preferred habitat, which has largely disappeared over the past century. The conservation of the White-headed duck could therefore also benefit other species which use and depend on similar wetland habitats. As with other wetland birds (e.g. geese and storks), its presence may aid the dispersal of aquatic plants and invertebrates.

THREATS AND PROTECTION

Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix II) • CMS (Appendices I and II) • AEWA (Annex 2)
Global threats	• Annual & perennial non-timber crops • Hunting & trapping terrestrial animals • Gathering terrestrial plants • Fishing & harvesting aquatic resources • Dams & water management/use • Invasive non-native/alien species/diseases • Industrial & military effluents • Agricultural & forestry effluents • Droughts [2]
European threats	• Annual & perennial non-timber crops • Livestock farming and ranching • Hunting & trapping terrestrial animals • Gathering terrestrial plants • Fishing & harvesting aquatic resources • Dams & water management/use • Invasive non-native/alien species/diseases • Problematic native species/diseases • Domestic and urban wastewater • Industrial & military effluents • Agricultural & forestry effluents [1,15]

OUTLOOK

After a period of steep decline in the 20th century, legal protection and conservation efforts have enabled the European White-headed duck population to experience a long-term increase. This has mainly been driven by the trend of the Spanish population, which has been a good example of species recovery and has now stabilised.

White-headed ducks in Europe still face significant threats. These include the risk of competition for resources and hybridisation with the non-native Ruddy duck, and the introduction of Carp (*Cyprinus carpio*) to wetlands in Spain, where habitat modification by the fish has resulted in habitat loss for White-headed ducks [1,5–7].

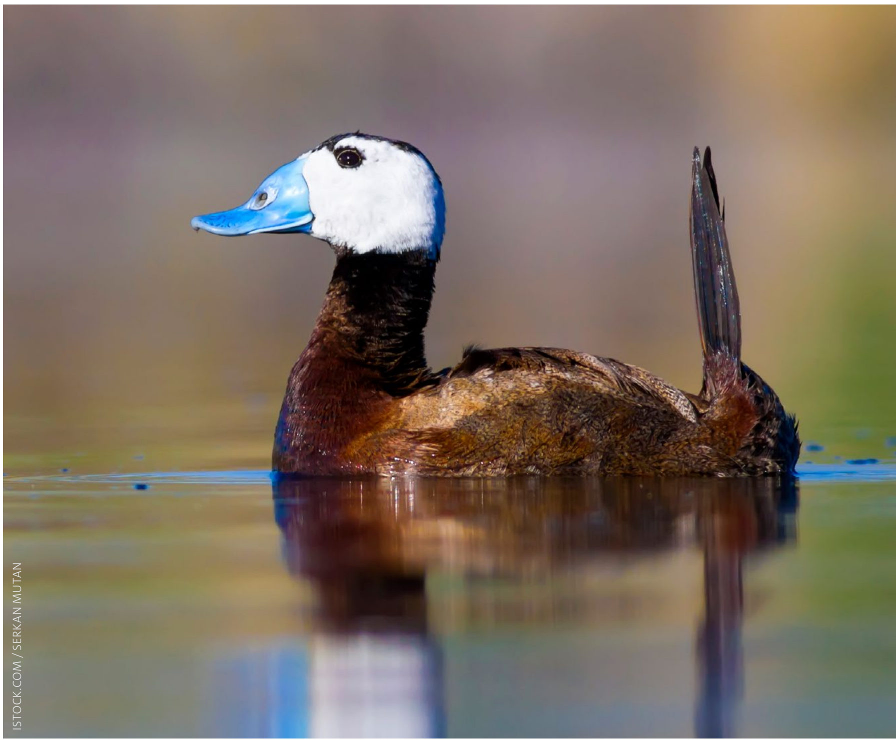
Habitat loss has also been a key factor in the species' population decline (with at least half of its breeding habitat having been drained or otherwise lost in the 20th century alone), limiting its potential to grow and recover. Continued inadequate management of wetlands (e.g. dam building, water abstraction for agriculture, drainage, etc.) can lead to these habitats drying out and increase the effects of eutrophication and pollution [5–7].

Pollution of wetlands from lead shot also heavily affects White-headed ducks. Although lead shot

has been banned in protected wetlands in Spain for over 20 years and is also now banned from use in and around all wetlands in the EU, past hunting activities in these habitats means that many are still highly contaminated. In addition, the species is still illegally killed in many areas of south-eastern Europe, and it is also known to be accidentally caught and drowned in fishing nets [1,5–7,19].

Climate variations have been shown to influence the species' demographics, with more rainfall in the breeding season being linked with better reproductive success. Therefore, an increase in the risk of droughts due to climate change and the subsequent drying out of wetlands (as is already happening in central Asia) will likely negatively influence the species [1,5,6].

To give the species a chance to recover in the whole of Europe, conservation actions must be increased and adequately funded. Better monitoring and research on the eastern European population, and in populations in the rest of the Palearctic, are needed in both breeding and wintering seasons, in order to better understand the species' ecology and demographics, as well as to ensure any presence of Ruddy duck is quickly detected and controlled. Legal protection from hunting is needed in all of the countries in the species' range, alongside strict enforcement, while key sites should be protected by wardens, water levels and quality should be closely monitored, and fishing should be regulated to prevent birds from drowning in nets [1,5].



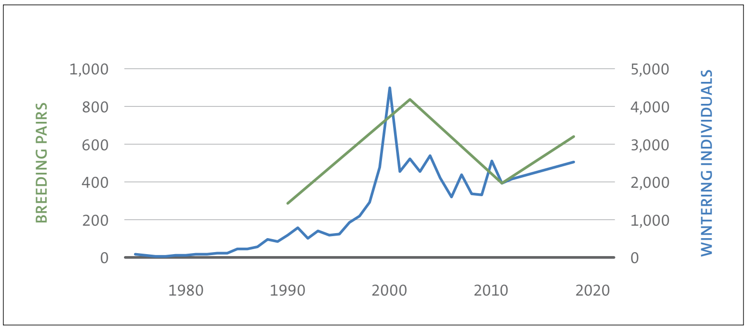


Figure 2. Estimated number of White-headed duck breeding pairs in Europe, and separately the estimated number of wintering individuals in the western European population [1,12–14].

REVIEWED BY:

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Whooper swan

Cygnus cygnus

The Whooper swan (*Cygnus cygnus*) is a migratory species, breeding across the northern Palearctic, from Iceland to Mongolia. Whooper swans inhabit taiga, birch or tundra forest. They usually nest monogamously, in solitary and highly territorial pairs, along vegetated banks or on islands in a variety of wetland habitats, such as shallow pools, slow rivers or marshes. Outside of the breeding season they congregate in large flocks, stopping over on migration to roost on lakes or in sheltered coastal habitats. Whooper swans are mostly herbivorous, foraging on aquatic plants, grasses, sedges and horsetails, but can also feed on invertebrates such as insects or mussels[7–9].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
	LC			+264%	+98%
Wetlands (inland), Artificial/Terrestrial, Marine Coastal/ Supratidal[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2020)[1]	Global: Unknown (2016)[2] Europe: Increasing (2020)[1]	Global: 166,000* (2019)[3] Europe: 130,500* (2021)[3,4]	Increasing, +264% 1986–2020**	Increasing, +98% 1980s–2010s[5,6]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In Europe, the species is split into three populations: the Icelandic population, which breeds in Iceland and mainly migrates to winter in the British Isles (a small percentage of this population remains in Iceland, and some birds may occur in Norway and Denmark) and a second North-west Mainland European population, which breeds mainly in Fennoscandia and north-west Russia (as well as increasingly in other parts of northern Europe), before wintering across the continent, from Scandinavia down to northern Italy. A third population winters in the Black Sea and the eastern Mediterranean region but breeds in north-eastern European Russia and western Siberia. However, more research is needed on this population's breeding grounds and movements[4,8–12].

In the 19th and early 20th centuries, the Whooper swan was intensely hunted and trapped, and its eggs collected, which drove it almost to extinction in many parts of Europe, excepting Iceland and Russia. This persecution pushed the north-west European population northwards, into an Arctic climate with poorer quality habitats, leading to reductions in its breeding success. During this time, the species' range in Sweden contracted up to 1000 km. By the 1920s only 20 pairs remained in Sweden and by 1949, only 15 pairs remained in Finland. Following its protection from hunting in the 1950s however, the species started to recover. Since then, the Whooper swan population has increased greatly, aided by the expansion of intensive agriculture, which has led to improved foraging opportunities in winter, and now its breeding distribution is once more extending southwards[7,8,13].


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* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

In recent years, Whooper swan numbers have continued to increase. The population in Iceland reached approximately 43,300 individuals in 2020 (up from around 16,000–17,000 individuals in the mid-1990s). In Sweden, its numbers have increased from 3,800 pairs in 2012 to 8,500 pairs in 2018, and in Finland numbers have increased from 8,000 pairs in 2010 to 10,800 pairs in 2018. Together with birds from Russia, these individuals form the core of the north-west mainland breeding population. The species has re-expanded its range southwards in Norway, Sweden, Finland and European Russia, and has re-established or newly established itself as a breeding species in the Baltic States, Belarus, Poland, Germany, the United Kingdom, Ukraine, Denmark, the Netherlands and Hungary. More recently, it has been recorded as breeding species in Czechia in 2017, in Slovakia in 2019, and in France in 2012 (as an isolated case) [1,4,8,10,13,14].

The winter distribution of the Whooper swan has not changed greatly, although some southward movement has been recorded in the British Isles. However, since the 1980s, the species has shifted from its traditional feeding grounds in wetlands and coastal bays to improved grassland and agricultural fields. Mid-winter censuses have confirmed that both the Icelandic and North-west Mainland European populations have more than doubled in size since 1995, with particularly large increases in Denmark, Germany and Great Britain (only small increases have been observed in the Black Sea/ Eastern Mediterranean population, which currently stands at 14,000 individuals). Nevertheless, the shift in feeding grounds, combined with great population increases, can cause conflicts with farmers as the species may damage crops and pastures [4,8,10,11].

The overall European breeding population of Whooper swans is estimated at approximately 41,000 pairs and has an increasing trend. In winter, the species' population size is estimated at around 195,700 individuals (including the Black Sea/Eastern Mediterranean population), and this trend is also increasing, despite little change in its range [1,3,4,8,10].

DRIVERS OF RECOVERY

The Whooper swan started recovering in the middle of the 20th century, mainly as a result of legal protection from hunting and egg collection. Another key factor was the increase in food availability, particularly during winter. This was mainly a side-effect of the expansion and intensification of agriculture, but the species has also been aided by the restoration of wetlands, which provide more

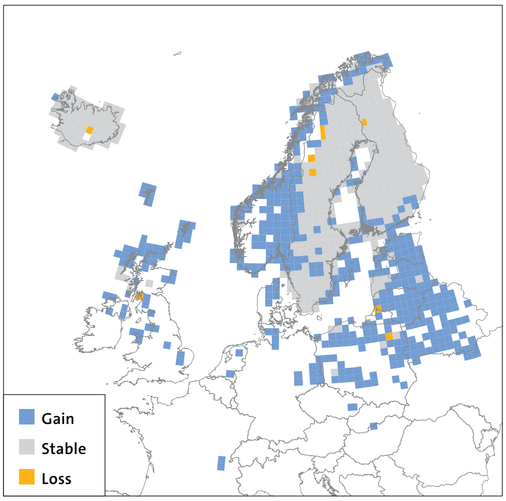

Figure 1a. Change in range of the Whooper swan between the 1980s [15] and 2010s [6] as per the EBBA2.

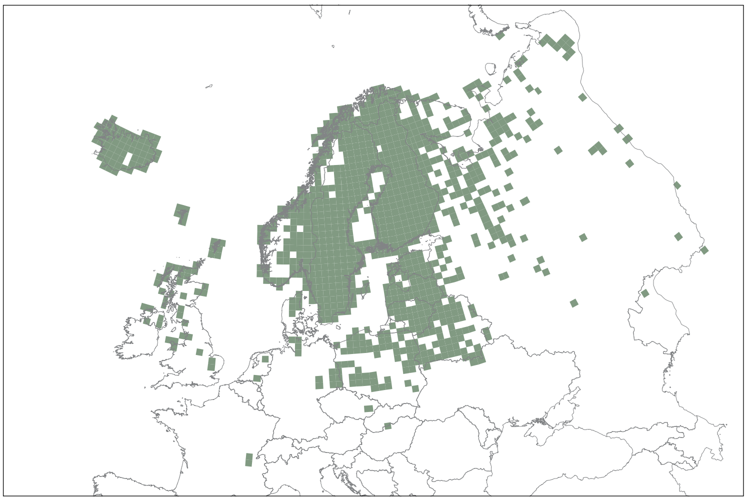

Figure 1b. Current distribution of the Whooper swan across Europe (2010s) [6].

roosting opportunities for the species away from coastal areas. In north-west Europe in particular, these improvements have contributed to the species' range expanding southwards, which in turn has led to shorter migration distances, and therefore more energy being used for survival and reproduction instead. Milder winters (a potential result of climate change) have also benefitted the species in a similar manner. Regular international censuses in winter have been important in helping to monitor the Whooper swan's demography and seasonal distribution, and in continuing to identify new sites of importance for the species. Research on threats (e.g. wind turbines in Denmark) is helping to understand their impact on the species and how these can be countered (e.g. modifying the height and spacing of turbines)[3,4,8,10,11].

BENEFITS OF COMEBACK

Whooper swans are mainly herbivorous and their grazing may affect the structure of its habitat. This may be beneficial to other species, particularly in its breeding grounds, and help maintain or even increase the biodiversity of the ecosystems it is present in. As with other species within functioning ecosystems, the Whooper swan can contribute to the dispersal of seeds and invertebrates, and to nutrient cycling within its habitats[14]. The Whooper swan, especially its eggs and young, also serve as a food source for some predators (e.g. mammals, large fish and birds of prey). In addition, this charismatic species may bring socio-economic benefits to the local areas in which it occurs, as birdwatchers and nature enthusiasts will travel to see it. Conservation of Whooper swans' breeding habitats may also help the conservation of other species.

OUTLOOK

With the legal instruments in place, protecting it from hunting, egg collection and disturbance, the Whooper swan is making a good comeback in Europe. Its range, as well as its population size, are increasing, particularly in countries around the Baltic Sea, thanks to milder winter temperatures and improved food availability. Given the drivers of this recovery are unlikely to change, the species appears likely to continue recovering.

However, as the number of individuals increases, so does the risk of conflict with agriculture and damage to crops and pastureland. This has led to scaring techniques being used in the species' winter feeding grounds, and potentially to instances of persecution[4,7,8].

The loss and degradation of suitable habitats, especially wetlands, is also still a threat for the Whooper swan. This is mainly due to land use change; for example, for agricultural expansion or transport infrastructure development (e.g. roads), but also from wetland water use for irrigation, overgrazing by livestock, or pollution from oil exploration and transport. Negative effects may also arise from pollution and subsequent poisoning from lead ammunition and fishing weights, as well as collision with utility lines and wind turbines[7,8]. These threats are based on the species' current distribution and may alter, or new threats may be added, if the species' range continues to expand.

Although many of these threats can cause mortality and significantly reduced breeding success, the species may suffer future high mortality rates from isolated events such as oil spills or of highly pathogenic avian influenza (H5N1 virus). The long-distance overseas flight between Iceland and Britain/Ireland may put birds in the Icelandic population at some risk of extreme weather events during migration, and the advent of climate change is also making natural disasters such as droughts or heavy snowstorms more likely, which can also increase the species' mortality risk[1,7,9,19].

It is therefore important for conservation efforts aimed at Whooper swans to continue. This includes improving and enforcing protection from hunting, identifying and protecting key sites (particularly wetlands) from any land use change or habitat alteration, and such legislation should be strictly enforced, including that relating to oil drilling and transportation. Careful planning of power line and wind turbine installations should be undertaken, taking into consideration the species and its flight paths. Additional research into Whooper swans' breeding and moulting sites, particularly for the north-western mainland and Black Sea/eastern Mediterranean populations, is also needed[1,3,7,10,11].

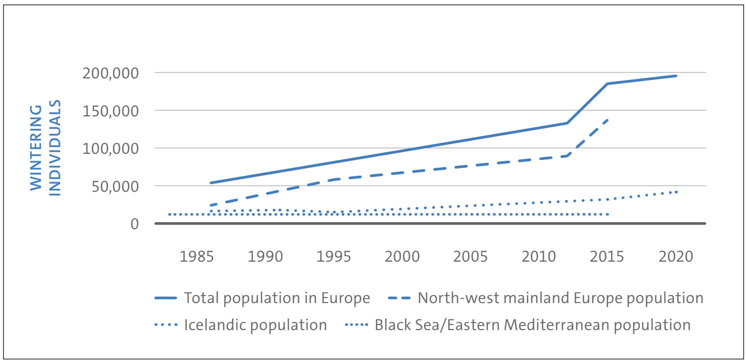

Figure 2. Estimated number of wintering Whooper swan individuals in the Icelandic, North-west Mainland Europe and Black Sea/Eastern Mediterranean populations[3,12,16,17].

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Dr Eileen Rees

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix II) • CMS (Appendix II) • AEWA (Annex II)
Global threats	• Annual & perennial non-timber crops • Livestock farming & ranching • Oil & gas drilling • Mining & quarrying • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities • Dams & water management/use • Viral/prion-induced diseases • Industrial & military effluents • Habitat shifting & alteration • Droughts • Other impacts [2]
European threats	• Annual & perennial non-timber crops • Livestock farming & ranching • Oil & gas drilling • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Recreational activities • Dams & water management/use • Viral/prion-induced diseases • Industrial & military effluents • Habitat shifting & alteration [1,18]


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Barnacle goose

Branta leucopsis

The Barnacle goose (*Branta leucopsis*) is a migratory goose species, which is near-endemic to northern and north-western Europe. The species has highly localised breeding and wintering grounds. It breeds in semi-desert tundra, nesting in colonies on rocky ground, cliffs, or on coastal islands. The species is herbivorous and nests near wetlands, as well as coastlines and mudflats, where it forages on grasses (Poacea) and other plants (including berries). More recently it has also started to use meadows on the mainland (e.g. in Russia and the Netherlands). During the non-breeding season, Barnacle geese become highly gregarious, and forage in dense groups in unmanaged coastal meadows, saltmarsh pastures and tidal mudflats. They are increasingly utilising agricultural grassland and arable land and can also feed on (winter) grain and harvest remains. Barnacle geese usually roost on water or on sandbanks near their foraging areas[1,6–8].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Grassland, Marine Intertidal[1]	Global: Least Concern (2018)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2018)[2] Europe: Increasing (2020)[1]	Global: 1,008,000* (2018)[3] Europe: 1,008,000* (2018)[3]	Increasing, +5,000% 1960–2020**	Increasing, +585% 1980s–2010s[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Barnacle goose has three distinct flyway populations, all of which have increased dramatically in size since regular monitoring began in the 1950s. This followed historical declines due to hunting, which was reduced in the 1950s. The species also used to be exploited for its eggs and down. In addition to this, the Barnacle goose wintering distribution has, over the past century, gradually shifted from areas of previously grazed land to areas of intensive agriculture. In north-western Europe, mild winters have also made it possible to winter in the southern part of the Baltic[1,6,7,9,10].

The Greenland population breeds on the east coast (and in Iceland since the 1980s), migrating to staging grounds in Iceland, and then onto wintering grounds in western Scotland and northwest Ireland, particularly on the island of Islay. In the 1970s, the Greenland population's wintering distribution extended to the Orkney Islands, but contracted in Ireland, with sites on the east coast progressively becoming abandoned since the 1950s. Since the late 1990s, an increasing number of birds also breed in Iceland[7,10]. The current Svalbard population was most likely created by a small number of founding birds from the Greenland population; there were very few records of Barnacle geese on Svalbard in the 19th century. The breeding population of Svalbard Barnacle geese is located on Spitzbergen, mainly on the western and south-western coasts of the island. This population winters exclusively in and around the Solway Firth in Scotland, with staging sites in western Norway and on the island of Bjørnøya. Barnacle geese were considered common in their wintering grounds on the Solway Firth in the early 20th century, although these may have been mainly birds from the Greenland population. However, substantial declines were observed in this area, and the population reached a low of less than 500 individuals in the 1930s. This decline was likely due to Greenland birds stopping to winter on Islay instead, as a result of improved feeding conditions arising from agricultural change. In the 1940s, the Solway population reached a new low of less than 300 individuals, due to increased hunting pressure and disturbance from military activities. From then on, the Svalbard population began to recover, showing steep increases in both the breeding and wintering seasons, thanks to the protection of the species and its winter feeding habitats in the 1950s[7,11].

* Mature individuals.

** Change calculated using the minimum population size estimated as start year.

Prior to the 1970s, the only known breeding areas of the Russian/North Sea/Baltic Barnacle goose population were on Novaya Zemlya and Vaygach in Russia. This population of Russian Barnacle geese was considered to be numerous in the 19th century, but it later declined, reaching only 10,000 individuals by the 1950s. Since then, however, the population has increased, doubling in size by 1960, and since the 1970s, the species' breeding distribution has expanded considerably. New breeding grounds in the Baltic region (in Finland and Sweden) were established in the 1970s, and the species' breeding range subsequently continued to expand simultaneously to the Barents Sea coast and south through the Baltic to the North Sea region. The species' range reached as far as Germany, Belgium and the Netherlands in the 1980s, most likely as colonies were founded by birds remaining to breed in stopover sites along their flyway, and in some areas (e.g. the Netherlands) subpopulations have become more sedentary. Their wintering grounds in north-western Europe have also expanded since the 1950s, reaching as far south as Belgium and expanding in a northward direction to Denmark and southern Sweden [7,9,12,13].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

All populations of Barnacle goose have continued to increase over the past four decades. The Greenland Barnacle goose population has increased from around 8,300 individuals in 1960 to 72,100 individuals in 2018, although shifts in its preferred wintering sites continue in Ireland, with the species abandoning sites off the Dublin Coast in the 2000s. The wintering population of Svalbard Barnacle geese increased from 1,650 individuals in 1960 to 31,000 in 2013, and most recently to 40,000 individuals in 2020. Russian/Baltic/North Sea Barnacle geese have also recovered, from less than 100,000 individuals before 1980 to 908,000 in 2009 and now to 1,400,000 individuals in 2018. The majority of this flyway population breeds in the Barents Sea area, although the Netherlands now holds a small but significant breeding population of approximately 19,000 pairs (along with smaller breeding populations in Finland, Denmark, Sweden, Germany and Estonia) [1,3,4,7,8,10,14].

The European wintering population of Barnacle goose is estimated at approximately 1,500,000 individuals in 2020 and has an increasing trend [3].

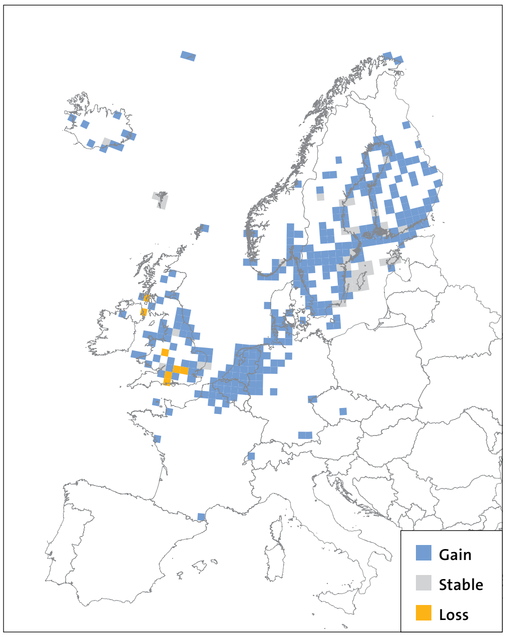

Figure 1a. Change in breeding range of the Barnacle goose between the 1980s [15] and 2010s [4] as per the EBBA2.

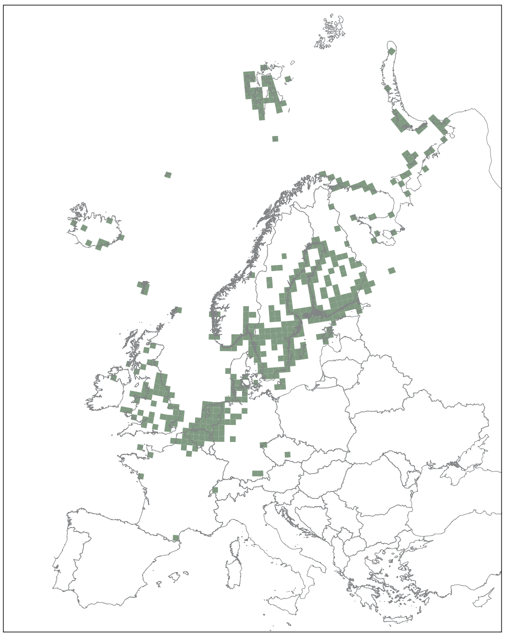

Figure 1b. Current breeding distribution of the Barnacle goose across Europe (2010s) [4].

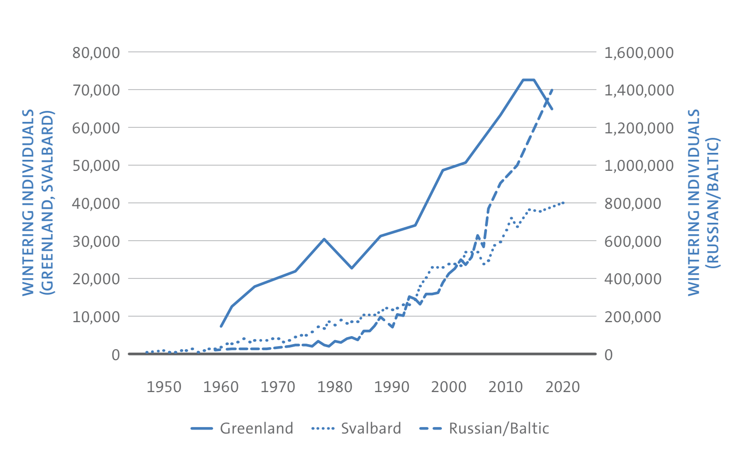

Figure 2. Estimated number of wintering individuals of Barnacle geese in the Greenland, Svalbard, and the Russian/Baltic/North Sea flyway populations [3,7,16,17].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix II) • CMS (Appendix II) • AEWA (Annex II)
Global threats	• Annual & perennial non-timber crops • Wood & pulp plantations • Hunting & trapping terrestrial animals • Problematic native species/diseases • Habitat shifting & alteration [2]
European threats	• Annual & perennial non-timber crops • Renewable energy • Shipping lanes • Hunting & trapping terrestrial animals • Recreational activities • Other ecosystem modifications • Invasive non-native/alien species/diseases • Problematic native species/diseases • Habitat shifting & alteration [1,18]

DRIVERS OF RECOVERY

The Barnacle goose's considerable expansion since the 1950s is due to full legal protection throughout its range, including protection of the species itself, as well as improved protection of its breeding and wintering habitats. This has led to a reduction in hunting pressure and human disturbance across the species' range (although in Russia this effect could also be the result of human depopulation of the region in which Barnacle geese are present). Monitoring has been a key factor in understanding the species' demographics, and the Svalbard and Russian/Baltic/North Sea populations are some of the best studied populations of migratory geese in the world. Due to this research, the Svalbard flyway population has one of the most comprehensive networks of key protected areas of any goose, swan or duck species, and many protected areas are also available for the Russian/Baltic/North Sea population in some regions, particularly towards the west. However, the Greenland population is not so well studied, and further research is needed [6,7,9,13].

The species has also benefitted from improved feeding conditions in its breeding and wintering grounds, caused by the increase in agricultural intensification, which has resulted in an increase in suitable short-sward improved grassland, and in winter crops. However, the potential damage caused to agricultural land by this and other goose species has generated conflict with farmers. This has resulted in the establishment of conflict prevention schemes (such as scaring away feeding flocks) in a number of countries, although these schemes have had mixed effectiveness overall. Countries have also adopted mitigation strategies, offering farmers compensation for damage to their land, or subsidy schemes, such as the successful Barnacle Goose Management Scheme in Scotland, that encourage goose-friendly farming (e.g. reducing scaring methods and other disturbance, and the fertilising of farmland around the species' wintering grounds). Conflict management is key for the sustained conservation and success of this species, and international flyway management plans are necessary to ensure the continued effectiveness of management efforts. The species is therefore now covered by an International Single Species Management Plan, and the Russian/Baltic/North Sea population has also been included on the European Goose Management Platform [1,6,7,19–21].

Legal tools which have supported these drivers of recovery include the species' inclusion in the EU Birds Directive, the Bern Convention and the Convention on Migratory Species (CMS). All three flyway populations (Svalbard, Greenland and Russian/Baltic/North Sea) are listed in the African-Eurasian Waterbird Agreement (AEWA) Action Plan [7]. These have now been in place for some decades, supporting the species' recovery in the long-term.

BENEFITS OF COMEBACK

Barnacle geese are an important primary consumer, especially in their Arctic breeding grounds. In this region, geese droppings may contribute to facilitating the availability of nitrogen for plant species, and can be consumed by other herbivores too, including sheep, cattle and reindeer. Barnacle geese are also themselves a source of food for predators, including eagles, Arctic foxes (*Vulpes lagopus*), and Grey wolves (*Canis lupus*) where present. Barnacle geese may also help the survival of species affected by lack of food due to climate change, such as the Polar bear (*Ursus maritimus*)[22–24].

Grazing geese may also affect habitat structure and plant species composition, creating disturbances and variation in the habitats they occur in. Being herbivorous, the species can help seed dispersal on a local level, as well as playing a small role in dispersing invertebrates. The protection of this species from hunting and disturbance can also benefit other species which may use the same habitats and be affected by similar threats. In addition, by helping plant and animal species disperse and therefore shift their distributions, they may contribute to enabling these species to adapt to climate change or other environmental conditions[24].

The presence of this species, particularly in mainland Europe and the United Kingdom, may also attract tourists, and thus contribute to local economies.

OUTLOOK

The species has greatly increased in Europe over the past century. It has expanded its range and has made a very successful comeback, thanks to legal protection and conservation efforts, but also unintentionally due to the intensification of agriculture. The change in this species' breeding and wintering distributions demonstrates its preference for and shift to improved grassland and agricultural fields. This not only creates and increases conflict with humans, but also may be enabling an artificial growth of the species' population. This success may contribute to the deterioration (damage, erosion, ecosystem breakdown) and subsequent habitat loss of fragile Arctic habitats where grazing and grubbing is intensified due to growing goose populations. Its expansion into areas where it was not previously present could lead it to become a competitor for resources with other pre-established species (such as the Greater white-fronted goose (*Anser*


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albifrons) and Bean goose (*Anser fabalis*) on Kolguev Island)[24,25].

Due to the protection afforded to the Barnacle goose and its habitats, and its adaptation to expanding agriculture, the pressures it faces currently are generally low. However, the amount of conflict with farmers relating to pasture and crop damage is increasing, particularly in the Greenland population's main wintering grounds on Islay, and in Belgium and the Netherlands for the Russian/Baltic/North Sea population. In such cases the use of culling, as is currently practised in the Netherlands, could have an impact on the whole flyway population. Intentional (persecution) and unintentional disturbance (from shooting other species) may also affect the species, particularly in winter, as well as in agricultural/pasture areas within its breeding range.

In addition, Barnacle geese are vulnerable to avian influenza, which, in the winter of 2021 killed over a third of the wintering Svalbard population. On the continent, the species is also one of the more susceptible to the virus. This sort of stochastic event may exacerbate the impact of otherwise minor pressures such as those described above[9,26]. Moreover, wind power generation could potentially become a significant threat in the future, if wind farms are increasingly built along its flyways[7].

As with other species breeding in the Arctic, the Barnacle goose may be vulnerable to threats from climate change. Increased predation may already be a sign of this, and the advent of milder winters and the species wintering further north in some areas along its flyways may already indicate that the species is being affected by climate change. The monitoring of the species' population, especially in its Arctic habitats, and the condition of these habitats could help assess these impacts.

In conclusion, continuing management of the conflict with farmers is needed, and international cooperation is essential to manage the threats to and impacts of the species both on natural and agricultural habitats, as well as to ensure the effective implementation of conservation efforts across the entirety of its flyways.

REVIEWED BY:

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Pink-footed goose

Anser brachyrhynchus

The Pink-footed goose (*Anser brachyrhynchus*) is a fully migratory goose species found in north-western Europe and Greenland. It breeds in territorial pairs, sometimes forming small loose colonies, nesting on cliffs, riverbanks, or islands and hummocks near dense vegetation in open Arctic tundra; it can often be found near seabird colonies. Pink-footed geese are diurnal and herbivorous. In Svalbard, they forage in damp sedge-meadows, whereas in Iceland the majority currently feed in farmland instead of their traditional upland foraging grounds. After breeding, they undergo a flightless moulting period, during which they remain close to open water, and after which they migrate to their wintering grounds. Outside of the breeding season, Pink-footed geese are gregarious, forming large flocks in autumn and winter, roosting together on open water[2,6,7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Grassland, Marine Neritic, Marine Intertidal, Artificial/ Terrestrial[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2016)[2] Europe: Increasing (2020)[1]	Global: 387,000* (2019)[3] Europe: 387,000* (2019)[3]	Increasing, +675% 1971–2020**	Increasing, +27% 1980s–2010s[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Pink-footed goose has two quite distinct flyway populations with almost no interchange or overlapping of breeding or wintering distributions (Figure 1b). One population breeds in eastern Svalbard (particularly in Spitsbergen) and winters in north-west continental Europe (in western Denmark, the Netherlands, as well as historically in small numbers in Belgium, and previously in Germany in the 1950s), with staging sites in Norway. In these wintering grounds, they forage mainly in grassland, but also in stubble fields and increasingly on autumn-sown cereal crops and maize. During spring migration across Norway, they used to graze in saltmarshes and fens, but since the 1980s they almost exclusively graze on managed grasslands[1,2,7].

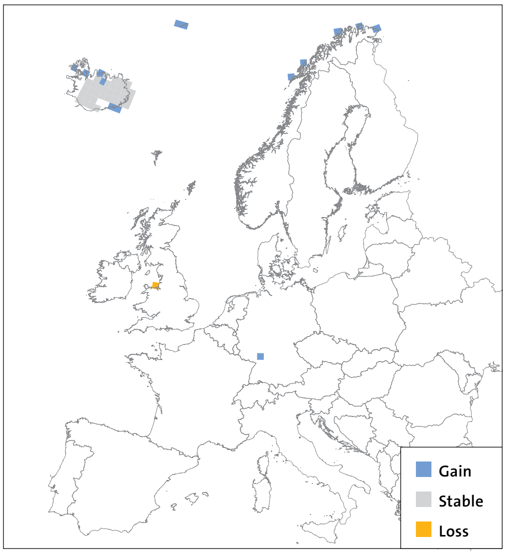


Figure 1a. Change in breeding range of the Pink-footed goose between the 1980s[13] and 2010s[4] as per the EBBA2.

The second population breeds in central Iceland and in smaller numbers along the eastern coast of Greenland, and winters in the British Isles. In Iceland, this second population used to occur exclusively in Pjorsaver, an area of wet meadows in the central highlands. Its wintering grounds were once limited to central Scotland, where it used to be considered a scarce winter visitor. However, since the 1950s, the majority of this population increasingly forage on managed grasslands and sugar beet fields instead of traditional salt and freshwater marshes. In addition, there is a new and rapidly expanding population in Novaya Zemlya (Russia), but as information on this population is not yet available, it is not covered in this report[2,6–8].

Both flyway populations have increased greatly since the 1950s, thanks to improved protection from shooting and to the increased availability of high-quality food in their wintering grounds, the latter being a result of the intensification of agricul-

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

tural practices. The growing population has led to conflict with farmers in parts of their flyways, as the Pink-footed goose can cause damage to agricultural land[7].

Although there are no data on the species before the 20th century (the Pink-footed goose was formerly not distinguished as a different species from the Bean goose (*Anser fabalis*)), it is known that hunting and egg collecting in Iceland resulted in the near extermination of a number of colonies between 1890 and 1930. Human exploitation continued to limit the range of the species in Iceland until the 1950s. In 1951, the Iceland/Greenland population was estimated at only 8,500 individuals. Thereafter, a combination of improving conditions on their wintering grounds, and a regular but non-limiting exploitation of the species in its breeding grounds, enabled the expansion of its breeding distribution in Iceland from the 1960s onwards[7,9].

The Svalbard population was around 11,000-12,000 individuals in the 1930s and 1950s. By the mid-1960s, when systematic autumn counts began, the population had increased to 15,000–18,000. Since the 1950s, there have been significant habitat changes for the Svalbard Pink-footed goose population – from natural wetlands to farmland, as agricultural practices have intensified. Furthermore, the species no longer stages in German sites during the autumn migration. Svalbard populations used to be found in small numbers in concentrated sites in Belgium, but new wintering sites there and in the Netherlands started being used after a period of severe winters between the 1960s and 1980s[6,7,10].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Pink-footed geese populations have undergone remarkable increases in population size (Figure 2), particularly since the 1980s when the rate of increase was the highest, and especially in the Iceland/Greenland population which reached 350,000 individuals by 2009 and 500,000 in 2019. Since the early 1980s, the Icelandic population of Pink-footed goose has spread out from the central area and now breeds over much of the interior of the country. The wintering grounds of the Icelandic population now cover a lot of Great Britain, and small numbers are also found in Ireland[1,4,7,11].

In the 1990s, almost 75% of the Svalbard population occurred in Belgium and the Netherlands in winter. Since then, however, this proportion has changed, with Belgium supporting

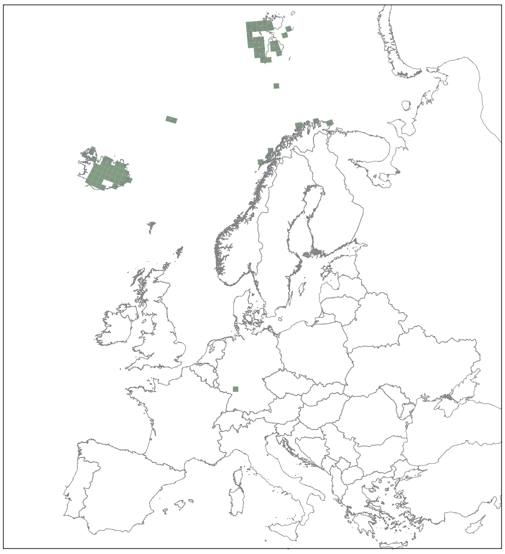


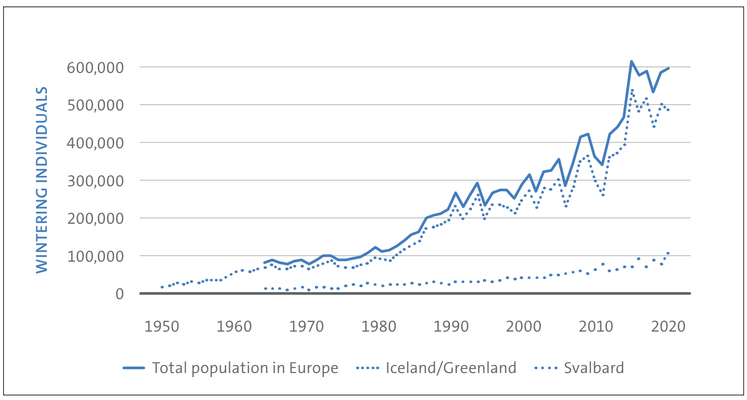
Figure 1b. Current breeding distribution of the Pink-footed goose across Europe (2010s)[4].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix III) • CMS (Appendix II) • AEWA (Annex II)
Global threats	• Annual & perennial non-timber crops • Livestock farming & ranching • Hunting & trapping terrestrial animals • Work & other activities • Dams & water management/use • Problematic native species/diseases • Habitat shifting & alteration [2]
European threats	• Annual & perennial non-timber crops • Hunting & trapping terrestrial animals • Recreational activities • Work & other activities • Dams & water management/use • Other ecosystem modifications • Problematic native species/diseases • Habitat shifting & alteration [1,4,17]

over half of the flyway population and approximately another 40% remaining in Denmark, with Germany now only supporting small numbers. This proportion has changed further since 2010, with even more birds remaining in Denmark and a particularly sharp decline in the Netherlands. The Svalbard population reached over 81,600 individuals in 2012 and this population's rapid increase has led to a rise in conflicts with farmers. To mitigate this, an adaptive management plan was created with its implementation resulting in a stabilisation and even slight decline in the Svalbard flyway population, with only approximately 80,000 individuals recorded in 2019 [1,3,7,11,12].

Overall however, the European wintering population of Pink-footed geese was estimated at approximately 580,000 individuals in 2019 and continues to show an increasing trend, despite little recent change in its broad geographic range (Figure 1a) [1,3,4].

Figure 2. Estimated number of wintering Pink-footed goose individuals in Europe, and separately in the Greenland and Svalbard populations [3,14–16].



DRIVERS OF RECOVERY

The most important drivers of the recovery observed over recent decades have been legal protection from unsustainable hunting (for example, through the EU Birds Directive), the protection of wintering sites, the use of compensation schemes to mitigate conflict with farmers, and the species' ability to adopt new wintering habitats and regions (which may be unintentionally enhanced for the species).

Increases in the Iceland/Greenland population have been directly linked to the protection of important wintering sites, improved feeding conditions and protection from hunting. The Svalbard population has also benefitted from the same factors. Changing behaviour and adaptation, with populations shifting from feeding grounds in areas vulnerable to human disturbance towards protected site such as reservoirs and managed grasslands, with less disturbance and better food quality, has likely helped with the recovery of the species. Protection from hunting led to a decrease in shooting pressure in staging and breeding sites. Historically, spring shooting was banned in staging and breeding countries between 1955 and the 1980s. In addition to this, shooting was banned in the Netherlands, Germany and Belgium in the 1970s and 1980s, and Denmark and Norway have adaptively limited goose shooting depending on the Svalbard population size [7,18].

Climate change has also been proposed as a key player in Pink-footed goose population changes, as it has been linked directly to warmer winters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and wetter summers in Europe, reducing the risk of harsh winters and increasing vegetation growth and availability, thus offering wider habitat ranges and more secure feeding conditions. The change in conditions has potentially increased food availability from intensive agriculture in wintering and spring staging areas, and also increased habitat availability in the high Arctic [4,19,20].

Legal tools which have supported these drivers of recovery include the species' inclusion in Annex II of the EU Birds Directive, Annex III of the Bern Convention, Appendix II of the Convention on Migratory Species (CMS) and Annex II of the African-Eurasian Waterbird Agreement (AEWA). It is also listed in Column A of the AEWA Action Plan [7].

These protections have now been in place for some decades, supporting the species' recovery in the long-term.

Although threats affecting the Pink-footed goose are being managed, the conflict with agriculture is still the main issue, with damage to managed grassland and crops increasing in tandem with the species' growing population size. Some governments (e.g. in the United Kingdom and the Netherlands), have offered compensation schemes to limit persecution and reduce conflict with agricultural practices. In 2012, an International Species Management Plan was developed for the Svalbard population, as concern about the impact of the growing Pink-footed goose population on tundra vegetation was increasing [2,6,7,18,21,22].

The reduction in persecution of the species in Belgium has enabled it to make more efficient use of edge vegetation between fields and along roads, as well as to feed in permanent grasslands, thereby causing less damage overall. This shows that conflict with agriculture can be lessened by reducing persecution and increasing conflict mitigation measures, but international coordination is necessary to effectively manage these threats at the flyway scale [7].

BENEFITS OF COMEBACK

This species is a primary consumer in the trophic web, contributing to the facilitation of nutrient availability for plants and herbivores in its Arctic habitats through its droppings. The species can also affect habitat structure and composition through

grubbing, and to a small extent, may also help seed and invertebrate dispersal which can contribute to these species' shifts in distribution and adaptation to climate change [23].

During the breeding season, it also supports species higher up the food chain, such as Artic foxes (*Vulpes lagopus*). It may also help the survival of other species affected by food-related threats such as Polar bears (*Ursus maritimus*), and perhaps take the pressure off other predated species such as Barnacle geese (*Branta leucopsis*) [6,24,25]. Therefore, predation should be considered when updating the species' management plan.

The protection of this species from persecution and disturbance due to hunting can also benefit other migratory goose species which may use the same habitats and be affected by similar threats.

It can also serve as a good indicator of habitat types, as its high population increase shows a parallel increase in suitable feeding areas, particularly in the non-breeding season.

OUTLOOK

The species is increasing in Europe, thanks to the legal protection and conflict mitigation measures set up over the past decades. However, the growing population may be contributing to the deterioration and subsequent loss of fragile Arctic tundra habitats where the species feeds. In addition, agricultural conflicts remain in place, particularly during spring in Norway [21,22].

In Iceland, the species' increase in population size and subsequent range expansion has resulted in many birds spilling over into unprotected areas, where they are at risk of persecution [7].

Disturbance at breeding sites may have also intensified, as tourism and infrastructure have increased in Svalbard, which could potentially impact the species. For example, growing building development and human activities caused the abandonment of wintering grounds of the Svalbard population in northern Germany. In addition, the abandonment of grassland management and the rise in development of hydroelectric projects (particularly in Iceland), will result in substantial habitat loss [6,7].

These threats are all likely to continue, as the species increases and needs more suitable habitat, especially in the breeding season, where its range has not expanded in parallel with its population size. This means that ultimately, Pink-footed goose numbers may reach a maximum limit, if breeding becomes constrained by habitat availability. However, considering there is little prospect of change in agricultural practices in Europe, winter food availability is unlikely to become a limiting factor.

It is essential to maintain the habitat protection already in place for this species, but also to manage and enhance these habitats (where possible). It is also important to ensure that the increase in this species' population size is not to the detriment of vulnerable habitats, such as those in the Svalbard tundra. Hunting should continue to be monitored and, for the Svalbard population, should continue to adhere to the species' management plan. In addition to this, the species is hunted illegally in the spring in Iceland, an added pressure which may have impacts on the species population. Therefore, stricter enforcement of legal species protection is necessary in some countries. It has also been suggested that the current compensation scheme in Norway could be made much more efficient, an idea which could be investigated in all countries with compensation schemes [2,4,6].

It is difficult to tell what challenges climate change may bring for Pink-footed geese, in addition to those already seen (e.g. new habitats available in the high Arctic, more predation). As it is an Arctic-breeding species, it may see changes sooner than species breeding further south. It would therefore be prudent to increase the monitoring of this species and its associated habitats, particularly in the breeding season, in order to identify changes and potential threats as soon as possible. Such an exercise may benefit many other Arctic breeding species too.

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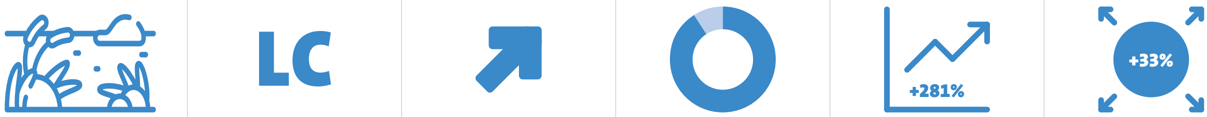
Common crane

Grus grus

The Common or Eurasian crane (*Grus grus*) is a large, diurnal, migratory bird, and one of the most abundant and widely distributed species of cranes in the world. Its breeding range extends from northern and western Europe to the far east of Russia. It breeds in swamps and mires in boreal and temperate forest wetlands, as well as in bogs and sedge meadows, and has also started using areas under intensive agricultural management. During migration, the species is gregarious and uses regular staging grounds. During this time and in winter, it uses a variety of habitats, foraging in newly seeded or stubble fields, pastures and meadows, and roosting in wetlands and alluvial habitats. Common cranes are omnivorous, feeding on plant material as well as invertebrates, and also occasionally prey on herptiles, small mammals, fish, and occasionally bird eggs and young [6–9].

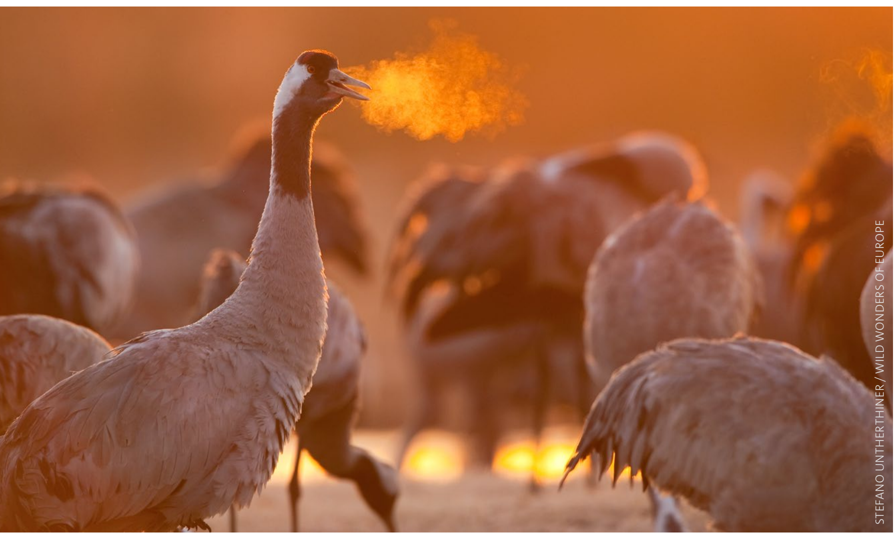


HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Savanna, Grassland, Wetlands (inland), Marine Intertidal, Artificial/Terrestrial, Artificial/Aquatic & Marine [1]	Global: Least Concern (2016) [2] Europe: Least Concern (2020) [1]	Global: Increasing (2016) [2] Europe: Increasing (2020) [1]	Global: 482,000* (2021) [3] Europe: 439,000* (2021) [3]	Increasing, +281% 1995–2020**	Increasing, +33% (1980s–2010s) [4,5]

Historical distribution and abundance

In Europe, the species is spread over three different migratory flyways: birds predominantly originating from northern and central Europe use the West European flyway, wintering mainly in France and the Iberian Peninsula (although some individuals may go as far as Morocco); those originating in Finland and the Baltic countries mainly use the Baltic-Hungarian flyway, travelling across central Europe to winter in North Africa; and birds originating in European Russia, Ukraine and Belarus use the Russian-Ukrainian flyway, travelling to wintering grounds in Turkey, the Middle East and East Africa [6–9]. From the 17th to the end of the 19th centuries, the species' population declined substantially in Europe and its range contracted considerably. This was mainly due to habitat loss (especially through drainage of wetlands) and hunting. The Common crane became extinct in the United Kingdom around the middle of the 17th century, and during the 18th and 19th centuries it disappeared as a breeding species from much of southern and western Europe, the Balkan Peninsula and southern Ukraine. In the first half of the 20th century, the species was extirpated from Bulgaria, Slovakia, Hungary and Austria, and from Spain, Denmark and the Balkan Peninsula in the 1950s and 1960s. Overall, by 1965, the population in Europe was estimated at just 45,000 individuals [7].

From then on however, the Common crane has recovered substantially. Its numbers have increased during the breeding season in Germany, Finland and Estonia, in staging areas in Slovakia and Hungary, and during winter in Spain and France. The species' range has expanded too, with re-establishment of the populations in the United Kingdom and Hungary in the 1980s [7].



* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix III) • CMS (Appendix II) • AEWA (Annex II)
Current threats (Global)	• Housing & urban areas • Annual & perennial non-timber crops • Wood & pulp plantations • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities • Dams & water management/use • Other ecosystem modifications • Agricultural & forestry effluents [2]
Current threats (Europe)	• Housing & urban areas • Annual & perennial non-timber crops • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities • Dams & water management/use • Other ecosystem modifications • Invasive non-native/alien species/diseases • Problematic native species/diseases • Agricultural & forestry effluents • Droughts [1,12]

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The population increases recorded from the 1960s onwards have continued through to recent decades (Figure 2), aided by the protection of both the species and its habitat, milder winters and improved feeding opportunities. The West European flyway population has increased significantly, from around 45,000 individuals in 1985 to 350,000 in 2014, reaching 400,000 birds by 2021. These population increases have also been accompanied by changes in the Common crane's range, with up to 30,000 birds wintering in Germany in recent years. The Baltic-Hungarian flyway population has also increased, albeit not as steeply as the West European flyway population, having grown from 40,000 individuals in the mid-1980s to 120,000–200,000 individuals in 2018. The Russian-Ukrainian flyway population was estimated to number 88,000–120,000 individuals in 2018, but it is not as well researched as the West European and Baltic-Hungarian populations. Nevertheless, breeding trends in Ukraine, Belarus and European Russia are currently positive [1,3,7,8].

The overall growth in the Common crane's population size is evident in breeding as well as wintering populations, with the species increasing in almost every country within its European range. The breeding population in Germany has increased from fewer than 1,000 pairs in the 1960s to 10,000 pairs in 2016. In Finland, numbers have increased from 4,200–5,000 pairs in the late 1980s to 44,900 pairs in 2018. And in Estonia, numbers have increased from 300 pairs in 1970 to 7,000–8,000 pairs in 2017. The breeding distribution has also increased over recent decades (Figures 1a and 1b), including in Czechia, France, the Netherlands, the United Kingdom, Denmark and western and southern Germany, while wintering areas have expanded northwards in France, Germany, and Hungary. In 2018, the Common crane's breeding population in Europe was estimated at around 181,000 pairs. At least 80% of the total European population breeds in the countries surrounding the Baltic Sea [1,7].

In addition to increases in the species' population size, migration patterns have changed. The West European flyway is becoming increasingly used by individuals from the northeast of Europe, particularly as food resources in northwest Russia have decreased due to land abandonment after the break-up of the Soviet Union. More birds are also spending the winter further north (e.g. in Germany and France), most likely due to milder winters and a greater availability of food [6,7].

DRIVERS OF RECOVERY

The factors that have driven the recovery of this species can be split into conservation actions targeting the species directly and unintentional consequences of anthropogenic activity. Targeted actions include legal protection from hunting and disturbance, protection of breeding, roosting and wintering sites, and pan-European collaboration on research and monitoring programmes, as well as the management of the species' habitats. This includes the development of habitat management

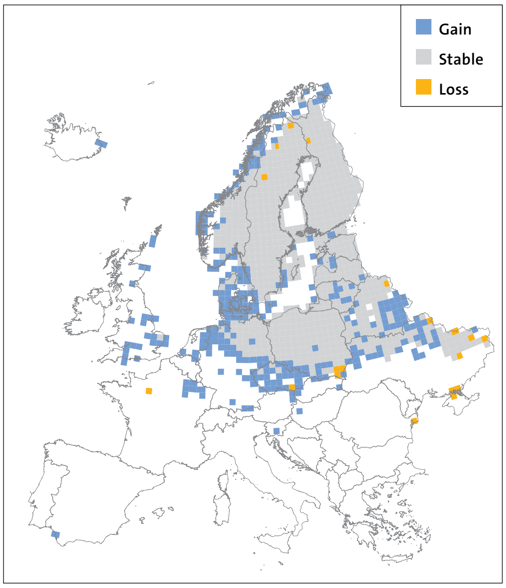


Figure 1a. Change in range of the Common crane between the 1980s [10] and 2010s [4] as per the EBBA2.

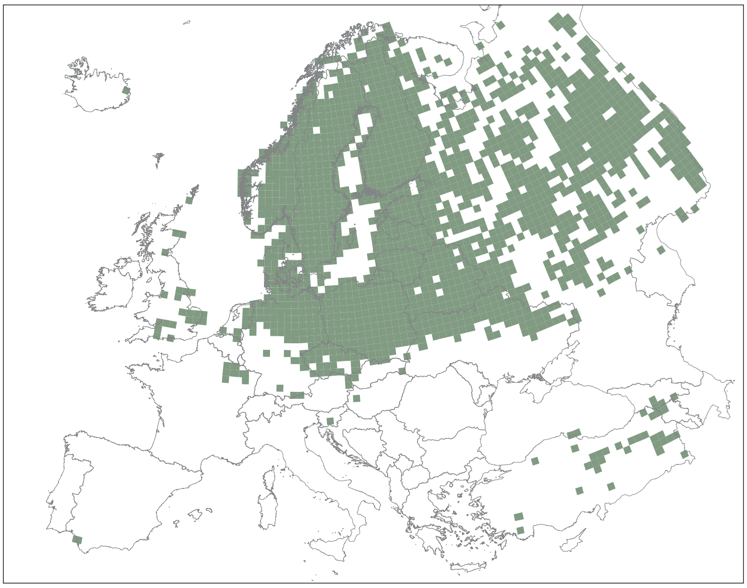


Figure 1b. Current distribution of the Common crane across Europe (2010s) [4].

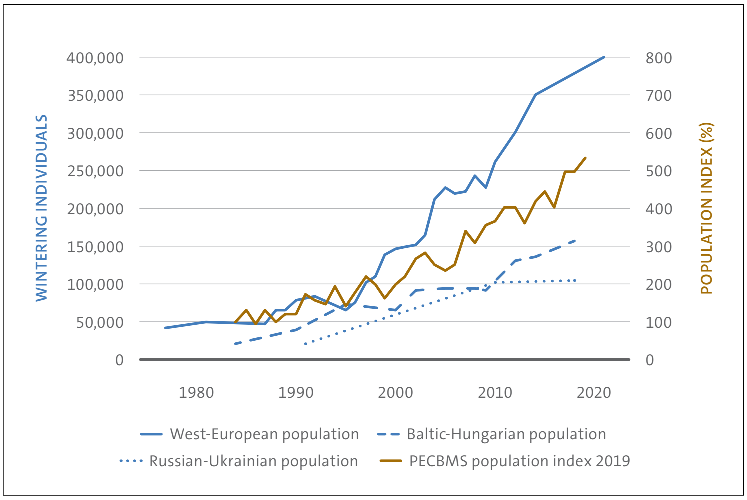
plans for protected areas, as well as the creation or restoration (by ceasing peat extraction and re-flooding old moorland) and subsequent protection of wetlands, and the protection of important staging areas. Collaboration with stake-holders such as private landowners is key for these activities. The burial or relocation of utility lines has also contributed to reducing threats to the species, and a reintroduction programme in the United Kingdom (the Great Crane Project) has also helped expand the species' range [1,6,7,9].

Legal tools which have supported these drivers include the EU Birds Directive, CITES, the Bern Convention, the Convention on Migratory Species (CMS), and the African-Eurasian Waterbird Agreement (AEWA). They have all been in place for some decades, helping the recovery of the species.

Unintended benefits arising out of anthropo-genic activity have included improved foraging conditions due to the intensification of agriculture and milder winters due to climate change. The reduction in suitable habitat along the entirety of its three flyways (over two-thirds of wetlands in Europe have disappeared over the last century), has led the species to increasingly use farmland as a food source. Agricultural intensification has led to higher crop productivity, including in winter, and this has increased the abundance of food available to Common cranes in winter. Feeding on winter crops now provides a valuable food source for the species and has encouraged it to stay longer in staging and wintering areas. This has led to more nutrient storage and increased adult survival rates, contributing to the species' recovery and the expansion of its range. Mild winters also increase food availability further north, and therefore enable Common cranes to shorten the distances they migrate, as there is no need to travel farther (i.e. short stopping), allowing birds to start breeding earlier, which in turn enables breeding pairs to have time to rear a second clutch if the first one should fail [6,7].

Unfortunately, the increase in food availability on cropland, combined with the reduction of natural habitats, has led to conflict with humans as the species can cause damage to agricultural crops, particularly as Common cranes gather in large, concentrated flocks during the non-breeding season. This conflict therefore must be managed to ensure threats do not ensue from it. Conservation management varies across the species' range, but has been effective, incorporating mitigation measures such as agri-environmental and compensation schemes (especially in areas where breeding pairs have resettled in former breeding habitat), and the installation of artificial feeding stations and 'lure crops' aimed at drawing the species away from actual crops [1,6,7].

Figure 2. Estimated number of Common crane individuals wintering in the West European, Baltic-Hungarian and Russian-Ukrainian flyways, and trend in the PECBMS population index since 1980 [1,3,8,11].



In order to coordinate conservation efforts for the species across Europe, the European Crane Working Group (ECWG) was created in the 1980s, covering activities such as research, monitoring and awareness raising.

BENEFITS OF COMEBACK

Common cranes are omnivorous, and therefore play the role of primary and secondary consumers within the trophic web, by feeding on plants and small animals, and being in turn prey to larger predators, thus providing links in the food chain and helping to keep different trophic levels balanced.

When the conditions are right, the species' presence may also be a good indicator of wetland habitat type and quality, as it prefers to nest in inaccessible sites, and needs a good plant and insect food base in the surrounding area. Unfortunately, due to the decreasing availability of good wetland habitat for Common cranes, some pairs are turning to smaller wetlands, or those less suitable, leading to the species' role as an indicator being diminished [9].

OUTLOOK

Among bird species, the Common crane has experienced one of the most remarkable comebacks. With its population still increasing and the conservation measures in place to support it, the species will likely continue to make a comeback in Europe.

However, the main threat to the species in Europe is habitat loss, fragmentation and degradation, due to land use change, principally for agricultural expansion and urbanisation. In particular, drainage of wetlands, dam construction, and the conversion of extensively managed land (such as dehesa pastures in Spain) to irrigated and intensive agriculture, have significant negative impacts on the species. The loss of smaller feeding and roosting sites has led to the species congregating in larger flocks outside of the breeding season (which increases competition for food) and has encouraged Common cranes to turn to agricultural crops as a source of food. This creates an ongoing conflict with farmers as the species can cause damage to their crops. This leads to persecution, particularly in southern Europe where illegal shooting still threatens the species. In areas where the Common crane population depends primarily on agriculture, the species may also be affected by pesticides [1,6,7].

Climate change is also playing an increasing role in habitat loss and degradation. A more frequent occurrence of droughts and the drying of wetlands in the Netherlands and Germany, for example, has resulted in poor reproduction success [8,9].

Development is also a threat due to disturbance from recreational activities, and this increases the risk of predation on more conspicuous or unguarded nests. The installation of utility lines is another important threat to the species, especially along its migratory routes and wintering range [1,6]. With increasing development, it is likely that these threats will continue to increase, and new risks to the species may emerge.

Continued management of these threats and the maintenance of current conservation actions are therefore essential for the continued recovery of Common cranes in Europe. Improvements could also be made, such as increasing the area of breeding, staging and wintering grounds, strengthening the protection of existing habitats, and improving the enforcement of the legal protection of the species itself. International cooperation is essential across its flyways, and collaborative research and conservation actions between countries could be increased. Awareness raising and education on the biology and ecology of the species, along with the threats it faces, are also important [1,6].

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Black stork

Ciconia nigra

The Black stork (*Ciconia nigra*) is a large, partially migratory bird, whose global range extends throughout continental Europe to eastern China and southern Russia, and south to South Africa. It inhabits old, undisturbed open forests, avoiding dense woodlands and large waterbodies. The species nests in pairs in large and preferably older forest trees, or on cliffs (particularly in Iberia), and tends to reuse nests over several years, or occupy old nests of other species (e.g. Griffon vulture (*Gyps fulvus*)). Outside of the breeding season, it may also use tidal estuaries and, in Europe, rice fields. It forages in wetland areas such as streams, pools, marshes and damp meadows, where it mainly feeds on fish, but can also take other small animals such as reptiles, amphibians, and small mammals and birds, as well as terrestrial and aquatic invertebrates[1,5–10].

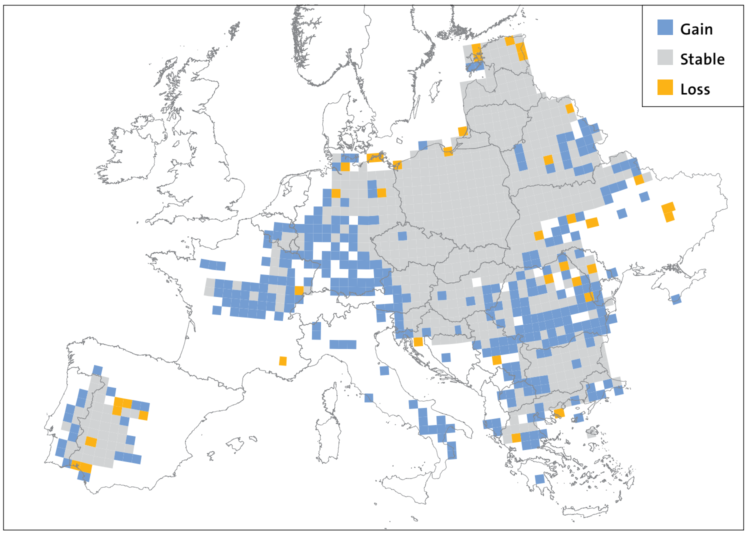
HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Wetlands (inland)[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2020)[1]	Global: Unknown (2016)[2] Europe: Unknown (2020)[1]	Global: 27,100* (2020)[3] Europe: 25,400* (2020)[1]	Increasing, +34% 2002–2018**	Increasing, +29% (1980s–2010s)[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Although it is nowhere particularly common, the Black stork breeds widely across Europe, from the Baltic countries in the north to Iberia in the south, and the Balkans, Turkey, the Caucasus and Russia in the east. Most populations are fully migratory, travelling to sub-Saharan Africa for the winter, although some birds can be sedentary, such as the population in Iberia, which is considered distinct from the rest of the Western Palearctic population[1,6,7,10].

Historically, the distribution of Black storks in Europe is believed to have been much larger. It is likely that the species was negatively impacted by the loss of woodland habitat and increasing human disturbance in the 19th and 20th centuries. Black storks disappeared from Belgium and parts of Germany and became very sparse in Iberia during the Industrial revolution. The species was then impacted more heavily during the two World Wars, as important habitats and nesting sites were destroyed. By the 1950s, the species' populations had declined so much as to go extinct in countries such as Denmark, Sweden and Norway. Only 10–20 pairs were left in Germany, and by 1960, only 3 pairs were left in Austria. The species' range continued to contract until the 1980s, and numbers are likely to have continued declining during that time[5,7,10].

Figure 1a. Change in range of the Black stork between the 1980s[14] and 2010s[5] as per the EBBA2.



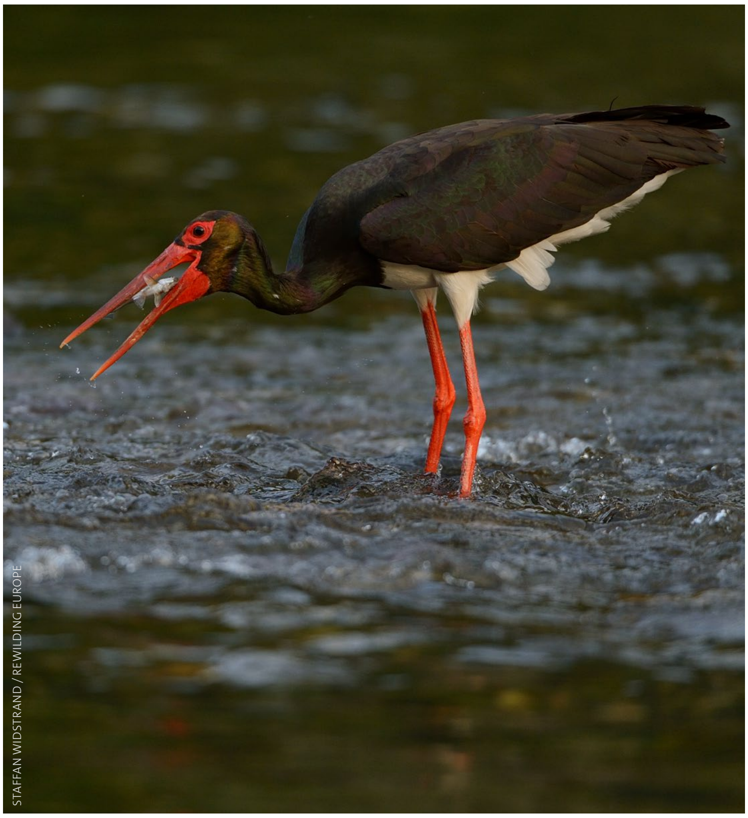
RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The Black stork started to recover from the 1980s onwards (Figure 1a). It has recently recolonised much of its former range in western and central Europe (such as France in 1977 and Belgium in 1982) (Figure 1b). By the start of the 21st century, the total European population was approximately 7,800-12,000 pairs, reaching 12,700 pairs in 2018 (Figure 2). Its range has also continued to expand, with Italy

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix III) • CMS (Appendix II) and AEWA (Annex 2).
Global threats	• Housing & urban areas • Tourism & recreation areas • Livestock farming & ranching • Marine & freshwater aquaculture • Renewable energy • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Dams & water management/use [2,10]
European threats	• Housing & urban areas • Tourism & recreation areas • Annual & perennial non-timber crops • Wood & pulp plantations • Renewable energy • Roads & railroads; utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Recreational activities • Dams & water management/use • Other ecosystem modifications • Invasive non-native/alien species/diseases • Domestic & urban waste water • Droughts [1,18]



and Greece also having been (re)colonised in this period. However, on a national level, trends are varied, particularly in the shorter term. Countries where the species is recovering from very low levels have experienced rapidly increasing trends. For example, France's population has grown five-fold since 2002, and Germany and Austria's increasing populations currently number approximately 850 and 300 pairs, respectively. Elsewhere, countries such as Poland or Belarus, which had retained a larger population, have seen slower growth (e.g. from 1,100–1,200 pairs in Poland in 1990 to 1,200–1,900 in 2018). In Czechia, the Black stork population may have reached its maximum carrying capacity [1,5,7,10–13].

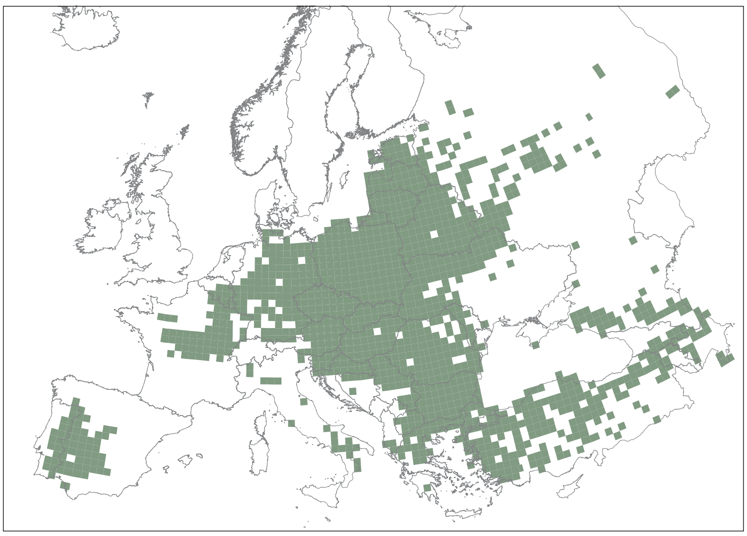
Although many countries are experiencing increases or stability, the species is declining rapidly elsewhere. This is particularly the case in the Baltic States, where the total population has declined from over 2,000 pairs at the end of the 1990s to under 600 pairs in 2018. This comes as a result of the increasing loss and degradation of habitats in this area due, at least in part, to unsustainable forestry activities and agricultural intensification. In addition, some countries which have the highest populations of the species, such as Romania, Turkey, Bulgaria or Russia, have unknown trends [1,7,10].

The Iberian population increased and sharply expanded its distribution between the 1990s and 2000s but seems to have stabilised since. In Spain, the population has declined in some regions while increasing in others, without actually colonising new regions in the last 30 years [1,5].

DRIVERS OF RECOVERY

The main conservation action which has driven this species' recovery in Europe is the protection, restoration, and management of its breeding habitat from damage and destruction. The species is also legally protected in most of its European range from hunting and, in particular, distur-

Figure 1b. Current distribution of the Black stork across Europe (2010s) [5].



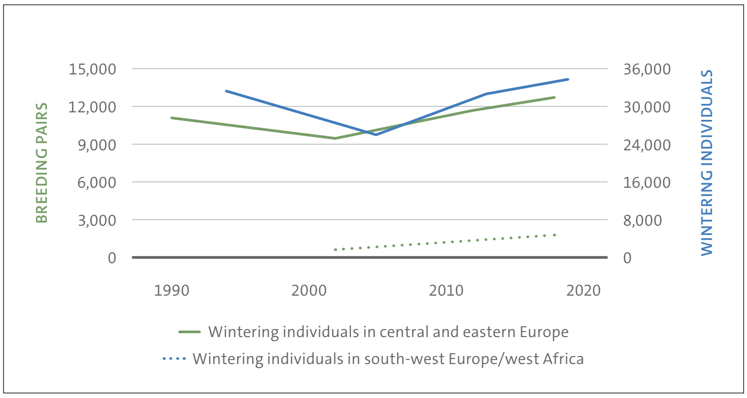


Figure 2. Estimated number of Black stork breeding pairs in Europe, and wintering individuals in central and eastern Europe and south-west Europe/west Africa [1,3,15–17].

bance, with systematic monitoring schemes in place. Awareness raising has also played a role in the species' recovery [1,6,10,19,20].

To coordinate these efforts, an International Black stork working group was set up, and a Conservation Action Plan was published, focusing on the wintering conditions in Africa for the European breeding populations [21]. The species was assessed as Moderately Depleted on the IUCN Green List at a global and European scale [10].

It is important to note, however, that the increases in central and western Europe may in part be due to the species' adaptation to human activity and decreases in the availability of its preferred habitat. Moreover, it appears that the species is also starting to adapt in Baltic states. For example, in Lithuania, Black storks have responded to forest lost and degradation by nesting closer to forest edges and using smaller trees to nest in [7]. This may help stabilise the population in this part of Europe in the future.

BENEFITS OF COMEBACK

The Black stork preys on fish and other small animals and is itself predated upon by birds of prey (e.g. White-tailed eagle (*Haliaetus albicilla*), Raven (*Corvus corax*), and Goshawk (*Accipiter gentilis*) or occasionally by carnivorous mammals (e.g. Eurasian lynx (*Lynx lynx*) or Pine marten (*Martes martes*)). In addition, the non-native invasive Red swamp crayfish (*Procambarus clarkii*) is a staple part of its diet in the Iberian Peninsula, which helps limit the growth of this species' invasion. Due to its migratory nature, the European population of the Black stork plays a role in ecosystems both in Europe and in Africa. Its role as an umbrella species means its conservation can also benefit other species using similar habitats. In addition, although the species has shown some adaptation to changing habitats, its feeding requirements and its preference for nesting in large, undisturbed trees in old, remote forests make it a good indicator for sustainable forestry practices and good quality wetlands [7,8,10,22–24].

The species could also have socio-economic benefits; for example, it can attract birders, generating eco-tourism opportunities at its stopover sites during migration.

OUTLOOK

After the steep declines experienced by the Black stork in the past century, its population is currently increasing and recovering its former range. Despite significant habitat loss which is still ongoing in many parts of Europe, the species is showing signs of adaptation to these changes and may be able to continue its current comeback, at least in the short- to medium-term, even if traditional forest nesting sites become scarce.

Indeed, the main threat to this species today is habitat degradation, due to the continuation of unsustainable forestry practices (including the removal of large nesting trees), deforestation (particularly in Russia and more generally in eastern Europe) and drainage of wetlands (e.g. for industrial development and agricultural expansion or irrigation), and the development of dams for hydroelectric energy. Habitat degradation can also take the form of increased human disturbance, to which the species is sensitive [1,6–8].

Habitat loss and degradation is also a threat on the Black stork's wintering grounds where its wetland wintering habitats in Africa are being lost due to land use changes (e.g. agricultural intensification), desertification and pollution (e.g. pesticides) [1,6].

The species is also illegally shot during migration in southern Europe and is known to suffer mortality following collisions with power lines and overhead cables. Moreover, in some cases in Iberia, the Black stork has been outcompeted for cliff nesting sites by Griffon vultures [1,6,7]. As the Griffon vulture is another species which is successfully recovering in Europe, and as suitable tree-nesting sites for Black storks are continuing to be lost, it is likely that such competition may become more common in the future.

In addition to the existing impact of droughts on Black storks, climate change is expected to impact the species through shifts and changes in its habitat and temperature extremes, which may test its observed ability to adapt [1,6,10].

Therefore, in order to give the Black stork the best chance at adapting and continuing its recovery across Europe, increased conservation actions, covering large areas of deciduous woodland and nearby rivers and wetlands, are key. The development of suitable and sustainable forestry management plans (which include the retention and protection of large old trees), and the protection, creation and management of suitable wetland feeding habitats, will be particularly important. Continued monitoring of the species is also important, as there are still gaps in our knowledge of large proportions of the European population. Monitoring the species' main habitats is key for the timely recording of any ecological changes. In addition, more research is needed on the impact of wind turbines on the species as this is not yet understood. There is also a need for better implementation and enforcement of laws protecting the species from poaching and disturbance (e.g. establishing no-go areas around active nesting sites) and the marking or burying of power lines can also help reduce collision-caused mortality. Lastly, the improved control on the over-exploitation of fish could contribute to improving breeding success [1,6,11].

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White stork

Ciconia ciconia

The White stork (*Ciconia ciconia*) is a large, charismatic, migratory bird. During the breeding season, its distribution extends from continental Europe, through the Caucasus and across to central Asia, and south to the Maghreb. It uses a variety of open habitats in the vicinity of water, including margins, shallow marshes, moist or irrigated grassland or cropland, usually with scattered trees to roost in. It breeds either solitarily or in loose colonies in large nests made from sticks, usually on roofs, pylons, cliff ledges and treetops, which are re-used each year. During winter, it migrates as far south and east as South Africa and Myanmar, respectively. It prefers dryer habitats but will gather near open wetlands such as lakes or slow-flowing rivers. White storks are carnivorous, feeding on a variety of prey including invertebrates, herptiles, small birds and their eggs, fish and small mammals. They will also feed at landfill sites[1,5–7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Grassland, Wetlands (inland), Artificial/ Terrestrial[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2016)[2] Europe: Increasing (2020)[1]	Global: >530,000* (2020)[1] Europe: 530,000* (2020)[1]	Increasing, +141% 1984–2018**	Increasing, +21% (1980s–2010s)[3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

There are two distinct populations of White stork in Europe. The larger eastern population breeds in eastern Europe, then migrates through the Bosporus and winters in the eastern half of Africa; the western population breeds in western and southwestern Europe and migrates across Gibraltar in order to winter in the northern tropics of West Africa, although this population also winters in substantial numbers in Spain, Portugal and southern France[5–7].

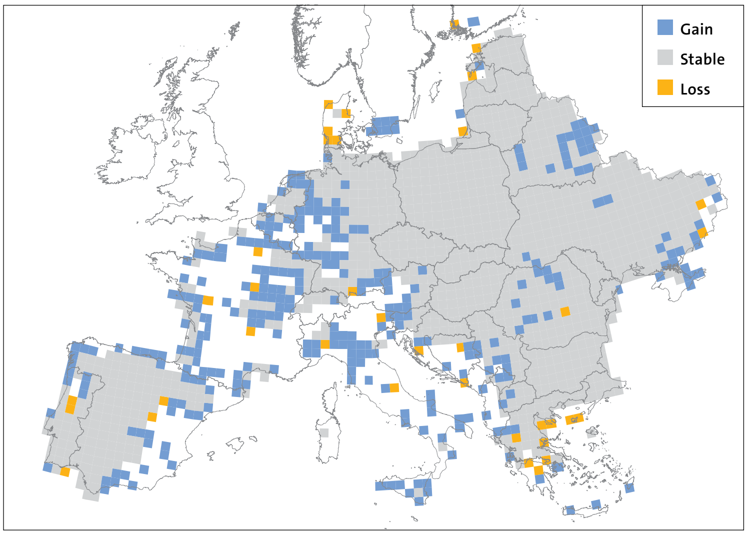


Figure 1a. Change in range of the White stork between the 1980s[9] and 2010s[4] as per the EBBA2.

Evidence suggests that the White stork was much more widespread in Europe in the past, with its distribution likely including Italy until the 16th century and most of France and Greece. The species retreated to the northernmost areas of these latter two countries in the 1800s, probably due to hunting pressure[6].

The White stork was noted to be declining in the early 1900s and this continued until the mid-1980s. This was caused by adverse climatic conditions, resulting in poor food availability in its wintering areas in Africa (including a prolonged drought during 1968–1984 in the Sahel region, affecting the wintering western population, and the migrating eastern population), and changing agricultural practices in Europe. The western population experienced the most dramatic declines, and the species went extinct in parts of its range, including Belgium in 1895, and Sweden and Switzerland by the mid-20th century, although it recolonised Italy in 1960. The eastern population also decreased, but at a lower rate. The large decrease in the species' population size led to the organisation of international monitoring for the species, which has been carried out since 1934[5,6].

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The White stork declined in Europe until the mid-1980s. Since then, the population size has increased (Figure 2) and expanded its range (Figure 1a). In the western population, these increases are due to changes in migration patterns and feeding strategies (with birds increasingly wintering in their breeding grounds, particularly in the Netherlands, southwestern Germany, Belgium and northern France), as well as improved food availability in both breeding and wintering grounds. Combined with conservation actions, particularly reintroduction projects, these factors have helped both the eastern and western European populations. The recovery of the species was noted during its 1994/5 and 2004/5 censuses. These trends have continued to be positive, with countries where it went extinct in the past being recolonised (e.g. Switzerland, Sweden, Belgium, Denmark, and the United Kingdom in 2020, where it bred for the first time in 600 years). The species' range has substantially reclaimed areas of the Netherlands, France, Italy and Iberia, and expanded into areas outside of its historical distribution, especially in the eastern part of its distribution in Ukraine and Russia (Figure 1b). Overall, the White stork distribution in Europe increased by 28% between 1949 and 2012, and by approximately 13% between 2007 and 2018 [1,5–8].

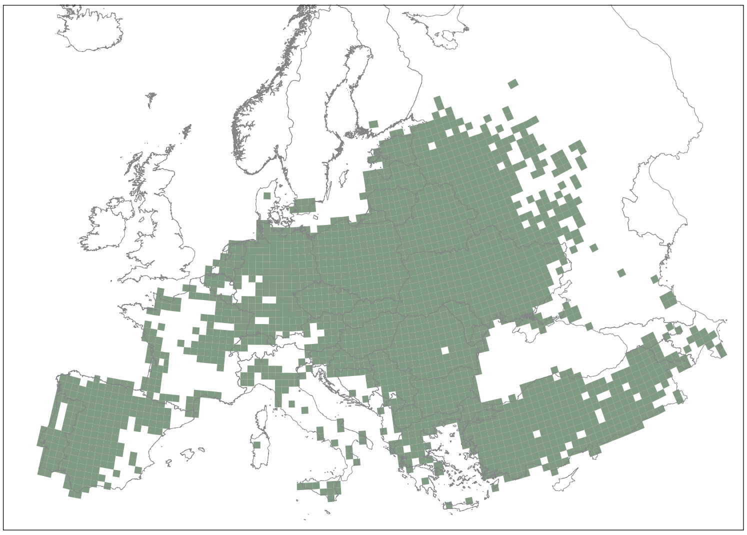
Its current population in Europe is estimated at around 265,000 pairs, with key populations found in Poland, Ukraine and Spain [1].

DRIVERS OF RECOVERY

The increases in the White stork population are partially a result of unintended anthropogenic factors as well as targeted conservation action.

Favourable climatic changes and the extensification of farming following the collapse of the Soviet Union, might be two factors contributing

Figure 1b. Current distribution of the White stork across Europe (2010s) [4].



THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix III) • CMS (Appendix II) • AEWA (Annex II)
Global threats	• Housing & urban areas • Annual & perennial non-timber crops • Livestock farming & ranching • Utility & service lines • Hunting & trapping terrestrial animals • Work & other activities • Dams & water management/use • Other ecosystem modifications • Agricultural & forestry effluents • Droughts[2]
European threats	• Housing & urban areas • Annual & perennial non-timber crops • Livestock farming & ranching • Renewable energy • Utility & service lines • Hunting & trapping terrestrial animals • Work & other activities • Dams & water management/use • Other ecosystem modifications • Agricultural & forestry effluents • Droughts[1,14]

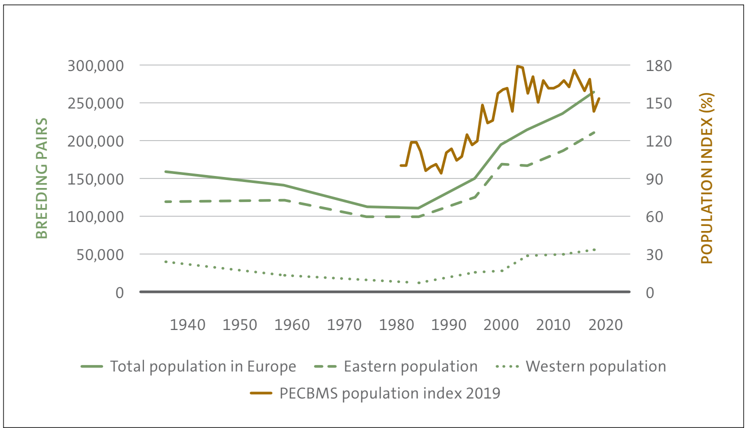


Figure 2. Estimated number of White stork breeding pairs in Europe, and separately in the eastern and western populations, according to International White Stork Censuses (IWSC), and trend in the PECBMS population index since 1980[1,6,10–13].

to the species' eastward expansion in Europe. Conversely, the intensification and irrigation of agriculture in Spain and the introduction in Iberia of the non-native Red swamp crayfish, (Procambarus clarkii), as well as the species' opportunistic foraging at landfill sites have resulted in both an increase in food and its year-round availability. As a result, many White storks in the southwest now winter on their breeding grounds. This is likely increasing the species' survival and breeding success due to the reduction in energy spent and dangers encountered on migration and at traditional wintering grounds[1,5,6].

Conservation actions, particularly reintroduction projects, but also the modification of power lines to mitigate the risk of collision and electrocution, and the installation of artificial nesting platforms, have contributed to the recovery of the species and natural recolonisation of western and northern Europe. However, reintroduced individuals do not demonstrate natural migration behaviour, and are dependent on supplementary food provisioning on their breeding grounds in winter[1,5,6,8].

Legal tools which have supported these drivers include the EU Birds Directive, the Bern Convention, the Convention on Migratory Species (CMS), and the African-Eurasian Waterbird Agreement (AEWA) Action Plan[1,5]. These have all now been in place for some decades, helping to explain the long-term increase in this species' population.

BENEFITS OF COMEBACK

White storks are carnivores, and therefore form a link in trophic webs, preying on small animals and being preyed upon by large birds of prey 15. In Iberia, they prey largely on the invasive non-native Red swamp crayfish, and therefore may contribute to limiting its proliferation.

The White stork is considered an ecosystem engineer. It can serve as a vector for seed dispersal, transporting a wide variety of seeds in its nesting material. The nests are long-lived and can be re-used and repaired from one year to the next, effectively creating small habitats which other species can use. For example, smaller birds like House sparrows (*Passer domesticus*), Kestrel (*Falco tinnunculus*) or small mammals (Norway rat (*Rattus norvegicus*) or Striped field mouse (*Apodemus agarius*) may build their nests along the edges of the White storks' nests[16].

White storks are also a very charismatic species; they are valued culturally, and are a flagship species for conservation in Europe. The presence of the species nesting in villages can attract tourists, which can directly and indirectly contribute to the local economy[1,6,17].

OUTLOOK

The species' increase since the 1980s is a good sign of its ability to adapt to changing conditions, in an increasingly anthropogenically modified world. However, if these changes go too far, the species may reach the limit of its adaptability. In addition, the White stork still faces major challenges in Europe and on its wintering grounds in Africa.

Reduced food supplies, in both its breeding and wintering grounds, are one of the major threats to White stork populations, as it can result in delayed migration and poor breeding success. In Europe, reduced food sources due to land use change, including agricultural intensification and expansion, hydrological modification, industrialisation and urbanisation continue to be major threats affecting the White stork population. In addition, open landfill sites, on which the western population has become heavily dependent in some areas (e.g. Iberia) are being closed under the EU Landfill Directive which will likely negatively impact this species' population, or at the very least affect their breeding and foraging behaviour [1,5,6,18].

As weather extremes (e.g. droughts) can affect the species' survival in staging and wintering grounds, it is possible that climate change could be a threat to the species in future. In addition, the species' food resources in Africa have also been negatively affected by overgrazing and the excessive use of pesticides, thus further reducing the amount of prey available to the species, and increasing the risk of poisoning [1,5,6].

Hunting and illegal killing during migration and in the species' wintering areas is an ongoing threat. However, thanks to its special status in human culture, and recent increases in legal protection, the White stork has never been heavily persecuted across its breeding range in Europe. Nonetheless, the species may see a decline in nesting sites, as modern buildings may not be suitable for nesting, and White storks are also vulnerable to collision with and electrocution by overhead power lines [1,5,6].

Therefore, in order to ensure the continued recovery of this species in Europe, in addition to existing conservation efforts, adequate foraging habitats need to be restored and maintained across Europe. Traditional livestock-farming practices, such as creating and managing herb-rich meadows for stock grazing and hay production, are beneficial to the species, as is the creation, protection, and management of wetlands. Where supplementary feeding is necessary, establishing extensive cattle (*Bos taurus*) pastoralism could be a better option than feeding platforms. In addition, increased efforts should be made to minimise disturbance to the species' nests in the breeding season. Key sites for the species should be monitored for ecological changes, and legislation in the species' wintering grounds should be improved and enforced, so as to limit hunting and poaching and the over-use of pesticides [1,5,19].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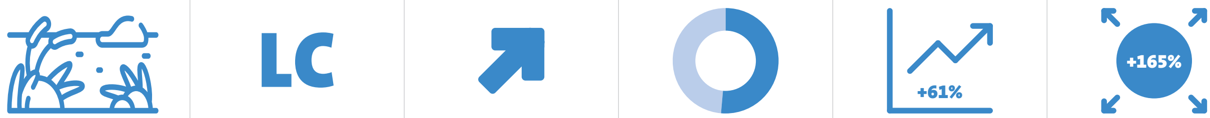
Eurasian spoonbill

Platalea leucorodia

The Eurasian spoonbill (*Platalea leucorodia*) is a fully migratory wading bird, found across the Palearctic, breeding from Europe to China. It inhabits a variety of wetlands, saline, brackish and freshwater habitats, with a preference for extensive areas of shallow water with mud or other fine substrates, where it can forage for small fish, aquatic invertebrates and small amphibians; it avoids thick vegetation and swift currents. The Eurasian spoonbill is also known to use artificial wetlands, such as fish farms, reservoirs or rice fields. In the breeding season, it shows a preference for wetlands with islands, reedbeds or scattered trees offering nesting opportunities. It nests on platforms of sticks, in colonies sometimes mixed with other species (e.g. herons, cormorants or gulls). Outside of the breeding season, Eurasian spoonbills migrate and roost in small flocks. It is commonly believed to be diurnal, being active mainly during the morning and evening. However, GPS trackers have documented further extensive activity at night[1,6–9].



HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Forest, Wetlands (inland), Marine Neritic, Marine Coastal/ Supratidal, Artificial/ Aquatic & Marine[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2020)[1]	Global: Unknown (2016)[2] Europe: Increasing (2020)[1]	Global: 43,000* (2016)[2] Europe: 22,200* (2020)[1,3]	Increasing, +61% 1989–2018**	Increasing, +165% 1980s–2010s[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In Europe, there are three distinct flyway populations: one breeding in western Europe, migrating along the East Atlantic coast and wintering in Africa (the Atlantic population), one breeding in the central part of Europe and wintering in Italy, Northern Africa (mostly Tunisia) and the Niger Basin, and one breeding in the south-eastern part of Europe and moving south-east through the Middle East to winter along the Upper Nile[6,7,9,10].

Before the 19th century, Eurasian spoonbills, particularly of the Atlantic population, bred across a much wider range, including in France up to the 16th century, and in the Netherlands, Germany, Denmark and southern parts of the United Kingdom until the 17th century. The species still bred in Poland and Belarus in the first half of the 20th century.

Unfortunately, due to the loss of wetland habitats, caused by drainage for land use change (e.g. into development or agriculture), and also due to human exploitation of the species' eggs and nestlings for food, Eurasian spoonbill populations have declined dramatically; by the 1950s, the Atlantic population was found only in the Netherlands and in southern Spain. The abandonment of grazing in wetlands and their conversion to fish farms also contributed to continued habitat loss in the second half of the 20th century[1,6,7].

* Mature individuals.

** Change calculated using the minimum population size estimated as start year.

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

European populations of Eurasian spoonbill have shown quite different demographics over the past 40 years (Figure 2). The central and south-eastern populations have shown an uncertain but rather negative trend between 1988 and 2006, driven mostly by severe decreases in countries in eastern and south-eastern Europe and Turkey. The species disappeared from Bosnia and Herzegovina and from North Macedonia in the 1980s and early 1990s, respectively, which contributed to this decline. Since then, declines have continued, notably in Ukraine and Hungary, although new colonies were established in Italy (around 1990), the Czechia and Slovakia (Figure 1a)[1,7–9].

By contrast, the Atlantic flyway population more than doubled between 1991 and 2012, then increased by another 50% by 2015, and currently accounts for over half of the species' European population. As an example, the number of Eurasian spoonbills in the Netherlands began increasing in the 1980s, and by 2012 there were more than seven times as many breeding pairs as there were in 1962; an increase that still continues[1,3,7,8,11].

Recolonisation has taken place elsewhere, especially in France and Italy in the 1980s, in Germany and Denmark from the mid-1990s, and in Belgium from 1999. In the United Kingdom, the first breeding colony of Eurasian spoonbills in more than three centuries became established in 2010 and increased to at least 28 pairs in 2020. In addition to these changes, an increasing number of Eurasian spoonbills overwinter in France and north-western Spain and Portugal[1,7,12].

Overall, the Eurasian spoonbill population in Europe has increased from approximately 9,500 pairs in 2007 to around 11,100 pairs and is still increasing[1,3].

DRIVERS OF RECOVERY

Habitat protection and management has been crucial in enabling the recovery of Eurasian spoonbills in Europe, with the majority of its breeding sites now protected.

Systematic monitoring schemes are also in place in most countries in Europe, and supplementary feeding sites have also been set up. To support and coordinate these actions, an International Single Species Action Plan for the Conservation of the Eurasian Spoonbill was published in 2008 and 2018. National or regional Action Plans and/or specialist working groups were also set up in a number of countries (Netherlands, Spain, Hungary, Romania, Serbia), although most of these have now been succeeded by the Eurasian Spoonbill International Expert Group[1,6–9,19].

Legal tools which have supported these drivers of recovery include the EU Birds Directive, CITES, the Bern Convention the Convention on Migratory Species (CMS) and the African-Eurasian Waterbird Agreement (AEWA). They have all been in place for some decades, helping the recovery of this species.

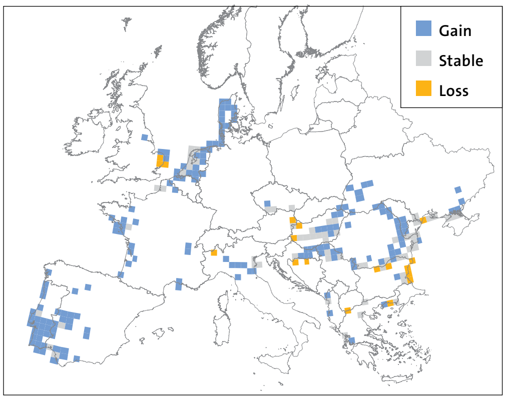


Figure 1a. Change in range of the Eurasian spoonbill between the 1980s[13] and 2010s[4] as per the EBBA2.

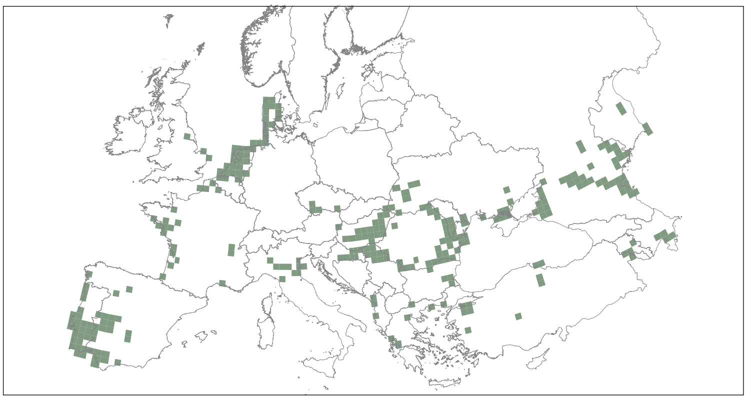


Figure 1b. Current distribution of the Eurasian spoonbill across Europe (2010s)[4].

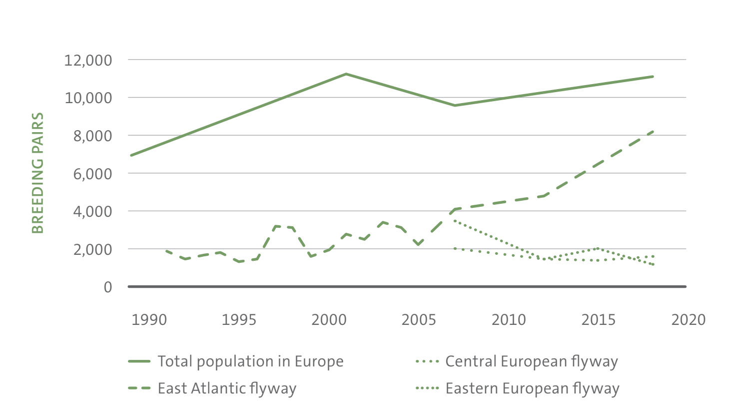


Figure 2. Estimated number of Eurasian spoonbill breeding pairs in Europe[1,7,14–17].

THREATS AND PROTECTION

Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix II) • CMS (Appendix II) • AEWA (Annex 2)
Global threats	• Annual & perennial non-timber crops • Utility & service lines • Hunting & trapping terrestrial animals • Fishing and harvesting aquatic resources • Recreational activities • Dams & water management/use • Problematic native species/diseases • Agricultural & forestry effluents[2]
European threats	• Commercial & industrial areas • Hunting & trapping terrestrial animals • Fishing and harvesting aquatic resources • Recreational activities • Dams & water management/use • Other ecosystem modifications • Invasive non-native/alien species/diseases • Problematic native species/diseases • Problematic species/disease of unknown origin • Agricultural & forestry effluents • Habitat shifting & alteration • Droughts • Storms and flooding • Other impacts[1,18]

BENEFITS OF COMEBACK

The Eurasian spoonbill is a relatively specialist feeder, and its feeding activities fill a unique niche within the trophic web. Its foraging habitat also overlaps with that of the Avocet (*Recurvirostra avosetta*), and therefore the conservation of the Eurasian spoonbill may also contribute to conserving this species, as well as benefitting waterbirds more generally[9,20]. In addition, in some areas it can feed heavily on the invasive Red swamp crayfish (*Procambarus clarkii*), potentially contributing to limiting the proliferation of this non-native species.

The Eurasian spoonbill is a charismatic and ecologically unique species in Europe, attracting birdwatchers and therefore can be of interest for ecotourism activities, and indirectly contribute to socio-economic benefits within the local area in which it is present.

OUTLOOK

The western population of the Eurasian spoonbill has recovered well over the past two decades, with its range expanding and its population growing. However, it is important to note that due to the significant loss of wetland habitats in Europe over the last century, and the specialised habitat requirements of the species, it may be that its continued expansion and recovery will be limited, unless new habitat is created. The comeback of the western population contrasts with the declining trends observed in the central and south-eastern European populations, where the species is not yet recovering, and where increased and improved conservation actions are needed.

The species is still threatened by ongoing habitat loss and degradation. These include the loss of reed swamps to drainage and pollution caused by agriculture and hydroelectric development, the lack of management or grazing in some areas, as well as the development of aquaculture. The species is also vulnerable to collisions with wind turbines and power lines, particularly during migration, while illegal killing is still a major issue in European staging grounds[1,6–8,21,22].

Human disturbance can be a problem at some sites. Hunting and other leisure or commercial activities, as well as overfishing, have caused declines in the past (e.g. in Greece) and may continue to be an issue. In addition, the species is vulnerable to outbreaks of avian influenza (H5N1 virus). Climate change may lead to increased occurrences of drought and flooding from extreme weather occurrences and therefore the species may see an increased loss of habitat in the future[1,6–8].

To mitigate these threats, it is essential to continue with existing conservation actions, and to ensure 'no-go' zones around colonies are established to protect them from disturbance. Suitable habitats for the species within its range must be protected, adequately managed and where possible restored. Monitoring the species' populations and its habitats will ensure any ecological changes at key sites are detected and promptly managed[1,6].

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Eurasian bittern

Botaurus stellaris

The Eurasian bittern (*Botaurus stellaris*) is a medium-sized partially migratory wading bird, known for its secretive behaviour, cryptic appearance, and characteristic booming call. It is the largest and most globally widespread of its genus, breeding across the Palearctic, and as a separate subspecies in South Africa. The Eurasian bittern can adapt to a variety of different prey and plant species in its habitat, restricted only by a requirement for flooded vegetation of sufficient structure, extent and stability to allow nesting, feeding and freedom of movement, although it avoids older, scrubby marsh habitats. It usually feeds solitarily along flooded margins, near good fish habitat of open water, on a diet mainly consisting of fish and amphibians. It will however take any prey available, including terrestrial and aquatic invertebrates, reptiles, and small birds and mammals, and can travel to feed in other habitats, including those with salt water, if prey is available in flooded vegetation[1,4–7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Wetlands (inland), Artificial/Terrestrial[1]	Global: Least Concern (2016)[2]	Global: Decreasing (2016)[2]	Global: >174,000* (2020)[1]	Increasing, +200% 1994–2018**	Increasing, +24% 1980s–2010s[3,4]
	Europe: Least Concern (2020)[1]	Europe: Stable (2020)[1]	Europe: 174,000* (2020)[1]		

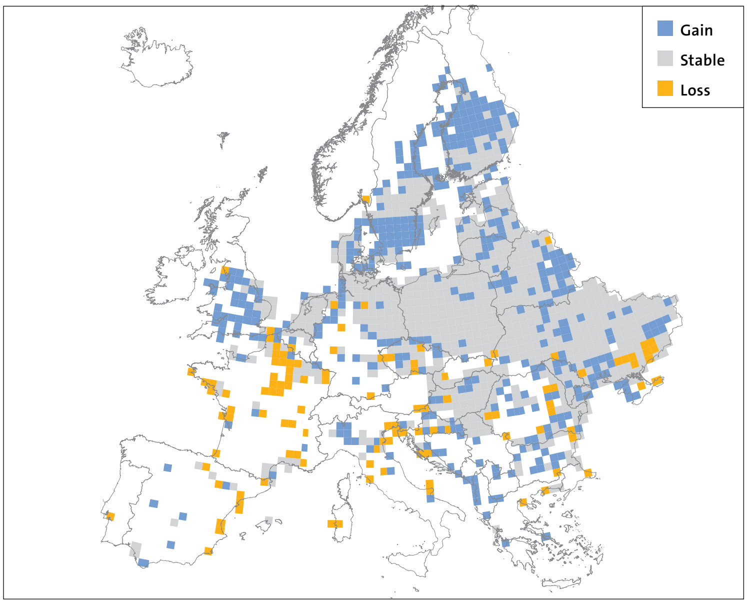
HISTORICAL DISTRIBUTION AND ABUNDANCE

The Eurasian bittern occurs throughout Europe, from southern Scandinavia across to the southern half of European Russia and south to the Caucasus and Turkey, and throughout the Mediterranean to the countries along the Atlantic coast (Figure 1b). It is mainly migratory in northern Europe, whereas elsewhere some populations, particularly those breeding near the Atlantic and Mediterranean coasts, are more sedentary due to milder winters. Migrating populations move through southern Europe and travel on to sub-Saharan Africa[1,4–7].

Its preferred breeding habitat is undisturbed reedbed (containing the right conditions, such as size, water depth, etc.), which is by nature inaccessible to most terrestrial predators. During the non-breeding season (but also occasionally for breeding), the species uses more varied wetland habitats, including those with running water, and anthropogenic areas such as irrigated agriculture, rice fields, fish farms, ditches or sewage treatment plants[1,4–7].

The Eurasian bittern has suffered two major declines in Europe in the past 200 years, due to persecution, and habitat loss and degradation. The first decline took place in the 19th century, although this was relatively short-lived, and the species started recovering at the start of the 20th century. A second decline occurred in the 1960s, exacerbated by some harsh winters, leading to a small and fragmented population, particularly in western Europe[4,6,8].

Figure 1a. Change in range of the Eurasian bittern between the 1980s[9] and 2010s[4] as per the EBBA2.



* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Although the species has remained relatively stable in eastern Europe since the 1970s, population declines continued in western Europe until the 1990s. During that time however, recovery already began in some countries (e.g. in Belgium, Denmark and Finland), thanks mainly to the protection of wetlands and legal protection from hunting and disturbance. These increases continued into the 1990s, and the species' range expanding further north in Fennoscandia, most likely due to mild winters occurring at the time. These changes are reflected in the 200% population size increase observed since 1994 (Figure 1a) [1,4–6,8].

Due to ongoing conservation efforts, the species' European population has now stabilised at approximately 86,900 calling males, and accounts for approximately half of the species' global population. Its main stronghold is still in the eastern part of Europe, particularly in European Russia and Ukraine. Although it is now either stable or increasing in most of the countries it occurs in, declines continue in some areas such as Sweden, central Europe, and in some south-eastern European countries. The population in western Europe remains sparse, and its range is still decreasing in some countries, particularly in France. These recent negative trends are likely due to continued loss of suitable flooded habitat, such as reedbeds, but also to harsh winters in the north (e.g. Sweden) [1,4–6,8].


MARINO PREMOLI / SKUA NATURE

DRIVERS OF RECOVERY

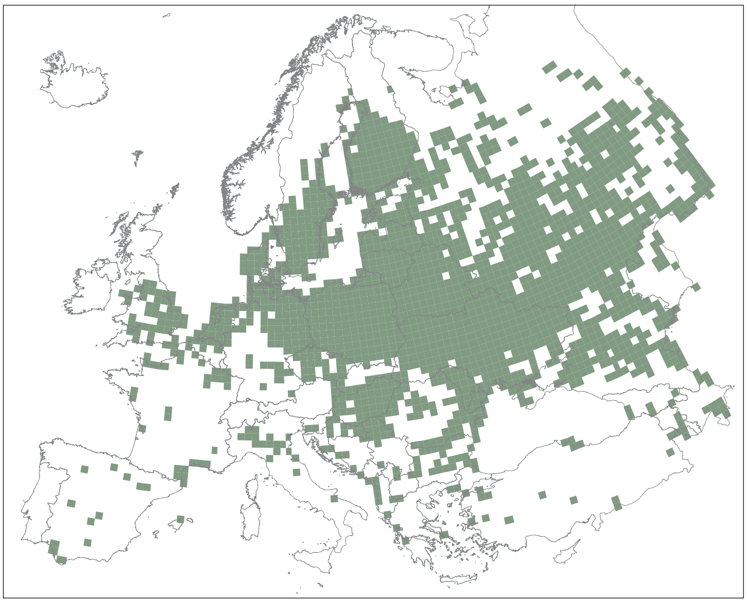
Legal tools, in particular the protection of the species from hunting, have been an important step in halting the species' decline, by lessening the risk of direct mortality. Another important factor in some countries (e.g. Denmark) has been the protection of other similar species, such as the Grey heron (*Ardea cinerea*) from hunting, thus reducing disturbance and accidental killing of Eurasian bitterns [8].

The species requires specialised habitats and therefore one of the main drivers of recovery has been the protection, creation, restoration, and management of wetlands. This includes the control of vegetation, water levels and water quality, the maintenance of healthy prey populations within or near suitable nesting habitat, and ensuring the absence of non-native predators which could target Eurasian bitterns, for example, American mink (*Neogale vison*) and Racoon dog (*Procyon lotor*). These actions contribute to successful breeding and fledging, and therefore to the increase in the species' population. In order to coordinate these conservation efforts, a European Union International Action Plan for the Conservation of this species was published in 1999 [7,8].

The biodiversity-friendly, small-scale commercial exploitation of reedbeds or other flooded vegetation (e.g. for thatching) can also improve the suitability of habitat for the species and enables habitat management to continue outside of purely conservation practices. The promotion of some fish-farming practices where reeds are present and managed to provide refuges for young fish can also be beneficial for this species [7,8].

Research has greatly increased knowledge of the species' ecology and has informed management activities within and close to Eurasian bittern habitats to benefit this and other heron species [6].

Figure 1b. Current distribution of the Eurasian bittern across Europe (2010s) [4].



BENEFITS OF COMEBACK

The Eurasian bittern preys on small aquatic animals and therefore forms a link in the trophic web of the habitats it occurs in. It predates, amongst many other species, on non-native Red swamp crayfish (*Procambarus clarkii*)[7,14], and can therefore contribute to limiting the proliferation of this and potentially other invasive alien invertebrate species.

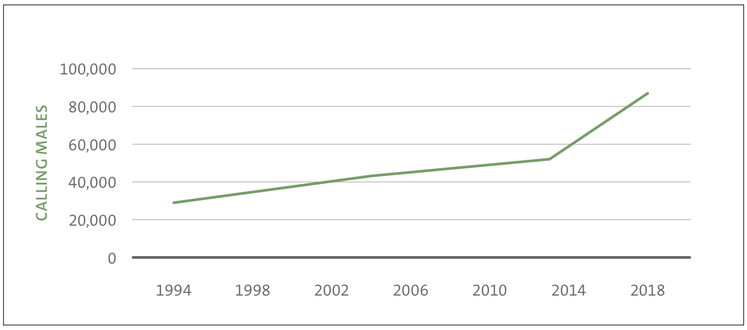
Moreover, the protection of wetland habitats to facilitate this species' comeback also has positive effects on other species (e.g. Purple heron (*Ardea purpurea*)), especially where these habitats are left in their natural state (i.e. without need for management, such as seasonally flooded river valleys) as these have a higher biodiversity richness. Larger wetland areas can be created and managed with a long-term plan providing many different successional stages at the same time, giving space to Eurasian bitterns and other species with different habitat requirements. Where smaller areas of habitat have to be managed to ensure suitability for the species (e.g. in order to limit succession), this will not be compatible with all other wetland species, so it is necessary to ensure that a balance is struck[6–8].

When done correctly, however, the management of wetland areas for Eurasian bitterns can positively impact overall biodiversity, by providing a higher diversity of habitat type, structure and species.

OUTLOOK

Although the stabilisation of the species' European population is a positive, its relatively small population leaves it in a fragile situation. Historically, the species and its suitable habitat would have been found in ephemeral transitional zones between open water and scrub, or more permanently in unregulated river valleys with seasonal flooding[8]. The latter are becoming increasingly rare in Europe, and the former usually only exists where wetlands have been created or preserved and are appropriately managed. Therefore, the species' continued existence is more and more dependent on active management. Ideally, to ensure an independent recovery, seasonally flooded river valley habitats would have to be restored. However, as this is a complex solution to implement, it is likely that the Eurasian bittern will remain conservation-de-

Figure 2. Estimated number of Eurasian bittern breeding pairs in Europe[1,10–12].



THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix II) • CMS (Appendix II) • AEWA (Annex 2)
Global threats	• Tourism & recreation areas • Annual & perennial non-timber crops • Hunting & trapping terrestrial animals • Recreational activities • Dams & water management/use • Other ecosystem modifications • Domestic & urban waste water • Agricultural & forestry effluents • Habitat shifting & alteration • Other impacts [2]
European threats	• Tourism & recreation areas • Annual & perennial non-timber crops • Livestock farming & ranching • Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Recreational activities • Fire & fire suppression • Dams & water management/use • Other ecosystem modifications • Invasive non-native/alien species/diseases • Domestic & urban waste water • Agricultural & forestry effluents • Droughts • Temperature extremes [1,13]

pendent in many countries, and so any decrease in effort or resources could result in new declines.

In addition, the species is still threatened by habitat loss and fragmentation, through water abstraction and land use changes resulting in wetland drainage. It is also more and more threatened by habitat degradation, not only from pollution, which can cause direct poisoning, water eutrophication and lack of food availability, but also from increased human disturbance, such as from untimely reed cutting, motor vehicles, boats, and recreational activities. The intensification of fish farms, especially where this causes a loss in surrounding reedbed, could also have an adverse impact on the species. Moreover, Eurasian bitterns and their nests are sensitive to water level changes due to variations in weather, and especially more frequent summer storms and flooding, as well as being vulnerable to harsh winters. Such weather extremes are predicted to become more common and rising in sea levels may additionally result in the encroachment of saline water into coastal freshwater wetlands with detrimental effects. However, climate change could also lead to increasingly milder winters in Scandinavian countries, enabling the species to continue to expand its range northwards [1,4–8].

In order to ensure this species' recovery in Europe, habitat management of suitable wetlands must continue, to maintain and increase current habitat and improve connectivity across Europe. These activities demand a high input of resources however, which may not be viable in the long run if only undertaken and funded through conservation channels. More economically sustainable wetland management practices, with long-term wetland management plans will therefore be important. Collaboration with stakeholders, such as small-scale commercial enterprises and owners or managers of private and commercial areas, will be an important step forward in order to carry out appropriate small-scale management of reedbeds. This management should have a particular emphasis on providing Eurasian bitterns with access to a sustainable source of food, through for example, extensive grazing or environmentally sustainable vegetation exploitation. Regional management schemes, as well as education campaigns (e.g. to decrease human disturbance around breeding sites) are also essential, as is continued research into this species' conservation needs and demography [1,5–8].

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ANSERIFORMES | GRUIFORMES | CICONIIFORMES | **PELECANIFORMES** | CHARADRIIFORMES | ACCIPITRIFORMES | FALCONIFORMES

Great white egret

Ardea alba

The Great white egret (*Ardea alba*) is a large, partially migratory bird which occurs on every continent except Antarctica. It inhabits a wide range of natural inland and coastal wetlands, as well as more modified waterbodies such as water reservoirs, fish farms, drainage ditches and irrigated agriculture. It nests colonially in reedbeds, scrub or trees, usually over water, or on inaccessible islands, and can reuse nests over the years. Outside of the breeding season however, it is more often found along coasts. Great white egrets are diurnal but are usually most active at dawn and dusk. Their diet mainly consists of fish, herptiles and aquatic invertebrates, although in drier habitats they feed on lizards, terrestrial invertebrates and small birds and mammals[1,4–6].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
	LC			+215%	+419%
Grassland, Wetlands (inland), Marine Intertidal, Artificial/Aquatic & Marine[1]	Global: Least Concern (2016)[2] Europe: Least Concern (2020)[1]	Global: Unknown (2016)[2] Europe: Increasing (2020)[1]	Global: 1,140,000* (2016)[2] Europe: 102,000* (2020)[1]	Increasing, +215% 2002–2018**	Increasing, +419% (1980s–2010s)[3]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In Europe, the Great white egret mainly breeds in southern and south-eastern parts of the region, and disperses in all directions after breeding, followed by migration to southern Europe, the Middle East and North Africa for the winter[1,4–6].

Before the 19th century, the species was likely much more widespread and common across the continent. During the 19th and early 20th century, it declined in both population size and range due to large-scale drainage of its wetland habitats and intense persecution for the plume trade, with this latter pressure exacerbated by the increase in the availability of firearms for hunting at the time. Large populations became heavily diminished or were lost entirely in countries including Hungary and Austria, and the species became extinct in Iberia at the end of the 19th century. During most of the 20th century, Great white egrets were a rare sight in western Europe. However, recovery began in the second half of the 20th century due to protection from their use in the plume trade, and they returned to many former breeding grounds, including Greece in the 1960s and the Netherlands and Latvia in the 1970s. In the 1970s and 1980s, the species also underwent a significant expansion northward, moving into Russia and Ukraine[1,4,6–8].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The Great white egret has continued its remarkable recovery in Europe since the end of the 20th century, largely due to the protection and restoration of its key nesting habitats, with a continuing expansion and growth of its breeding and wintering population sizes within the region. This has been most obvious in northern and western Europe, with, for example, the species re-establishing itself in Iberia, Italy, France and Poland in the 1990s, and Belgium, Germany, Denmark, Estonia, Finland, Lithuania and Sweden in the 2010s, before breeding in the United Kingdom for the first time in 2012[6,7,9,10].

Substantial increases have been noted in many countries including the Netherlands (from 86-90 pairs in 2008 to 230 pairs in 2018), Poland (from 36 pairs in 2010 to 955 pairs in 2021), the UK (from 2 pairs in 2012 to about 50 pairs in 2021) and France (from 180 pairs in 1994 to 600 pairs in 2014). In the second half of the 1990s, the total European breeding population was estimated at 12,900–17,500 breeding pairs, with almost half of this population found in Russia; this increased to 20,248–32,928 pairs by 2015 and to approximately 50,800 pairs by 2018[1,5,9,10].

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

The species' wintering population size and range has also expanded in line with the increasing breeding population. The main wintering areas were previously located in the eastern Mediterranean and North Africa, but these areas have recently expanded to incorporate central and western Europe, and wintering further north, or closer to their breeding grounds, is becoming increasingly common, particularly during mild winters [1,4–7,11].

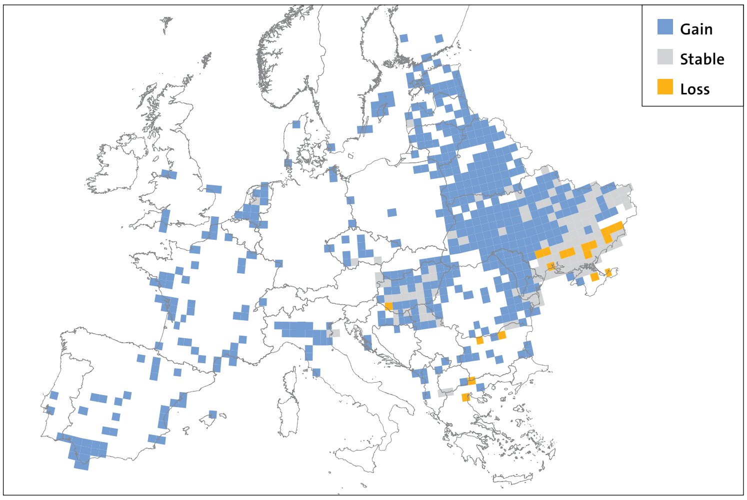

Figure 1a. Change in range of the Great white egret between the 1980s [12] and 2010s [3] as per the EBBA2.

DRIVERS OF RECOVERY

The main drivers of recovery have been the legal protection of the Great white egret, particularly from hunting, and the protection, creation, restoration and management of important breeding and wintering sites. These drivers are also likely to be key for the continued recovery of Great white egret in the future [6].

Monitoring continues to be an essential element of this recovery, as it allows important nesting and feeding sites to be identified and protected. Management of sites not only includes the management of vegetation, but also protection from disturbance, and the monitoring and control of pollutants and hydrology in feeding areas. Artificial sites are key to support the species in many areas. For example, the creation of polders in the Netherlands resulted in the re-establishment

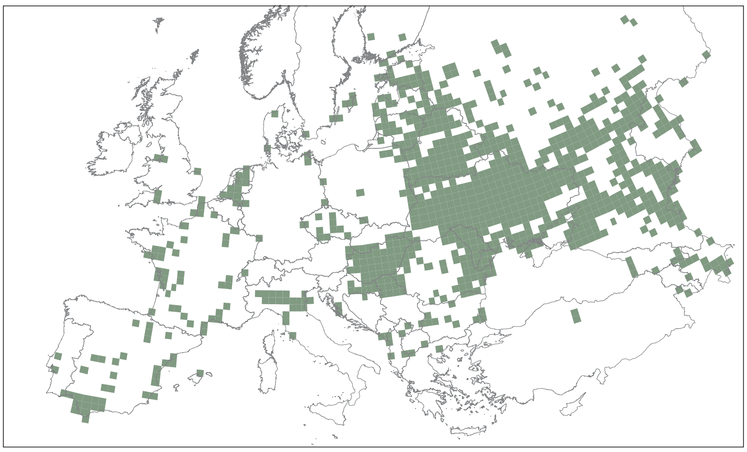

Figure 1b. Current distribution of the Great white egret across Europe (2010s) [3].

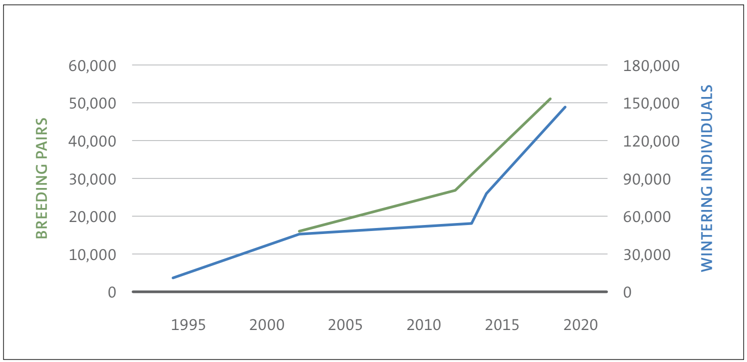

Figure 2. Estimated number of Great white egret breeding pairs in Europe, and wintering individuals in central Europe/eastern Mediterranean [1,13–15].

of the species in the country, while in France, the creation of an artificial nesting island in the Camargue, as well as the increase of rice cultivation in the region, has facilitated the species' return [1,4,6,7]. However, changing fishery practices with expanding aquacultures, and the overfishing of large predatory fish which increases the availability of small prey fish species, are likely to have driven an increase in winter food availability, along with a shift to foraging in agricultural (stubble) fields in winter. Climate change may also be influencing the change in this species' wintering behaviour [6,7].

In addition, it appears that the species' breeding can be affected by toxic pollutants such as organochlorine pesticides. Accordingly, the European ban on the use of DDT may have helped improve the species' breeding success [6].

BENEFITS OF COMEBACK

The Great white egret is carnivorous, and feeds mainly on small fish and invertebrates. Although the adults do not have many predators, their eggs and chicks may be preyed on by mammals or birds. Thus, the species constitutes an important trophic link within the ecosystems it inhabits.

This is also an impressive species, popular with eco-tourists, and could indirectly contribute to local economies around the habitats it inhabits.

OUTLOOK

The species has increased substantially over the past few decades in Europe, and both its breeding and wintering ranges continue to expand. The ability to feed in many different wetland habitats, including feeding in artificial sites such as aquaculture ponds, has aided this expansion.

However, habitat loss and degradation (e.g. from drainage, overgrazing, land-use change, pollution and invasive plant species) is still a key threat to the species today. Improved and expanded protection of wetlands across the continent will support continued recovery. Wetlands should continue to be monitored for and protected from disturbance, pollution and changes in hydrology and ecology which could cause reductions in the species' breeding success. The future impacts of climate change are uncertain, and adverse effects such as reduced foraging opportunities, and egg and nestling exposure may result from likely changes in hydrology, more extreme weather events, higher temperatures and changes in rainfall patterns. Pollution can also be an important factor, as it can affect food availability. Historically the species has been observed to accumulate toxic pesticides (e.g. DDT), which led to reduced breeding productivity [1,4–6].

Great white egrets are increasingly wintering on or near their breeding grounds in response to increased food availability from intensive agriculture and aquaculture [6,17]. Although this may be seen as a positive, this is an artificial and unintentional effect which does provide the potential for conflict with fish farmers in particular, as the species is seen as a piscivore and stressor to farmed fish [17]. Improved communication and awareness raising of the species' ecology amongst stakeholders, in order to ensure fish stock protection and cohabitation is possible, is therefore a key component in helping the species' continued recovery in Europe.

THREATS AND PROTECTION

Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix II) • CMS (Appendix II) • AEWA (Annex II)
Global threats	• Annual & perennial non-timber crops • Wood & pulp plantations • Hunting & trapping terrestrial animals • Dams & water management/use • Invasive non-native/alien species/diseases • Habitat shifting & alteration • Droughts [2]
European threats	• Annual & perennial non-timber crops • Wood & pulp plantations • Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Recreational activities • Dams & water management/use • Problematic native species/diseases • Habitat shifting & alteration • Droughts • Storms & flooding [1,16]

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Dalmatian pelican

ANSERI-FORMES | GRUI-FORMES | CICONII-FORMES | **PELECANI-FORMES** | CHARADRII-FORMES | ACCIPITRI-FORMES | FALCONI-FORMES

Pelecanus crispus

The Dalmatian pelican (*Pelecanus crispus*) is the largest species of pelican and one of the largest birds capable of flight. Its distribution extends from eastern Europe, particularly the Balkan Peninsula, through Kazakhstan to western Mongolia and China. It is highly faithful to traditional breeding grounds, breeding most often in dense colonies in inland freshwater wetlands such as lakes and reedbeds, deltas, estuaries and coastal lagoons, making nests of reeds and sticks, mainly on small, isolated islands. Outside of the breeding season, it is a long-distance migrant in most of its range, travelling as far as southern Pakistan and northwest India, although in south-eastern Europe it can be resident or dispersive. Dalmatian pelicans feed almost entirely on fish in freshwater and brackish wetlands and tend to forage alone or cooperatively in small groups, including with other species such as Great white pelicans (*Pelecanus onocrotalus*) and cormorants (Phalacrocoracidae) at sites up to 190 km away from the breeding colony[1,6–8].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Wetlands (inland), Marine Coastal/ Supratidal[1]	Global: Near Threatened (2017)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2018)*[3] Europe: Increasing (2020)[1]	Global: 18,000** (2018)[3] Europe: 8,300** (2020)[1]	Increasing, +435% 1994–2018***	Increasing, +67% (1980s – 2010s)[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Dalmatian pelican used to breed across western Europe during the Neolithic period, with fossils found as far west as Great Britain. However, the species suffered massive declines in recent centuries and its range contracted significantly due to habitat loss and degradation, and persecution. This was particularly the case during the 19th and 20th centuries, when many colonies disappeared in central Europe and the Balkan Peninsula. The species became completely extinct in Hungary in 1868 and in Ukraine by the end of the 1940s. The most important pressure that drove the population decline was the loss of wetlands, due to drainage or other hydrological modifications for agriculture, as well as human disturbance within wetlands. Although the species returned to Ukraine in the 1970s, its overall decline continued until the 1980s[7,8].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The species' population stabilised in the 1980s at around 4,000–5,000 pairs, and since 1990 most colonies have been stable or increasing across Europe, thanks to conservation efforts across its range (Figure 1a). A notable exception to this is Albania, where only one colony remained after 1990 and its size continued to decrease until 2007, threatened mainly by disturbance. The population in Greece, which currently accounts for about half of the species' European population, increased from 70–120 pairs in 1980 to about 1,200 pairs in 2008 and approximately 2,100 pairs in 2018 (Figure 2). Less is known of the previous population sizes and trends of the species' Russian population, but recently it has increased by 30–50% between 2010 and 2018, at which point the country held approximately 1,100 pairs. In Romania, the situation is less certain, although trends suggest stability, and although Turkey holds a significant number of breeding pairs, the trend there is not known. Overall, the current European population appears to be increasing, and is estimated at around 4,100 pairs[1,7–9].

However, the species is still restricted to eastern parts of its historical range in Europe (from Montenegro to Greece and Bulgaria, and south and east Ukraine to southern Russia, the Caucasus and Turkey) (Figure 1b). Its largest known colony is in Lake Mikri Prespa in northern Greece, and the

* Global trend taken from most recent Species Action Plan.

** Mature individuals.

*** For south-east Europe only. Change calculated using the minimum population size estimated as start year.

Danube Delta in Romania is also a key site for the species [7].

Unfortunately, the Dalmatian pelican was hit very hard by a wave of avian influenza in early 2022, which appears to have killed a significant proportion (over a fifth) of the European population. It is not yet clear how this will impact the species' population demographics in Europe, and successful breeding in 2022 and the coming years may help mitigate this loss [9,10]. Such events highlight the vulnerability of small populations and the importance of constant monitoring of this species, to identify and understand the severity of such events early on and whether any further action needs to be taken to conserve the species in Europe.

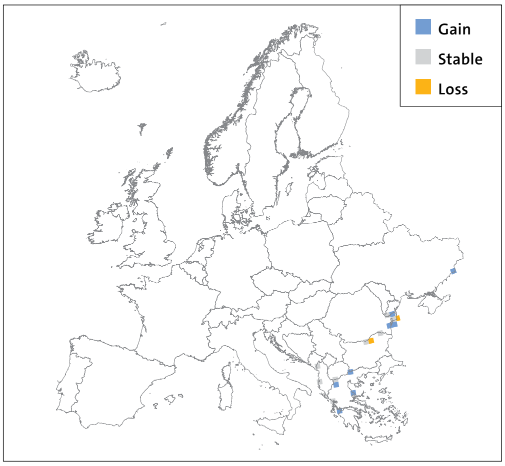


Figure 1a. Change in range of the Dalmatian pelican between the 1980s [11] and 2010s [5] as per the EBBA2.

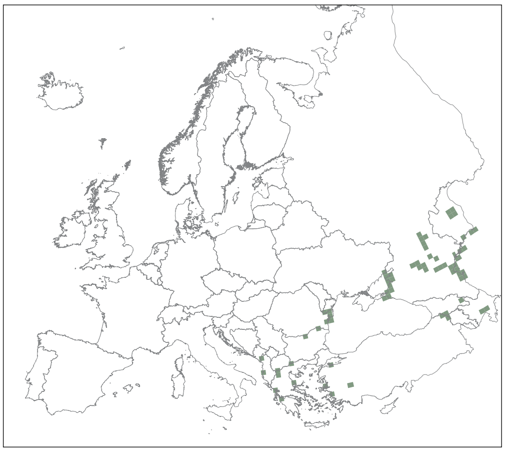


Figure 1b. Current distribution of the Dalmatian pelican across Europe (2010s) [5].

DRIVERS OF RECOVERY

The species has shown a remarkable recovery in Europe, especially in Greece. This is mainly thanks to successful targeted conservation efforts, which have aimed to reduce human disturbance, and manage and restore the species' habitats. The provision of artificial nesting platforms and rafts has also had a positive impact, particularly in large lakes, as they are less likely to be disturbed or to flood. The marking, burying and dismantling of power lines has helped to reduce collisions

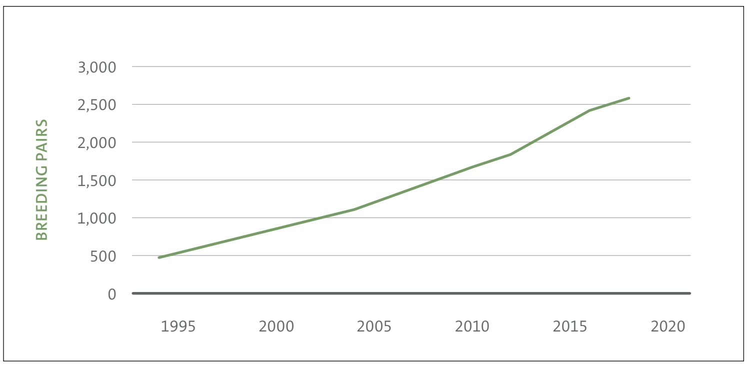
and associated mortality, and the management of water levels has improved breeding success. Conservation actions also include research and continued improvement of knowledge on the species' ecology and demography, and education programmes are helping to raise awareness of the species and the threats it faces [6,7].

The Dalmatian pelican is internationally protected under the EU Birds Directive, CITES, the Bern Convention, the Convention on Migratory Species (CMS) and the African-Eurasian Waterbird Agreement (AEWA). However, the enforcement of protection legislation remains poor in most countries, and there is limited capacity to carry out management or the work of designated wardens. The species is overall management-dependent and so the removal of conservation measures (e.g. due to limited resources) could lead to future population declines. The Dalmatian pelican is still vulnerable to many threats, including disturbance, overhead power lines and habitat degradation. In addition, most of the habitat suitable for the species is already utilised, so there is limited scope for the future establishment of new colonies [7].

Where attempts at reintroduction have been made (e.g. in Croatia), human conflicts have arisen. Efforts have been made to manage such conflicts, especially persecution by fishermen, but have not been very successful. Nevertheless, efforts to raise awareness and mediate conflicts should continue, as they are important steps to take to promote coexistence and can, at the same time, help resolve issues relating to the overexploitation of fish stocks [6,7].

To coordinate conservation efforts and render them more effective, a European Species Action Plan for the species was created in 1996, and subsequently reviewed in 2010. This has been most completely and successfully implemented in Greece. A new International Species Action Plan was published in 2018 [3].

Figure 2. Estimated number of Dalmatian pelican breeding pairs in south-eastern Europe [1,3,12–14].



BENEFITS OF COMEBACK

Dalmatian pelicans feed almost exclusively on fish and therefore form a key part of wetland ecosystems within their range. They are an indicator species, and their conservation can indirectly help the restoration and improvement of wetland habitats, thereby benefitting other species. As a large and charismatic bird, one of only two species of pelican occurring in Europe, it can generate a lot of interest, and the presence of Dalmatian pelicans can be a great attraction feature for local areas. Ecotourism related to the species can generate income and employment, either directly or indirectly [16]. Additionally, in the conservation sector, it is an ambassador species [17], useful for communicating the need for

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix I) • Bern Convention (Appendix II) • CMS (Appendices I and II) • AEWA (Annex 2)
Global threats	• Annual & perennial non-timber crops • Renewable energy • Utility & service lines • Roads & railroads • Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Recreational activities • Dams & water management/use • Problematic native species/diseases • Agricultural & forestry effluents [2]
European threats	• Annual & perennial non-timber crops • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Recreational activities • Work & other activities • Dams & water management/use • Invasive non-native/alien species/diseases • Problematic native species/diseases • Agricultural & forestry effluents [1,15]

large and well-connected wetlands across Europe, and highlighting the necessity of increasing, improving and enforcing legal protection of these sites as well as protecting the species itself.

OUTLOOK

The species has greatly recovered from its past declines, thanks to the large amount of conservation effort put into supporting the species in Europe. However, it is entirely management-dependent, and resources for such activities are low. It is therefore possible that Dalmatian pelicans may start declining once again, should these efforts not be maintained.

Additionally, much of the species' habitat has been lost over the past centuries; indeed, two thirds of wetlands in Europe have disappeared. This loss limits the opportunities for new colonies to develop and the population to grow, as there is little suitable habitat left available within its range. Habitat loss and degradation is still one of the most important current threats faced by the species. This is caused not only by changes in land use, such as for housing development, but also by pollution and hydrological changes, leading to eutrophication and alteration of functioning wetlands and coastal lagoons, and to erosion or flooding of the breeding colony islands. Pollution can also cause the ingestion of harmful chemicals – high levels of organochlorides (e.g. DDT) have been found in both the species' eggs and its prey species – and hydrological changes can also be detrimental e.g. low water levels can allow otherwise inaccessible nests to be predated on by mammals [1,6,7].

Other ongoing threats include human disturbance (e.g. from fishing and tourism), illegal persecution (e.g. by fishermen), collision with utility lines (particularly during migration and the non-breeding season) and with wind turbines. The latter issue is likely to increase and could have a high impact on the species in the future, as windfarms continue being developed along the species' main flyways and near key wetlands [1,6,7].

Dalmatian pelicans are also vulnerable to the H5N1 virus (avian influenza), which can spread rapidly, especially as the species tends to form colonies. This has been particularly the case in spring 2022, when a significant proportion of the European population returning to their breeding colonies died from the disease. At Lake Mikri Prespa, Greece, one of Europe's most important colonies, over half of the population succumbed to the virus [6,9,10].

The situation in spring 2022 illustrates the fragility of the species' state in Europe, and its potential to rapidly decline. The support given to the species through continued conservation action is key to limiting the effects of emerging threats (such as avian flu or climate change) and for providing opportunities for the species to recover. Continued monitoring of the species and the condition of its habitats, as well as further research, should be undertaken to help improve the effectiveness of existing conservation actions and potentially find new solutions to known conflicts. Wetlands require enhanced protection and proper enforcement of that protection, and the species would benefit from establishing patrolled areas to reduce human intrusions around breeding colonies, and improved protection from persecution. Work on reducing mortality from collisions with powerlines should continue [1,6,7].

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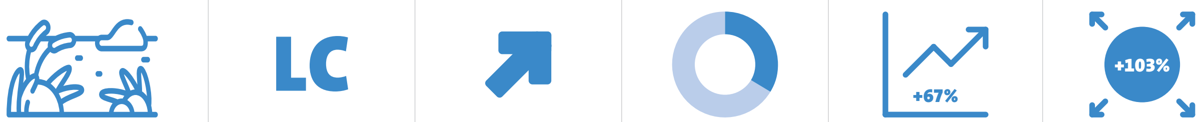
Black-winged stilt

Himantopus himantopus

The Black-winged stilt (*Himantopus himantopus*) is a widely distributed, partially migratory wader found on every continent except Antarctica. It usually breeds solitarily or in small colonies, in inland or coastal open areas near the water level, on islets or on the edges of shallow, and often ephemeral, lowland wetlands. It can also be found in man-made habitats such as irrigated land, aquaculture ponds and sewage treatment plants. Black-winged stilts can disperse long distances in response to regional variations in environmental conditions during the breeding season, such as droughts. Outside of the breeding season, Black-winged stilts are gregarious and gather in large numbers around the shores of inland and coastal wetlands offering extensive areas of mudflats or sand. They feed mainly on aquatic invertebrates, but also amphibian spawn, fish eggs and small fish, and can sometimes also eat seeds [1,4–8].

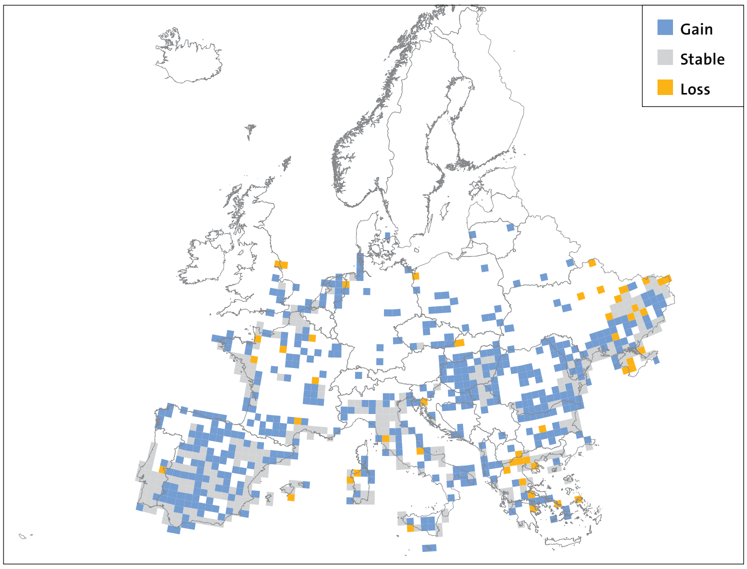


HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Grassland, Wetlands (inland), Marine Neritic, Marine Intertidal, Marine Coastal/Supratidal, Artificial/Aquatic & Marine [1]	Global: Least Concern (2016) [2] Europe: Least Concern (2020) [1]	Global: Increasing (2016) [2] Europe: Increasing (2020) [1]	Global: 395,000* (2016) [2] Europe: 158,000* (2020) [1]	Increasing, +67% 2000–2018**	Increasing, +103% (1980s–2010s) [3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In Europe, the Black-winged stilt breeds mainly in the south, from France and Iberia in the west through the southern half of Central Europe to Russia in the east, as well as throughout the Black Sea and Mediterranean regions (Figure 1b). Small populations are found in the north of the continent. Northern populations migrate south to winter in sub-Saharan Africa, whereas those from the south can be sedentary [1,5].

Figure 1a. Change in range of the Black-winged stilt between the 1980s [13] and 2010s [4] as per the EBBA2.



Over the past 200 years, little has been recorded about the Black-winged stilt's distribution and trends. Nevertheless, it is known that the species has experienced declines in Europe during the 19th and 20th centuries due to the degradation and loss of wetland habitats. In the 1960s and 1970s, the Black-winged stilt suffered large declines in Hungary due to unfavourable weather conditions, human disturbance and habitat loss, which were also the likely reasons for the species' overall decline across Europe during that time. However, also in the 1970s, the species' range in European Russia started expanding, most likely due to an increasing area of rice fields [4,6,9–11].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Over the past 40 years, the species' population size has recovered well, most likely due to reductions in pollution and the protection of wetlands in some areas; it has also shown a shift towards nesting in man-made habitats such as sewage plants and drained aquaculture ponds. Despite these adaptations, the Black-winged stilt is still vulnerable to habitat loss and is sensitive to hydro-

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

logical changes and variations in annual rainfall, which leads to regional fluctuations of its numbers between years [1,4,8].

Currently, the species' strongholds are in Spain and European Russia, with the Spanish population showing a steadily increasing long-term trend (from about 10,500 pairs in 1989 to 26,700 pairs in 2018). Trends are believed to have fluctuated over the long-term in European Russia, although it is likely that there has been a slight overall increase in this population too. In addition, the range of the Black-winged stilt has expanded (Figure 1a), particularly northwards and towards the interior of the continent, both within existing range states and to new countries, including in Belgium in the 1980s, Austria and Slovenia in the 1990s, and the Netherlands, Germany, Malta, Poland, the United Kingdom and Lithuania in the 2000s and 2010s. The species was also recently discovered breeding in Bosnia and Herzegovina [1,4,6,9–12].

Overall, the current Black-winged stilt population in Europe is estimated at around 79,000 pairs and is increasing (Figure 2). Both the population size increase and range shift have been aided by the effects of climate change, which leads to new habitats becoming available for the species, especially in the north of the continent [1,4,8].

DRIVERS OF RECOVERY

The species is protected from hunting and disturbance in many European countries. However, the most important driver to the Black-winged stilt's recovery in Europe is likely to have been the protection, restoration and management of suitable breeding and nesting sites from loss and degradation. Targeted management includes the control of fishpond water levels to ensure active nests are not flooded, and the control of vegetation on breeding islands to enable nesting. Important sites for the species have been identified over its entire range, while it also benefits from broader protection of wetland habitats, without having to be the target of specific interventions. Wetland management which has benefitted the Black-winged stilt includes the creation of open water and associated islands in reedbeds, as well as the use of grazing livestock to control vegetation growth. It is likely that the restoration of any wetland habitats containing shallow areas and fine substrates would be beneficial for the species [1,11].

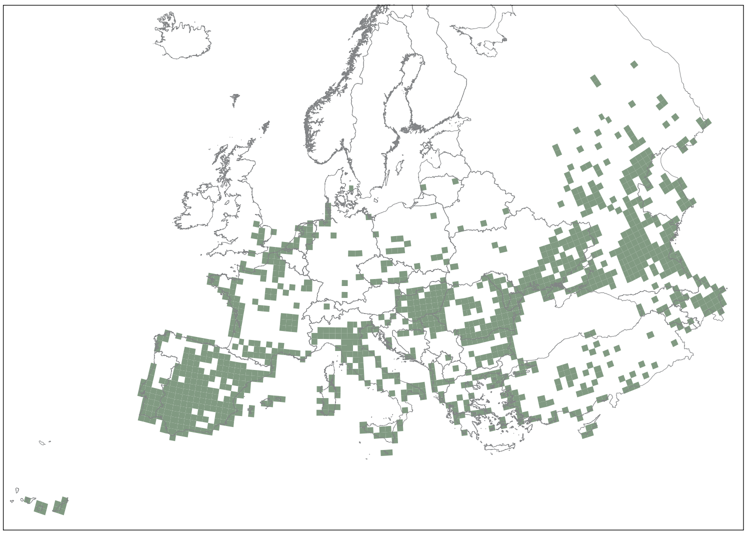


Figure 1b. Current distribution of the Black-winged stilt across Europe (2010s) [4].

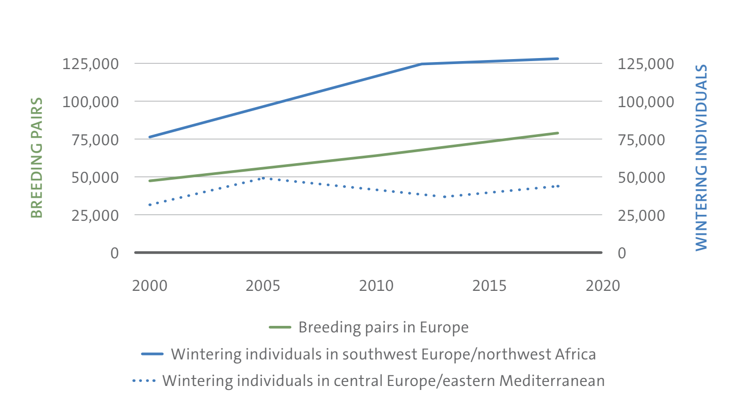


Figure 2. Estimated number of Black-winged stilt breeding pairs in Europe, and wintering individuals in southwest Europe/northwest Africa, and in central Europe/eastern Mediterranean[1,14–17].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix III) • CMS (Appendix II) • AEWA (Annex 2)
Global threats	• N/A[2]
European threats	• Housing & urban areas • Commercial & industrial areas • Annual & perennial non-timber crops • Recreational activities • Dams & water management/use urban drainage • Other ecosystem modifications • Problematic species/disease of unknown origin • Domestic & urban wastewater • Industrial & military effluents • Agricultural & forestry effluents • Droughts[1,18]

Legal tools which have supported these drivers include the EU Birds Directive, the Bern Convention, the CMS and AEWA. They have all been in place for some decades, helping the recovery of the species. In addition, systematic monitoring schemes are in place in many countries across the region[1].

BENEFITS OF COMEBACK

The Black-winged stilt feeds on small aquatic invertebrates. In turn, the Black-winged stilt (particularly its eggs and chicks), can become prey to mammalian or avian predators (e.g. Red fox (*Vulpes vulpes*) and other Canids (*Canis* spp.), Rats (*Rattus* spp.), Mustelids (*Mustelidae*), Corvids (*Corvus* spp.), Gulls (*Larus* spp.) and Harriers (*Circus* spp.). It may also occasionally fall prey to predatory fish. It is therefore an integral part of the trophic web of the ecosystems it inhabits[6,11,19].

The protection and management of habitats for Black-winged stilts can also benefit other species that use similar habitats and require the same breeding or feeding conditions (e.g. Avocet (*Recusvirostra avosetta*), Kentish plover (*Charadrius dubius*) and Northern lapwing (*Vanellus vanellus*))[9–11,19].

OUTLOOK

The Black-winged stilt is a highly adaptable and opportunistic species, which can easily colonise new sites to breed or forage if past breeding or foraging sites become unsuitable, sometimes travelling hundreds of kilometres to find new sites[4,7]. This could give it an advantage in rapidly changing environments.

The species is still however threatened by habitat loss and degradation, and changes in water levels due to the drainage of wetlands for agriculture or industrial or urban development, water abstraction or droughts. Black-winged stilts are also sensitive to water quality, such as may be affected by agricultural or urban runoff, and to human disturbance. Climate change may make new habitats available to Black-winged stilts but will also likely amplify the effects of the threats this species faces, by increasing the severity of droughts (e.g. in Iberia) or, conversely, of rainfall and flooding. Droughts may also reduce the occurrence and time of existence of ephemeral freshwater habitats, which the Black-winged stilt uses opportunistically, thus further reducing its potential habitats. Projections suggest that because of climate change the species' current range in Iberia will contract, shifting northwards. At the same time, the expansion of the northern boundaries of its range may be a demonstration of the species' ability to adapt, at least in the short-term[1,4,7,8,20].

It is important therefore, that conservation actions aimed at protecting, managing and restoring wetlands and their water quality are continued, while care must be taken in man-made sites in which the species breeds to prevent the destruction of their nests. In addition, it is essential for this and many other wetland-dependent species to ensure wetlands are protected against detrimental land use change and that this protection is implemented and enforced, at all levels, from international and national legislation to local policies.

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Audouin's gull

Larus audouinii

Audouin's gull (*Larus audouinii*) is a partially migratory coastal marine species, found around the Mediterranean and Saharan coastal waters. It rarely occurs inland, breeding in colonies on rocky cliffs and on offshore islands or islets. It uses habitats varying from bare rocks to substantial bush cover for breeding, although it is adaptable and can use sites in harbours or on roofs, where these sites are predator-free. It feeds along the coast and over the continental shelf, with a foraging range going up to 200 km out to sea. Audouin's gull feeds mainly on epipelagic fish, but it also makes extensive use of fisheries discards, to the point where some populations' fortunes can be linked to changes in discard amounts. It can also take some aquatic and terrestrial invertebrates, small birds, and plant material such as peanuts, olives, and grain. On rare occasions, it may be found feeding at landfill sites [1,2,5–10].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
VU				+34%	+67%
Marine Neritic, Marine Intertidal, Marine Coastal/Supratidal [1]	Global: Vulnerable (2020) [2] Europe: Vulnerable (2020) [1]	Global: Decreasing (2020) [2] Europe: Decreasing (2020) [1]	Global: 43,589* (2020) [2] Europe: 36,300* (2020) [1]	Increasing, +34% 1992–2018**	Increasing, +67% (1980s–2010s) [3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The global population of Audouin's gull is mainly concentrated in Europe, with much of the European population nesting in Spain. During the non-breeding season, a significant part of the population migrates to the north-west African coasts (mainly southern Morocco, Sahara and Mauritania), while some birds remain in the Mediterranean and an increasing number occur along the coasts of Portugal [1,5,9,11].

Not long ago, Audouin's gull was a rare and localised species, numbering around 1,000 pairs in 1975, when it was restricted to some pristine rocky islets. However, a rise in the number of Protected Areas (including beaches and sand dunes) helped limit threats such as egg collection and other human disturbance. Coupled with an increase in fisheries discards in areas such as the Ebro Delta (which peaked in the early 2000s, leading to a parallel peak in the species' population size), the global population was able to increase between the 1980s to mid-2000s (Figure 2), particularly in the western half of the Mediterranean, peaking at approximately 25,000 pairs in 2007, when the Ebro Delta colony accounted for over 60% of the global population [5,9,12,13].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

The total European breeding population of Audouin's gull was estimated at 15,700–21,000 pairs in 2018, and is currently distributed across the Iberian Peninsula, Italy and France in the western half of the Mediterranean, and across Greece, Turkey, Croatia and Cyprus in the eastern half (Figures 1a and 1b).

Despite the species' long-term increase over the last 40 years, it has undergone a slight decrease in population size since 2010, which is expected to continue for some years yet (Figure 2). This recent reduction in population size is thought to be mainly due to increased pressure from predators. Coupled with a loss of suitable habitat and likely exacerbated by a recent reduction in the availability of fisheries discards in the vicinity of the breeding colonies (leading to the loss of food source), this led to the collapse of the Audouin's gull's largest breeding colony in the Ebro Delta after some years of very low reproductive output. Until its decline, this colony had acted as a source of new breeding nuclei, supporting and generating other colonies as birds dispersed, in e.g. Spain, Portugal and Croatia. Despite an overall decline

* Mature individuals.

** Change calculated using the minimum population size estimated as start year.

in breeding pairs, the collapse of the colony has accelerated the formation of new colonies. This is particularly evident in the colony present on Ilha Deserta de Faro in Portugal, which has grown substantially in recent years and now hosts many birds that formerly bred in the Ebro Delta, and is now the largest known colony for this species, with approximately 5,300 pairs. Although the reasons behind the species' western shift around the Iberian Peninsula are not completely understood, it is likely that this is at least in part linked to the deterioration of fishing stocks in the Mediterranean and to increased fishing activity in southern Portugal [1,4–6,9,14,15].

In the eastern half of the Mediterranean, the breeding population size is much smaller, exhibiting a rapidly declining trend, and only accounts for about 3% of the total European population. The trend direction and scarcity of the species in this region may be indicative of a less healthy population in this part of the region [1,9].

DRIVERS OF RECOVERY

Legal tools which have supported the recovery of Audouin's gull include the EU Birds Directive, the Convention on Migratory Species (CMS) and the African-Eurasian Migratory Waterbird Agreement (AEWA). To coordinate conservation work, an International Species Action Plan was created for this species, and National Action Plans have also been set up (e.g. in Spain and Italy). Sites of importance for the species have received protection, as well as the species itself being protected from human disturbance and persecution.

Audouin's gull remains vulnerable to predation from native species. However, the control of invasive species (e.g. the Black rat (*Rattus rattus*)) on some islands (e.g. in Greece) has also been beneficial. Captive breeding programmes focusing upon drawing birds back to specific colony sites were attempted in the early 2000s, but these were not very successful, and as the species constantly prospects for and can easily colonise new sites, the protection of potential suitable breeding habitats is a more efficient tool to help its recovery [1,2,5,9,12,22–24].

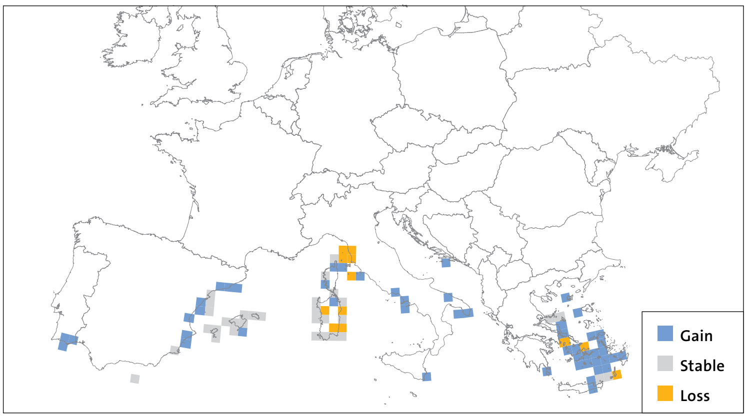


Figure 1a. Change in range of Audouin's gull between the 1980s [16] and 2010s [4] as per the EBBA2.

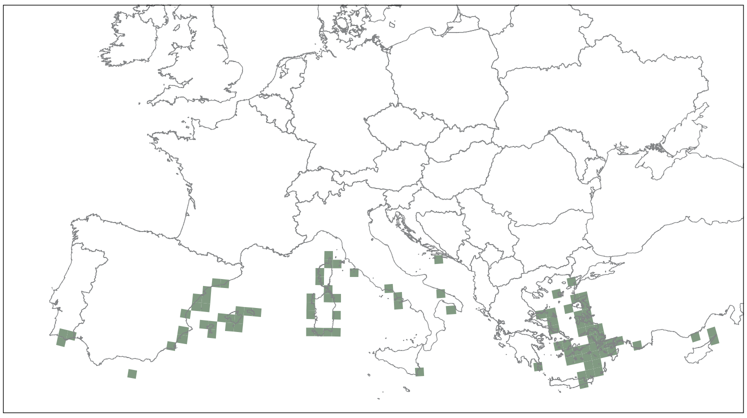


Figure 1b. Current distribution of Audouin's gull across Europe (2010s) [4].

BENEFITS OF COMEBACK

Audouin's gull plays the role of a secondary consumer in the food webs it occurs in, both predating on fish and being predated on by other species, although its role as a prey species is not likely to be significant at the ecosystem level. As well as fish, and amongst other invertebrates, it preys on the non-native invasive Red swamp crayfish (*Procambarus clarkii*), and therefore may help to keep this species' proliferation in check. It tends to prefer predator-free habitats, with good foraging areas nearby, and shows some colony-site fidelity depending on previous successful breeding. Conservation actions taken to protect this species may therefore also benefit other seabird species that use similar habitats and food sources [5,9,25].

OUTLOOK

The sudden decrease in this species' population size over the past decade may seem to be cause for concern. However, the peak population size was dependent on increased food availability from unsustainable fisheries discards, which have now greatly decreased. Furthermore, considering the present and foreseeable distribution of its native predators, as well as the continuing anthropogenic fishing pressure on pelagic fish populations, it is unlikely that the population will ever reach such numbers again[1,2]. Nonetheless, as this species' population previously increased due to a combination of factors aided by human action, a short-term decline followed by an eventual stabilisation may be regarded as a return to a more natural, self-sustaining population size.

To understand whether this is actually happening, however, more information is needed on the Audouin's gull's historical distribution, as well as its ecology, and more time is needed to continue to study the evolution of the species' demography without the influence of fisheries discards.

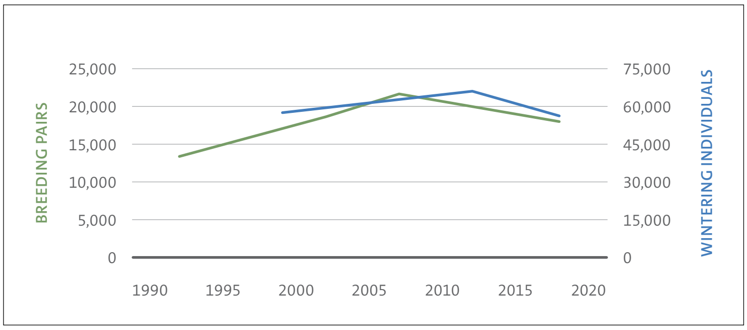
Given continued pressure from multiple threats, particularly from predation and habitat loss, it may not be possible to study the demography of this species in a natural scenario, within a healthy ecosystem. In addition, there is a risk that current threats may limit the species' capacity to stabilise[5].

The reduction in area and quality of nesting and nearby foraging habitat for this gull species, as coastlines are developed and degraded, is leading to the species nesting in suboptimal habitat. As a consequence, predation by native mammals becomes more significant; as large colonies grow, they are discovered by and become easy prey for predators. Audouin's gulls are also prone to bycatch, especially from longline and recreational fisheries, and have been shown to be more attracted to these types of fisheries when trawlers (and their associated discards) are not operating. This indicates that the threat of bycatch may increase in the future, as discards from trawlers are reduced. The species' western shift may also be due to the deterioration of fish stocks in the Mediterranean, with ominous implications for the region's wildlife. Lastly, the species is sensitive to human disturbance and to pollution (e.g. heavy metals, organochlorines, oil spills etc.)[5,9,12,14,25].

Until these underlying issues are tackled, the species will remain very much dependent on active conservation interventions, such as protection from predators, or else breeding failure and predation will remain high. This can be done by, for example, protecting new and existing foraging and nesting habitats for Audouin's gull from degradation and loss[5] and by creating and restoring coastal areas for the species where possible. The protection of any new colonies formed as the species disperses is especially important, in order to ensure this species' stabilisation. Tackling the threat of bycatch, but also of fish stock depletion, would be highly beneficial, for this species and many other seabirds.

In addition to these actions, more information is needed on this species, particularly in discovering where the species has dispersed to and formed new colonies, but also to better understand the threats faced by it and their effects on the Audouin's gull population (e.g. effects of bycatch in the wintering grounds). The continued and increased monitoring of this species, not just in Europe but over its entire global range, is essential[5,14].

Figure 2. Estimated number of Audouin's gull breeding pairs and wintering individuals in Europe[1,17–20].



THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix II) • CMS (Appendices I and II) • AEWA (Annex 2)
Global threats	• Tourism & recreation areas • Fishing & harvesting aquatic resources • Invasive non-native/alien species/diseases • Problematic native species/diseases[2,9,15]
European threats	• Tourism & recreation areas • Renewable energy • Shipping lanes • Utility & service lines • Fishing & harvesting aquatic resources • Work & other activities • Dams & water management/use • Invasive non-native/alien species/diseases • Problematic native species/diseases • Pollution • Industrial & military effluents[1,9,15,21]

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Roseate tern

Sterna dougallii

The Roseate tern (*Sterna dougallii*) is a migratory coastal seabird, which breeds on all continents except Antarctica. It breeds in colonies located on small offshore rocky islands, or in brackish lagoons, with a preference for sites which are close to clear, shallow and sandy fishing grounds. Roseate terns often breed and forage together with other species. They will rest and fish in shoals, tide rips, sheltered estuaries and inshore waters, and can travel several kilometres offshore, to forage over sand banks or upwellings. Roseate terns are almost exclusively piscivorous, and as specialist foragers they feed by plunge diving and surface splashing for small fish, although they may also take crustaceans and other invertebrates. On migration they utilise cold water upwellings which may improve their feeding opportunities[1,3,6–10].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Marine Neritic, Marine Oceanic, Marine Intertidal, Marine Coastal/Supratidal[1]	Global: Least Concern (2018)[2] Europe: Least Concern (2020)[1]	Global: Unknown (2018)[2] Europe: Increasing (2020)[1]	Global: 140,000* (2018)[2] Europe: 5,360* (2019)[3]	Increasing, +79% 1985–2019**	Decreasing, -39% 1980s–2010s[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

In Europe, Roseate terns are currently split into two distinct breeding metapopulations, one in the Azores (Portugal), and one in Ireland, the United Kingdom and France (the northwest Europe metapopulation) (Figure 1b). After the breeding season they remain gregarious and will migrate southwards to coasts in West Africa (from Ghana to Sierra Leone and Liberia) for the winter. Some individuals breeding in the Azores can also travel to eastern South America[3,6–8,11,12].

In the 19th century, Roseate terns declined to very small numbers in Europe, with persecution for the millinery trade driving the species almost to extinction. At that time, they disappeared from sites in northwest Europe, they were extirpated from Ireland and nearly disappeared from Britain. Legal protection from hunting, however, allowed them to recover, and they returned to Ireland in 1913.

Unfortunately, in the late 1960s, a second period of very rapid decline occurred. This was the result of increased human disturbance, predation and competition (especially from increasing large gull populations) and bad weather (including the loss of the colony on Tern Island in Ireland due to storms). The northwest Europe metapopulation declined as a result, from 3,900 pairs in 1967, to only 700 pairs in 1977. Food shortage and persecution on its wintering grounds added to this negative trend. Targeted conservation efforts, such as colony protection from disturbance, habitat management and predator control were then put in place, which have greatly helped the species to stabilise and resulted in population increases from the 1990s onwards[7,8,13].

Little is known of the Azores population before censuses began in 1984[7].

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

After a stabilisation period throughout the 1980s, from the 1990s onwards the total European population (northwest and Azores combined) has experienced a gradual increase in numbers, reaching 1,779 pairs in 1995 and 2,275 pairs in 2012. Thanks to conservation efforts, the species has continued to recover, and in 2019, the total European population of Roseate terns was estimated at 2,679 pairs (approximately 70% of its size in 1967) (Figure 2) [1,3,7].

The increase described above appears to have been driven by increases in the northwest Europe metapopulation, consisting of only four viable colonies. In Ireland, the 2018 population showed an increase of 27% compared to 2012. The United Kingdom population continued to decline until 1996, when it started showing a slow increase. The small population in northern France, on the other hand, has remained relatively stable, particularly since 2011, with 55 pairs recorded in 2020. There has been little interchange recorded between the colonies in France and those in Ireland and the United Kingdom; nevertheless, as its breeding productivity is low, it is likely that the stability of the population in France is due to immigration from other colonies (Figure 1a) [1,3,7,8,14].

The Azores population, which comprises over a quarter of the breeding pairs in Europe, appears to experience fluctuations, but is overall stable. The species also used to breed in small numbers in Madeira (Portugal), and sporadically in the Canary Islands (Spain), but there have been no recent observations of this over the past few years [1,3,7,8].

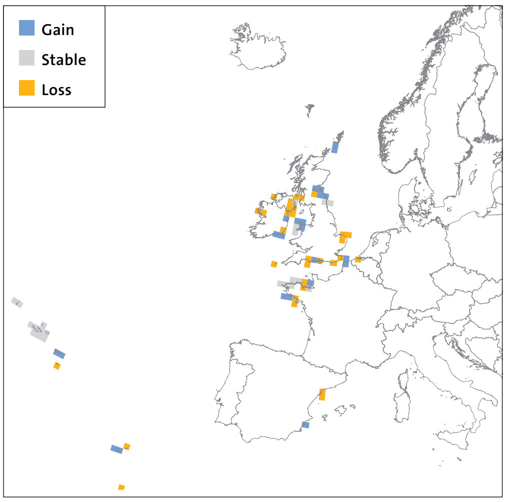

Figure 1a. Change in range of the Roseate tern between the 1980s [15] and 2010s [4] as per the EBBA2.

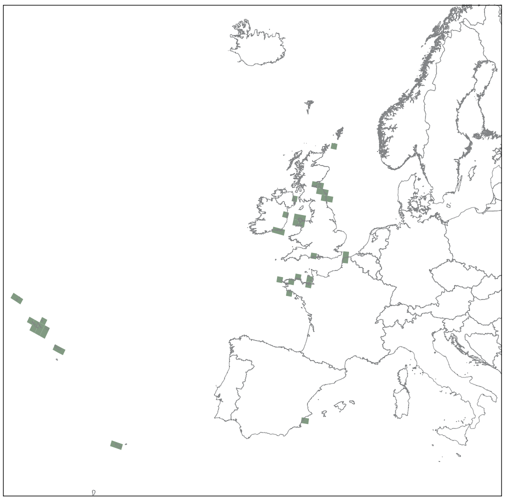

Figure 1b. Current distribution of the Roseate tern across Europe (2010s) [4].

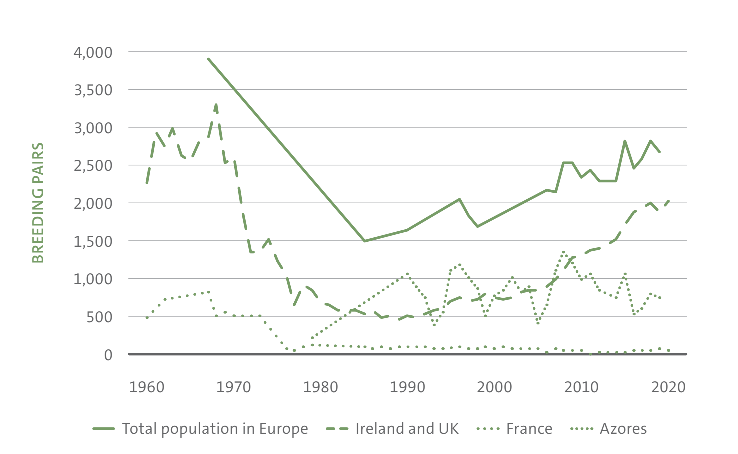

Figure 2. Estimated total number of Roseate tern breeding pairs in Europe, and separately in the Azores metapopulation, the Ireland and United Kingdom populations, and the population in France[1,3,8,16–18].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • Bern Convention (Appendix II) • CMS (Appendix II) • AEWA (Annex 2)
Global threats	• Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Invasive non-native/alien species/diseases • Problematic native species/diseases • Habitat shifting & alteration • Storms and flooding[2]
European threats	• Marine & freshwater aquaculture • Renewable energy • Hunting & trapping terrestrial animals • Fishing & harvesting aquatic resources • Recreational activities • Work & other activities • Other ecosystem modifications • Invasive non-native/alien species/diseases • Problematic native species/diseases • Industrial & military effluents • Agricultural & forestry effluents • Garbage & solid waste • Habitat shifting & alteration • Other impacts[1,19]

DRIVERS OF RECOVERY

The four main drivers of recovery that followed the declines in the 19th and 20th centuries in the northwest Europe metapopulation were the protective legislation that banned the hunting, trapping and egg collecting of Roseate terns, predator control in breeding grounds, habitat management, and the protection of breeding sites from disturbance. Together with habitat restoration and the provision of nest boxes, these measures have helped to improve colony productivity and size. The presence of wardens at breeding sites has been very successful in stopping egg collecting and human disturbance. The colony on Rockabill has particularly benefitted from such efforts, and the enhanced productivity there has subsequently driven the increase in the species' population elsewhere in Ireland, and indeed on Coquet Island[1,3,6–8,20].

In the Azores, habitat restoration work on Praia Islet, such as European rabbit (*Oryctolagus cuniculus*) eradication, limiting soil erosion and the reintroduction of native plants have also been beneficial, as has been the installation of nest boxes on Contendas Islet[1,3,6].

In Europe, the Roseate tern is fully protected by national and international law during the breeding season, but outside of European territorial waters and in the coastal waters of other countries, legal protection and enforcement can be more limited. In Ghana for example, the species is fully protected, but some trapping still occurs. Therefore, education and awareness raising campaigns in the wintering grounds in West Africa are equally important alongside conservation efforts in Europe[1,3,6–8,20].

For the coordination of this work, a European Action Plan for the Roseate tern was launched in 1987. After its successful implementation, and to continue cross-boundary cooperation, an International Species Action Plan for the Eastern Atlantic Roseate tern population was published in 1999 and was subsequently updated in 2021 as part of the Roseate Tern LIFE project[3].

BENEFITS OF COMEBACK

Roseate terns are specialist foragers associated with oceanic upwelling systems and can therefore also serve as a indicator species for marine issues along the East Atlantic Flyway. Because of their ecological sensitivity, changes in Roseate tern population size, distribution, feeding grounds or in the species and quality of foraged fish (such as the recent depletion of sardinella (*Sardinella* spp.) stocks in many countries in West Africa) could serve as indications of broader changes in climate[8].

Given their rarity and aesthetics, Roseate terns can have socio-economic value, attracting visitors, enhancing ecotourism, and bringing consumers to the local area in which they are present.

Due to their tendency to nest in mixed colonies and their strict breeding habitat requirements, the conservation efforts put into protecting Roseate terns are likely to benefit other seabird species too, particularly other terns[20,21].

OUTLOOK

Thanks to conservation action, the Roseate tern has steadily increased in Europe since the 1980s. Nonetheless, the species requires sites with low predation and high densities of prey, meaning it has a naturally very restricted range. The Roseate tern has relatively low adult survival rates, meaning that high productivity is essential for population stability. At present, high productivity at the large Irish colony has been responsible for increases elsewhere; similar trends at other colonies would reduce this reliance on a single colony. On the other hand, the small number of self-sustaining colonies in northwest Europe demonstrate the vulnerability of the overall European population. Therefore, although the signs of recovery are encouraging, the species is still on its way to making a full comeback [1,6,7,20].

Predation, human disturbance (particularly in the Azores, from development and recreational activities) and habitat loss (e.g. from erosion) are still highly significant ongoing threats. The risk of predation, in particular from both natural and introduced avian and mammalian species, is an unpredictable factor, as the status of predator populations in areas around Roseate tern colonies can rapidly change (e.g. increasing populations, introductions, etc.). This risk increases when colonies are disturbed. Predators are monitored and, if needed, controlled around Roseate tern colonies, making the species very much conservation-dependent. Extreme weather events have also caused the local extinction of some colonies and with climate change, the risk of such events may increase in the future. As with other terns, the species is also vulnerable to pollution and disease, with food shortages along its migration routes and in its wintering grounds also having potential impacts on its survival [1,6–8,22].

More recently, the increase in the development of offshore windfarms (as planned near the Rockabill colony), could pose a serious threat to the still fragile northwest Europe Roseate tern metapopulation. Windfarms only present a small risk of collisions for the species, but they can significantly reduce their foraging areas, and the amount of prey available [3,8].

To ensure its continued comeback in Europe, in addition to ongoing conservation actions, legal protection needs to be put in place and enforced throughout the species' range, considering both breeding and wintering seasons. Improvement of existing and former large colonies of other tern species (particularly Common tern (*Sterna hirundo*)) through site protection, disturbance prevention, and habitat and predator management, could be beneficial for the Roseate tern's breeding success and recolonisation. Great care is needed when planning the construction of offshore windfarms to ensure tern foraging areas are maintained and accessible [1,3,6,8].

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Osprey

Pandion haliaetus

The Osprey (*Pandion haliaetus*) is a mainly migratory bird of prey, widespread across all continents, except the Antarctic. It is generally solitary, occurring in a variety of habitats near open, and often shallow water, including areas of dense human population and activity, of which it is quite tolerant. It nests on exposed natural or artificial structures (e.g. trees, cliffs, pylons, radio towers, nesting platforms, etc.), close to water, usually high up, away from the reach of ground predators, or on predator-free islands. The Osprey usually returns to, repairs and uses the same nest each year. It feeds almost entirely upon fish, which it dives feet-first to catch near the surface of the water. There have been anecdotal accounts of the species feeding on other prey such as herptiles, molluscs, birds and small to medium-sized mammals (e.g. Voles or Ground squirrels (*Citrellus* spp.))[1,4–6].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE*	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
	LC			+45%	+7%
Forest, Wetlands (inland), Marine Neritic, Marine Coastal/ Supratidal, Artificial/ Aquatic & Marine[1]	Global: Least Concern (2021)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2021)[2] Europe: Increasing (2020)[1]	Global: 100,000–1,200,000** (2021)[2] Europe: 23,000** (2020)[1]	Increasing, +45% 1992–2018***	Increasing, +7% (1980s–2010s)[3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Nowadays, the Osprey in Europe breeds from the United Kingdom in the west through Scandinavia to Russia in the east, with small populations as far south as Portugal and Bulgaria (Figure 1b). Most birds migrate (although some around the Mediterranean are residents) to western sub-Saharan Africa and the southern parts of the continent, but it can also winter on the north-western and southern Mediterranean coasts[1,4–7].

In the past, Ospreys used to occur in any suitable habitat throughout Europe. However, like many other birds of prey, it was persecuted heavily from the Middle Ages onwards, and thus underwent severe declines, particularly during the 18th to 20th centuries. Egg collecting and taxidermy, which were particularly fashionable in the 19th century, were contributing factors, as was habitat loss, particularly deforestation. As a result, the species disappeared from large parts of western, southern and central Europe, and only populations in the northern half of Europe, mainly countries bordering the Baltic Sea, remained. The species reached a low point in the 1920 and 1930s, but thanks to the introduction of legal protection, it started to recover, and returned to some of its former breeding range (e.g. the United Kingdom in the 1950s). In the second half of the 20th century, particularly from the 1950s to the 1970s, the use of organochlorine pesticides (such as DDT) contributed to another decline, both in Europe and worldwide. The ban on these toxic chemicals in the 1970s, as well as its protection from hunting and disturbance, enabled a recovery, although this has been hampered in places by unsustainable forestry, and the continued loss of large trees and other natural habitat in the second half of the 20th century[1,4–6,8,9].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Legal protection from persecution and the ban of toxic organochlorine pesticides have resulted in lower mortality rates, which enabled the recovery of the Osprey from the 1980s onwards. As a species with low sensitivity to human activity and disturbance, Ospreys have taken to nesting in man-made areas, given the right habitat conditions are in place (e.g. predator-free nesting sites in close proximity to waterbodies)[1,5,6].

Since the 1980s, the Osprey population in Europe

* *European proportion of the population calculated using the minimum estimated population sizes.*
** *Mature individuals.*
*** *Change calculated using the minimum population size estimated as start year.*

has at least doubled, and is currently estimated at approximately 11,500 pairs (Figure 2). Its range has expanded (Figure 1a), with its strongholds still being in Fennoscandia and European Russia. Countries with re-establishing or recovering populations (especially in northern and western Europe, e.g. the United Kingdom) have seen a most dramatic increase over the past 40 years, whereas countries that already held substantial populations, such as European Russia, have seen stable or more moderately increasing trends. Recovery has also been observed in Iberia [1,4,6,8].

During the end of the 20th and start of the 21st centuries, reintroduction and translocation projects began in several countries in Europe (e.g. the United Kingdom, Spain, Italy, Portugal), which have helped Ospreys recover much of their previous range [1,6,8].

DRIVERS OF RECOVERY

The two main drivers of the species' recovery in Europe have been the ban on organochlorine pesticides (reducing it to a largely historical threat) and legal protection from persecution (including egg-collecting) combined with enforcement of these protections. A reduction in other pollutants, such as mercury, may have also helped stop the decline in the Fennoscandian population, and elsewhere across Europe. Many sites have been protected specifically for Ospreys, which has facilitated reintroduction and translocation efforts [1,5,6,9]. In addition, the installation of artificial nesting platforms in suitable habitat has provided new breeding sites. However, the fact that the species readily takes to nesting on anthropogenic sites, such as specifically made nesting platforms, pylons and radio towers, is mainly due to the loss of its natural nesting habitat, the development of shorelines, and the necessity to nest away from ground predators [1,5,6].

Therefore, although nesting platforms can compensate for the loss of large trees [9], in order for the species to cease being conservation-dependent, it is essential to ensure that suitable nesting trees for the species are protected and that deforestation in Europe is stopped.

Legal tools which have supported these drivers of recovery include the EU Birds Directive, CITES, the Bern Convention, the Convention on Migratory Species (CMS) and the Raptors MoU. They have all been in place for some decades, helping the recovery of the species. Moreover, a lot of research has been undertaken on the species' ecology and life history, and it is included in many national monitoring schemes [1,5].

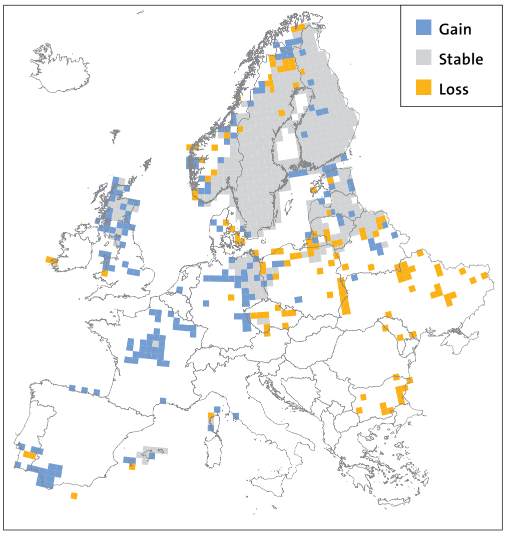


Figure 1a. Change in range of the Osprey between the 1980s [10] and 2010s [4] as per the EBBA2.

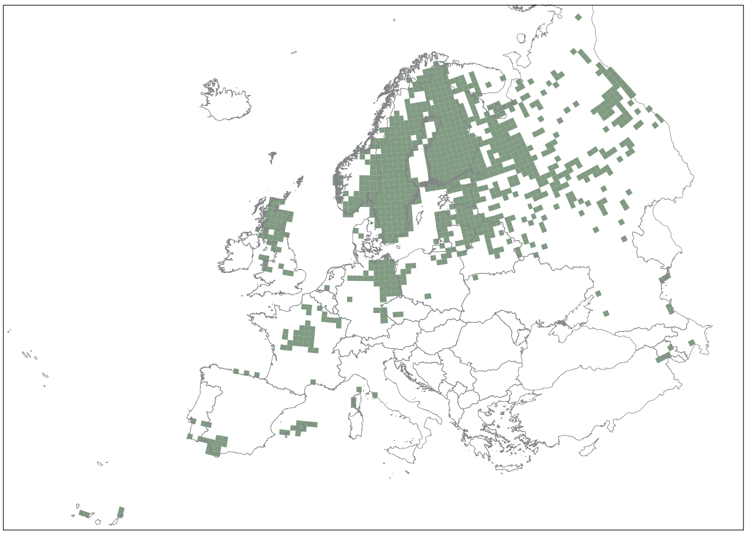


Figure 1b. Current distribution of the Osprey across Europe (2010s) [4].

BENEFITS OF COMEBACK

Ospreys are piscivores, and so are part of the trophic web that contributes to the top-down control of natural populations of fish, particularly in large waterbodies. Ospreys have also been suggested as an indicator species for water quality, specifically for the presence of contaminants in water, through the analysis of the composition of its feathers, eggs and blood, as the species can bioaccumulate pollutants through the ingestion of its prey [6].

Ospreys are also well-loved and charismatic species, which can attract thousands of visitors to areas where they can be seen nesting or feeding, with viewpoints and nest cameras specifically set up for their observation. Such ecotourism can directly and indirectly benefit the local community around the sites where the species occurs, socially and economically [8].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix I) • Bern Convention (Appendix III) • CMS (Appendices I and II) • Raptors MoU (Annex I)
Global threats	• Annual & perennial non-timber crops • Wood & pulp plantations • Renewable energy • Hunting & trapping terrestrial animals • Recreational activities • Logging & wood harvesting • Agricultural & forestry effluents [2]
European threats	• Wood & pulp plantations • Renewable energy • Utility & service lines • Hunting & trapping terrestrial animals • Agricultural & forestry effluents [1,14]

OUTLOOK

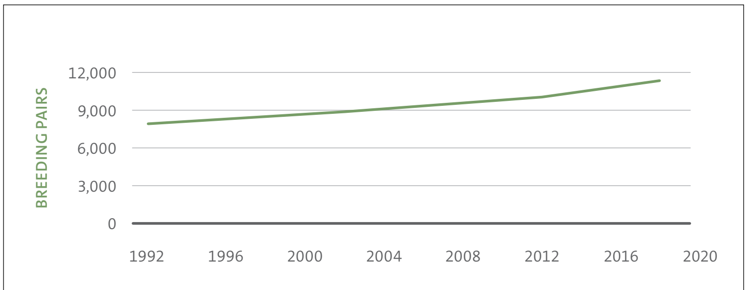
The Osprey has returned to much of its former European breeding range and is expected to continue its recovery.

Despite its adaptation to artificial structures for nesting, the continued loss of its natural habitat (due to deforestation and the cutting of large old trees) is still a major threat to the species. Moreover, when artificial structures are chosen by Ospreys as nesting sites (excluding specially made nesting platforms) it can compromise these structures' intended purposes, causing conflict or creating hazards for the species (e.g. a risk of electrocution in the case of their use of pylons). To mitigate this risk, higher alternative nest sites should be provided nearby [1,5,6].

In addition, fishing practices can also affect the species negatively, both directly through entanglement in nets and disturbance from motorboats, but also indirectly through unsustainable harvesting leading to reduced fish stocks. Persecution in some areas, such as in southern Europe (and particularly Malta), remains a threat to the species, affecting many individuals during migration, and the increasing presence of wind farms and power lines can increase mortality from collisions [1,5,6].

To ensure the continued comeback of the Osprey in Europe, apart from continuing the current conservation actions, nests should be more widely and actively protected from both disturbance and damage, particularly by wardens ensuring nest protection and minimum disturbance zones are in place. Moreover, legislation protecting the species from killing and disturbance should be expanded across more countries, strengthened where needed, and appropriately implemented and enforced. Fishing legislation should be improved and enforced, to prevent overfishing. Waterbodies should also be monitored for contaminants (e.g. mercury) and where contaminants are detected, efforts should be made to reduce their level. Establishing suitable natural habitats should be considered a long-term solution to supplying more nesting habitat for this species and ensure it does not become conservation dependent. This means ensuring the halt of deforestation across Europe, but also the restoration of previously destroyed or degraded habitats where the species used to breed. In the United States, it has been shown that the species was historically negatively impacted by the decline of beavers and their engineered freshwater habitats. Therefore, the recovery of Eurasian Beavers (*Castor fiber*) in Europe may benefit the Osprey [1,5,6].

Figure 2. Estimated number of Osprey breeding pairs in Europe [1,11–13].



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Bearded vulture

Gypaetus barbatus

The Bearded vulture (*Gypaetus barbatus*) is a highly distinctive, long-lived and specialised scavenger, and one of the largest of the Old World vultures. It inhabits mountains in Eurasia and Africa, usually above 1,000 m altitude. The Bearded vulture has a very large home range and can cover up to 700 km in a day in its search for food. It feeds mainly on carrion, particularly bone, which comprises up to 85% of its diet, but it also eats flesh, especially from dead mammals, and meat forms an important part of a chick's diet. The species is known for its habit of breaking big bones by lifting them high into the air and dropping them on rocks. The Bearded vulture constructs large nests located on remote overhung cliff ledges or in caves up to 2800–2900 m above sea level, which it re-uses over the years. Juveniles can wander very widely before reaching reproductive age[1,6–8].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE*	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Shrubland, Grassland, Rocky areas (e.g., inland cliffs, mountain peaks), Artificial/Terrestrial[1]	Global: Near Threatened (2021)[2] Europe: Near Threatened (2020)[1]	Global: Decreasing (2021)[2] Europe: Increasing (2020)[1]	Global: 1,700–6,700** (2022)[1,3] Europe: 1,200–2,000** (2022)[1,3]	Increasing, +121% 1991–2021***	Increasing, +23% (1980s–2010s)[4,5]

Historical distribution and abundance

The Bearded vulture was widespread until the end of the 19th and beginning of the 20th centuries. In Europe, direct persecution (mostly shooting) and the use of poison baits against wildlife led to its disappearance from most of its historical range. The species was exterminated from Bosnia and Herzegovina in the late 19th century, from the Alps at the beginning of the 20th century, from Romania, Czechia and Slovakia in the first half of the 20th century, from Serbia, Montenegro and Bulgaria in the 1950s and 1960s, and from continental Greece and North Macedonia in the late 1990s. Habitat loss and a reduction in extensive livestock farming in many mountain ranges also played a role in the species' decline (as both a decrease in wild mammal populations and the disappearance of domestic mammal carcasses led to a reduction in food availability). During most of the last century, the Bearded vulture survived only in the Pyrenees and on two Mediterranean islands (Corsica and Crete), with the population remaining stable, but very small, between 1970–1980[1,6–8].

ANDREA GREPPI / REWILDING EUROPE

Recent changes in abundance and distribution

During the 1980s, the Bearded vulture population was mainly reduced to the Pyrenees (France and Spain) and the mountains of Crete (Greece) and Corsica. Nevertheless, the European breeding population of the species was mostly stable between 1980–1990[1,7].

Since the end of the 20th century, the Pyrenean population started to increase, as did the overall

* *European proportion of the population calculated using the minimum estimated population sizes.*

** *Mature individuals.*

*** *Change calculated using the minimum population size estimated as start year.*

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix III) • CMS (Appendices II) • Raptors MoU (Category 1)
Global threats	• Housing & urban areas • Livestock farming & ranching • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities • Invasive non-native/alien species/diseases • Agricultural & forestry effluents • Habitat shifting & alteration • Other threats [2]
European threats	• Housing & urban areas • Annual & perennial non-timber crops • Wood & pulp plantations • Livestock farming & ranching • Renewable energy • Roads & railroads • Utility & service lines • Flight paths • Hunting & trapping terrestrial animals • Recreational activities • Invasive non-native/alien species/diseases • Agricultural & forestry effluents • Habitat shifting & alteration [1,13]

European population (Figure 2). This was largely due to conservation actions, such as reintroduction programmes in the Alps, the Grands Causses (France) and in Spain (in Andalucía, Maestrazgo and the Cantabrian Mountains), which have led to the population increases currently observed in these areas (Figure 1a). Captive-bred birds released in the Alps resulted in the re-establishment of a growing wild population, with some Alpine birds having subsequently been recorded in western France and the Netherlands, and as far afield as the Baltic countries (Figure 1b). Recent releases in Germany have also further contributed to the species' expansion in Europe. The population in the European part of Russia (which holds approximately a quarter of the total for the continent) is also increasing [1,3,6–8].

In other parts of Europe, the Bearded vulture is not yet recovering. The relatively large population in Azerbaijan is decreasing, while populations in the Balkan Peninsula have disappeared. The species' range and population in Turkey also appear to have declined in recent years. The species is considered extinct in Albania, Croatia, Bosnia and Herzegovina, Czechia, Slovakia, Bulgaria, North Macedonia, Serbia and Montenegro [1,6–8].

The current Bearded vulture population in Europe (including European Russia and the Caucasus) is estimated at approximately 792 pairs and is increasing overall [1,3].

DRIVERS OF RECOVERY

Initially, the legal tools put in place were the most important element to halting the decline of Bearded vultures in Europe. These included a ban on carcass poisoning and direct persecution, as well as the relaxation of laws in certain areas that had previously prohibited farmers from leaving dead animals on their land. Later, the species has been included in the Annexes/Appendices of various legal frameworks and multi-lateral environmental agreements. Most recently, a Multi-species Action Plan for African-Eurasian Vultures was produced in 2017 and a Single Species Action Plan for the conservation of the Western Palearctic population of Bearded Vultures was prepared in the framework of the LIFE EuroSAP (LIFE14 PRE/UK/000002) project in 2018. These Action Plans provide a programme of research and conservation measures needed for the species to recover in Europe and globally, and identify those threats that still need more attention and action [6,14,15].

In addition, several conservation projects have contributed to the species' recovery, e.g. the highly successful reintroduction programme in the European Alps, initiated in the 1980s under the coordination of the Vulture Conservation Foundation (VCF), using captive-bred birds from the VCF's own Bearded vulture captive breeding programme, or the equally successful reintroduction project in Andalusia (led by the VCF and by the Junta de Andalucia). Annual conferences relating to the Alpine reintroduction project have further facilitated the exchange of information relevant to the continuing management of this population. The setting up of supplementary feeding stations for vultures (e.g. in the Pyrenees) has further facilitated the species' recovery, while in the Alps, the use of annual citizen science

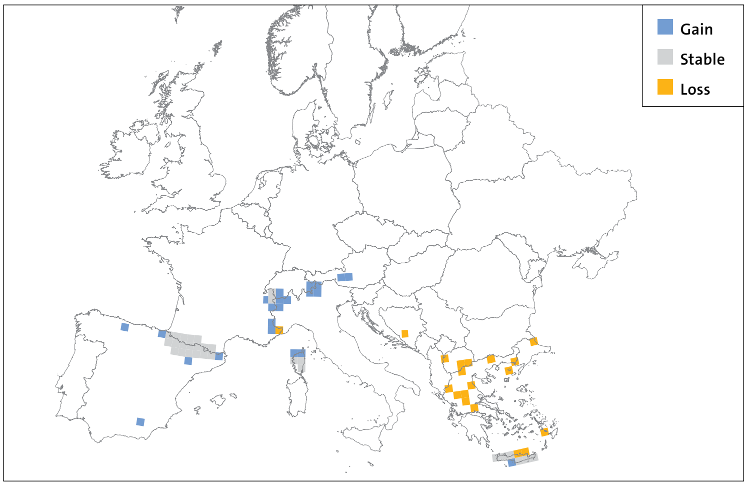

Figure 1a. Change in range of the Bearded vulture between the 1980s [9] and 2010s [5] as per the EBBA2.

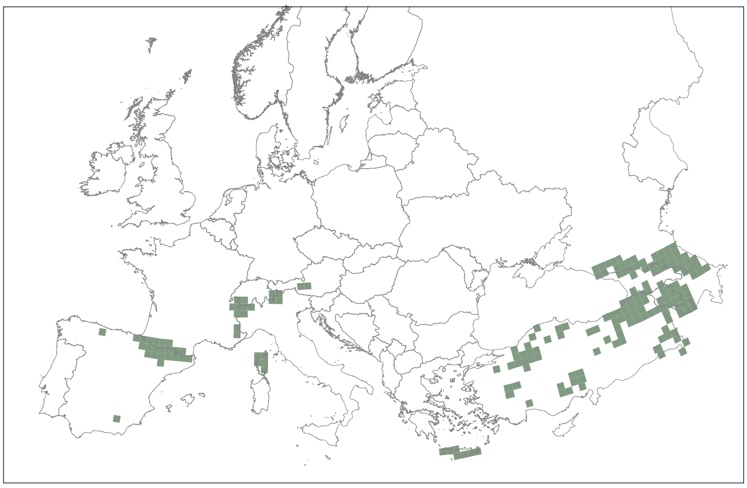

Figure 1b. Current distribution of the Bearded vulture across Europe (2010s) [5].

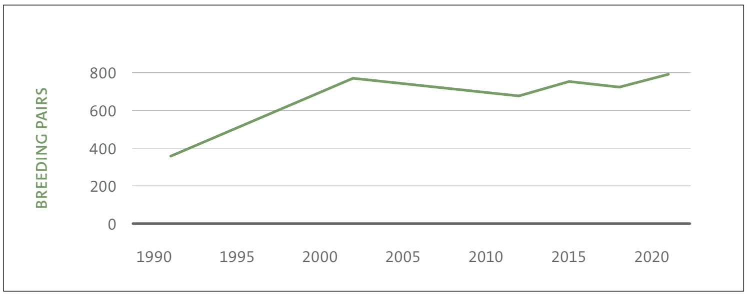

Figure 2. Estimated number of Bearded vulture breeding pairs in Europe [1,3,10–12].

events has helped raise awareness about the species. Anti-poisoning programmes have been an especially important contributor to the recovery of this species [1,6–8].

There are, however, no feeding stations in the Alps, and the population of Bearded vultures in this region depends heavily on large wild ungulates, especially during the breeding season. Therefore, increased numbers of wild ungulates (such as Alpine ibex (*Capra ibex*) and Northern chamois (*Rupicapra rupicapra*)) have been crucial to the recovery of the Bearded vulture in this region. To this end, the use of hunting quotas and Protected Areas has been pivotal, benefitting wild ungulate and Bearded vulture populations in many European mountain areas [8].

BENEFITS OF COMEBACK

All European vultures are scavengers, helping to keep landscapes free of carrion. Scavengers are thus an often overlooked but important link in healthy ecosystems. The Bearded vulture is a particularly specialised scavenger, assisting in a second stage of carcass disposal, eating what other scavengers may leave behind. They maintain the transfer of energy in the food web and contribute to nutrient cycling within ecosystems.

The removal of carcasses by obligate scavengers such as the Bearded vulture also helps to regulate the populations of facultative scavengers such as Red foxes (*Vulpes vulpes*), by regulating their access to food. The recovering numbers of Bearded vultures, and other vulture species, provides a very efficient, environmentally-friendly and valuable ecosystem service, particularly in mountainous areas where carcass removal may otherwise require a lot of resources (human, financial and time), with greenhouse gas emissions otherwise released into the atmosphere during the carcass-removal process [16–18].

The provision of feeding stations in the Pyrenees and awareness-raising about this emblematic species at release sites in the Alps also produces opportunities for ecotourism, especially as this species' population continues to grow and become more visible, which in turn can provide social and economic benefits in the local area [8,16,18].

Moreover, the conservation of the Bearded vulture in the Alps has largely depended on action to increase wild ungulate populations, which has in turn contributed to the conservation of these other species.

OUTLOOK

The recovery of the Bearded vulture population in southwestern Europe has been remarkable over the past 20 years and this population, with the help of reintroduction programmes, is expected to continue to grow. However, as current sites become saturated, new areas for release will need to be identified. Continued assistance will be required to ensure the species' range expands, while different sites where Bearded vultures are present stay connected to ensure good genetic diversity over the whole of Europe.

Despite its recovery, the species' population size in Europe remains relatively small and fragile, and dependent on conservation actions. In addition, the fact that Bearded vulture reproductive rate is low and that habitat saturation can lead to reduced productivity is also concerning. Cases of polyandry and polygyny have been observed in the Pyrenees and the Alps, attributed to high breeding density, biased sex ratios, low food availability, or genetic relatedness between males [6,7].

The Bearded vulture remains susceptible to threats, with the main problems for its European population being human persecution and poisoning (accidental), collisions with powerlines and transport cables, inadequate food availability, changes in livestock-rearing practices and habitat degradation (e.g. in Turkey, which has seen a rapid increase in grazing pressure; or in the Caucasus, due to the disturbance of breeding birds following improved accessibility to mountain sites) [6–8]. Lead poisoning, usually caused by the ingestion of lead shot, is a particularly prevalent yet underreported threat in Europe, as Bearded vultures can feed on discarded carrion from hunters. Lead tends to accumulate over time and can lead to direct mortality, but also causes more insidious harm via reduced breeding success [8,19,20].

Veterinary drugs and livestock pathogens have also been shown to be a threat to scavengers, with failed Bearded vulture eggs and dead nestlings reported in the Pyrenees in the late 2000s. Samples taken from these cases have shown evidence of livestock pathogens and high concentrations of multiple veterinary drugs. The first confirmed death of a vulture (a Cinereous vulture (*Aegypius monachus*)) from the veterinary drug Diclofenac was recorded in Spain in 2020 [1,6].

It is therefore clear that more conservation action is needed to secure the successful comeback of the Bearded vulture in Europe. This should include reintroduction programmes, the continuation of anti-poisoning programmes, close monitoring of the species, maintaining the use of Protected Areas and hunting quotas to benefit wild ungulates, limiting the impact of diclofenac and other drugs used for livestock, supplementary feeding to boost population exchanges, decreasing the incidence of lead poisoning by substituting hunting ammunition with non-lead alternatives, reducing disturbance around nesting areas, reducing the impacts of powerlines and other cables, raising awareness for the species and ensuring the enforcement of protection laws [1,8].

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Griffon vulture

Gyps fulvus

The Griffon vulture (*Gyps fulvus*) is a long-lived, partially migratory scavenger, with many European breeding individuals overwintering in Africa, while others are resident or nomadic. They live in predominantly rocky areas such as inland cliffs and mountain peaks, where they roost and breed in colonies on large, sheltered ledges or in small caves in rocky outcrops, undisturbed by humans. They soar high over open areas of rocky escarpment and low vegetation, such as shrubland and grassland, in search of food, but tend to avoid woodland, feeding mostly from carcasses of medium-to-large dead animals. Griffon vultures fly on average 300 m above ground level, but can reach heights of 2,500 m [1,6,7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Shrubland, Grassland, Rocky areas (e.g. inland cliffs, mountain peaks) [1]	Global: Least Concern (2021) [2] Europe: Least Concern (2020) [1]	Global: Increasing (2021) [2] Europe: Increasing (2020) [1]	Global: 80,000–900,000* (2021) [2] Europe: 69,600–89,400* (2021) [1,3]	Increasing, +885% 1986–2021**	Increasing, +14% (1980s–2010s) [4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Griffon vulture has an extremely large range, extending, in Europe, from the Iberian Peninsula right through to Crimea and the Caucasus. In the past, it reached the southwest of Germany (up to the end of the Middle Ages), south Poland (up to the early 19th century), and more recently it occurred in Romania, Moldova, Ukraine, and south of the Ural Mountains [1,2]. The Griffon vulture declined throughout its European range until the end of the 20th century. Carrion poisoned by humans against mammalian predators, combined with a reduction in available food had, in the 1800s and 1900s, the unfortunate side effect of drastically reducing its numbers. More locally, disturbance to nesting cliffs and direct persecution, through shooting and egg robbing, also contributed to the widespread decline in Griffon vulture numbers between the end of the 19th century and beginning of 20th century. This resulted in its extinction in some areas, such as in the French Alps and the Carpathians. In the second half of the 20th century, legal protection came into force and the use of the most lethal poisons against wildlife was prohibited. However, by then, the species had disappeared from many countries in the region [6–8].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

In the last forty years, the Griffon vulture has staged a remarkable comeback, with the number of breeding pairs increasing substantially in most of the species' European range (Figure 2), especially in the west (across the Iberian Peninsula and France). Its population has also been increasing in Italy and the Balkans, where it appears to be recovering, due to strong conservation action and successful reintroduction projects [1,5,7,8].

* *European proportion of the population calculated using the minimum estimated population sizes.*

** *Mature individuals.*

*** *Change calculated using the minimum population size estimated as start year.*

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix III) • CMS (Appendix II) • Raptors MoU (Annex I)
Global threats	• Livestock farming & ranching • Renewable energy • Hunting & trapping terrestrial animals [2]
European threats	• Tourism & recreation areas • Annual and perennial non-timber crops • Wood & pulp plantations • Livestock farming & ranching • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities [1,14]

The Griffon vulture still has a patchy distribution (Figure 1b), although its range has latterly increased and expanded in many places (Figure 1a). In recent years, individuals have been seen with more frequency in central Europe, including in Belgium, the Netherlands and Germany, and a large summering population of mostly vagrant immature birds occurs in the Alps between May and August. However, whilst there have been overall increases in the European population, these are quite recent, and significant losses still occurred in the early 2000s in the Balkan Peninsula, Turkey, Cyprus, and other south-eastern European countries [1,5,7,8].

The current European population of the Griffon vulture is estimated at approximately 39,600 pairs (including Russia, Ukraine and the Caucasus) [1,3].

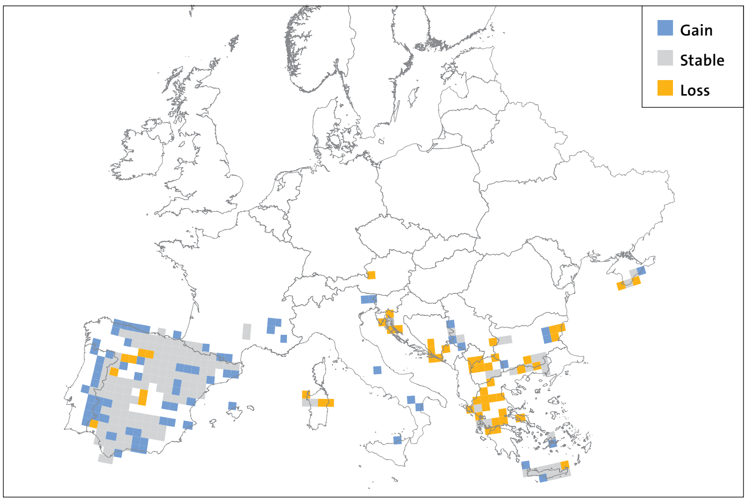

Figure 1a. Change in range of the Griffon vulture between the 1980s [9] and 2010s [5] as per the EBBA2.

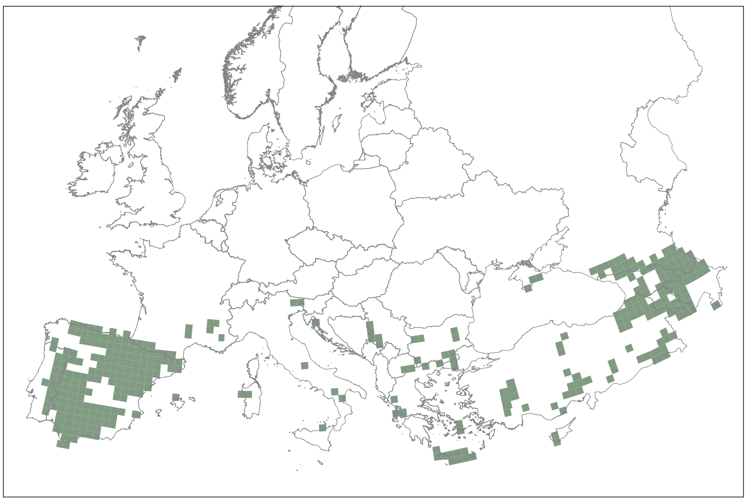

Figure 1b. Current distribution of the Griffon vulture across Europe (2010s) [5].

DRIVERS OF RECOVERY

European populations of the Griffon vulture have increased in recent decades thanks to a number of legal measures. These have included a ban on poisoning carcasses, and on direct persecution, as well as the relaxation of laws that prohibited farmers from leaving dead domestic animals on their farmland. Legal species protection under the EU Birds Directive, CITES, the Bern Convention, the Convention on Migratory Species (CMS), and the Raptors Memorandum of Understanding (MoU) has been in place for some decades, helping to explain the long-term increase in this species' population. In Spain, for example, the Griffon vulture became legally protected in 1966, and as a result, population recovery started there as early as the mid-seventies [7].

Various conservation actions, such as the creation of supplementary feeding stations and numerous successful reintroduction projects (e.g. in

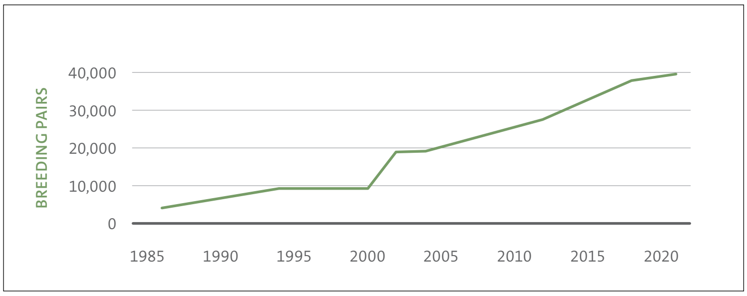

Figure 2. Estimated number of Griffon vulture breeding pairs in Europe [1,3,7,10–13].

France, Italy, Bulgaria and Cyprus) have had significant positive effects. These are often accompanied by awareness raising and communication activities, which along with key campaigns against poisoning, also help improve public perception of these valuable scavengers and support their recovery.

BENEFITS OF COMEBACK

Griffon vultures are scavengers, feeding exclusively on carcasses. They play a key role in maintaining the healthy functioning of ecosystems by providing a necessary nutrient-cycling link in the food chain. By reducing the amount of carrion available, they also help regulate the population of opportunistic scavenging mammals (e.g. Red foxes (*Vulpes vulpes*) or feral Domestic dogs (*Canis familiaris*)), and may also limit the spread of diseases (such as rabies) in these species. As some of the most efficient terrestrial scavengers, vultures provide an essential and sustainable clean-up service, which would otherwise require substantial human, energy and financial resources. It has also been shown that this service prevents greenhouse gases from being released into the atmosphere, reducing the energy expenditure that might otherwise be used during the processing of carcasses, as well as during manual removal and transport. In Cyprus, studies have shown that the carcass disposal service provided by Griffon vultures could reduce the greenhouse gas emissions associated with the transport and incineration of carcasses by between 40% and 60% [15–18].

Vultures are also present in human culture and spirituality. They attract many tourists, particularly birdwatchers and wildlife photographers, who congregate around their breeding sites and at feeding stations, and this can significantly contribute to tourist revenues in the local area (potentially over €600,000 in Cyprus alone) [16,18].

OUTLOOK

Griffon vulture populations in Europe have made an impressive recovery. Further growth in numbers is expected, as well as continued range expansion into previously lost sites, mostly in the southern part of Europe [7].

However, some threats, especially accidental poisoning (from poisoned mammal baits and from lead ammunition) are still present. Key issues for Griffon vultures are also direct persecution and disturbance, as well as the risk of electrocution and collisions with power lines. Lack of food, due to changes in carcass disposal or changes in land use and grazing practices, also still threatens the species. In addition, in recent years, collision with wind power infrastructure has been an emerging issue for the species, alongside the effects of non-steroidal anti-inflammatory drugs (NSAIDs) used for veterinary purposes [1,5,6,19,20].

The successful return of the Griffon vulture therefore continues to depend on the implementation of effective conservation actions, including anti-poisoning programmes, reintroductions, monitoring, the maintenance of vulture feeding stations, improving food availability, and the upholding of policies and policing against persecution, as well as continued awareness raising about the species. These conservation measures would also be likely to benefit other species, such as eagles, falcons, and other vultures [1,6,8].

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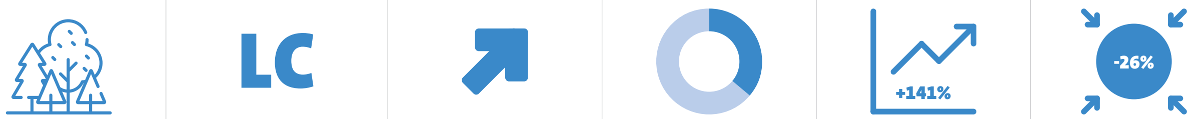
CINEREOUS VULTURE

Aegypius monachus

The Cinereous vulture (*Aegypius monachus*), also known as the Eurasian black vulture, is a long-lived, resident but dispersive scavenger, and one of the largest and most spectacular birds of prey in the world. It has a patchy distribution that ranges from western Europe to China, and as far as South Korea and south-east Asia in winter. In Europe, it prefers forested areas and Mediterranean maquis, between 300 and 1,500 m above sea level. The Cinereous vulture breeds in loose colonies and its huge nest is almost always located in trees (usually evergreen oaks (*Quercus* spp.) and pines (*Pinus* spp.), but also junipers (*Juniperus* spp.)), although in some areas of its range the species can also nest on the ground or on rocks. Cinereous vultures will mainly feed on medium- to large-sized mammal carcasses, foraging over many types of open habitats, such as dehesas or montados in Spain and Portugal. Live prey is very rarely taken[1,6–9].



HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE*	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Forest, Shrubland, Grassland[1]	Global: Near Threatened (2020)[2] Europe: Least Concern (2020)[1]	Global: Decreasing (2016)[2] Europe: Increasing (2020)[1]	Global: 16,000–21,000** (2021)[3] Europe: 5,800–6,700** (2021)[1,3]	Increasing, +141% 1991–2021***	Decreasing, -26% (1980s–2010s)[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Historically, the Cinereous vulture used to occur in many places in Europe, mainly in its central and southern parts, including Iberia, southern France and the Balkans. However, during the 20th century its populations started to decrease and/or disappear, especially in the Balkan Peninsula. The main causes for this were widespread poisoning to control predators, habitat changes and loss, as well as reduced availability of carcasses, both of wild herbivores and livestock, due to the modernisation of agriculture, and, in the EU, the introduction of carcass disposal requirements. In addition, in Iberia, the loss of nest sites and disturbance due to forestry operations also became an important threat locally[1,7,8].

Persecution, and especially poisoning, played a critical role in its decline, leading to the extinction of the species in some countries/regions. The poisoning of Grey wolves (*Canis lupus*) and other large carnivores in the Balkans also caused accidental poisoning of vultures, leading to the near extinction of the Cinereous vulture population in the region. In Spain alone, about 500 individuals have been found poisoned since 1990[7].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Over the past few decades, the Cinereous vulture's European population has increased enormously (Figure 2), from approximately 1,130 pairs in 1996 to approximately 3,000 pairs in 2021. Its European range is still discontinuous, but it appears to be expanding (Figure 1a), with the species mainly found in the south (Figure 1b), from the Iberian Peninsula, across southern France to the southern Alps, through the Balkans, Ukraine, Russia, up to the Caucasus and Turkey[1,3,6,7].

The significant population increase in Spain, where the majority of Cinereous vultures in Europe now occur, has allowed for the recolonisation of some of its former range. For example, in France, recolonisation was aided by successful reintroduction projects using Spanish and captive-bred birds[1,7].

Individuals have started to be seen more frequently in the Alps, in northern France and Romania, as well as Crete. The relatively small populations in Ukraine and Georgia are also increasing, and the small population in Greece appears to have stabilised since 2018. A reintroduction project has been successfully initiated

* *European proportion of the population calculated using the minimum estimated population sizes.*

** *Mature individuals.*

*** *Change calculated using the minimum population size estimated as start year.*

in Bulgaria since 2018, with the first successful fledging of a chick in the wild in 2021. However, population declines are being observed in eastern Europe, including in Russia and the Caucasus, likely due to poisoning, changes in agricultural practices, human migration from the countryside to the cities, and declines in wild ungulates [1,6–8,10].

DRIVERS OF RECOVERY

The significant overall population increase of Cinereous vultures in Europe in the past few decades is due to several factors, including recent EU regulations allowing the operation of feeding stations (or 'vulture restaurants') which provide a safe, poison-free food sources for scavengers, and successful anti-poisoning campaigns, as well as effective protection of breeding colonies. Captive breeding and reintroduction programmes, such as those in France and Bulgaria, have also contributed to this success [1,7,8,10].

One important component of recovery, particularly in Spain, has been the cooperation of national and local governments with conservationists to mitigate the effects of poisoned baits (named the 'Antidote Programme' in Spain), producing anti-poisoning strategies and campaigns, alongside an increase in food availability from wild ungulates through the control of hunting bags [1,6,18].

Cinereous vultures are internationally protected, being included in the EU Birds Directive, CITES, the Bern Convention, the Convention on Migratory Species (CMS) and the Raptors Memorandum of Understanding (MoU). While hatching success is generally high, many pairs do not breed every year, so the species has a slow recovery potential – the fact that these tools have been in place for several decades helps explain the long-term increase in the species' population. Another important, although not legally binding, tool are species Action Plans, which define the priority conservation actions for the species. The first Action Plan for the Cinereous vulture in Europe was published in 1996, and implemented in several countries, especially in Spain, France and Greece. Further international coordination led to the publication of the Balkan Vulture Action Plan in 2004, and the Multi-species Action Plan for African-Eurasian Vultures and Flyway Action Plan for the Conservation of the Cinereous Vulture in 2017, as well as the European International Species Action Plan for the Cinereous Vulture, produced in 2018 by the Vulture Conservation Foundation through the LIFE EuroSAP project [1,6,7,16,19,20].

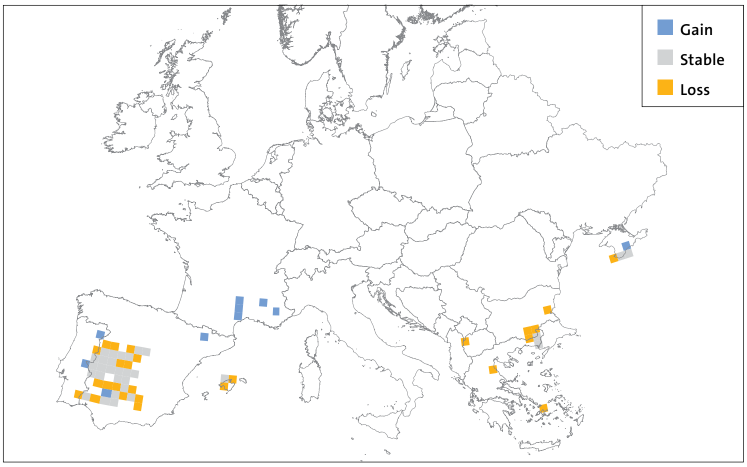


Figure 1a. Change in range of the Cinereous vulture between the 1980s [11] and 2010s [5] as per the EBBA2.

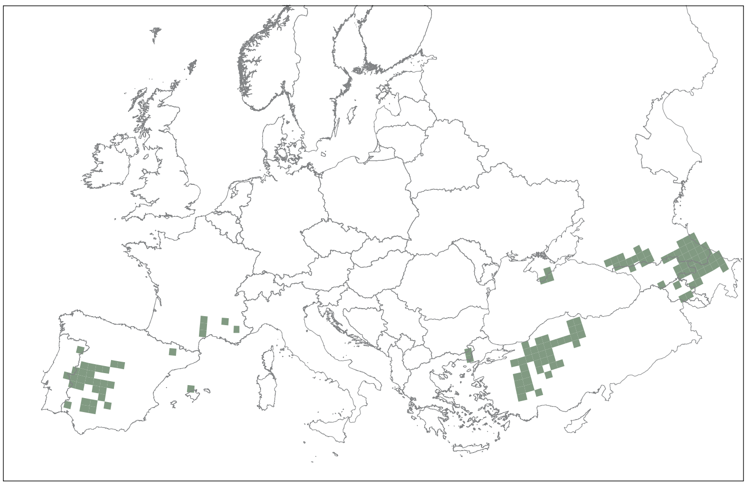


Figure 1b. Current distribution of the Cinereous vulture across Europe (2010s) [5].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix III) • CMS (Appendix II) • Raptors MoU (Annex I)
Global threats	• Annual & perennial non-timber crops • Renewable energy • Hunting & trapping terrestrial animals • Utility & service lines • Work & other activities • Other ecosystem modifications • Temperature extremes • Other threat [2]
European threats	• Sports, tourism & leisure activities • Livestock farming & ranching • Wood & pulp plantations • Renewable energy • Utility & service lines /transmission of electricity and communication • Hunting & trapping terrestrial animals [1,17]

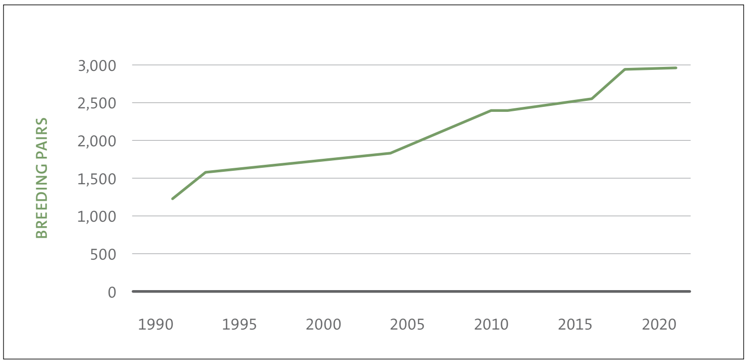
BENEFITS OF COMEBACK

Vultures are scavengers, and as such are often overlooked as necessary links in healthy ecosystems. They help keep landscapes free from rotting carrion, by quickly finding and processing carcasses, which in turn prevents the opportunistic use of carrion by mammalian scavengers, thus limiting their population size and reducing the pressure that large numbers of mammalian predators can put on other species, such as vulnerable populations of ground nesting birds. Therefore, vultures (and other scavengers) provide a valuable ecosystem service which would otherwise require significant human resources and incur high economic and environmental costs. Indeed, the process of eliminating carrion manually, through carcass removal programmes, produces significant amounts of greenhouse gases emitted during transport, decomposition or incineration, most of which are eliminated if the service is provided by vultures [8,21–25].

Raising awareness for such species and their role in ecosystems, could also be an integral part of biodiversity education, and in broadening the public's acceptance of the essential role that nature plays in human lives. A good example of a conservation activity, which also helps raise awareness about vultures and brings economic value to local communities, is organising tourist visits to vulture feeding stations. This can help increase public support for the Cinereous vulture, as well as for the conservation of other vulture species.

Vultures are also charismatic birds, which can provide additional socio-economic benefits, as they attract many visitors to their breeding and feeding grounds [25].

Figure 2. Estimated number of Cinereous vulture breeding pairs in Europe [1,3,12–16].



OUTLOOK

Cinereous vulture populations in Europe have made a strong recovery in the past few decades. A continued growth in numbers is expected, which could lead to more range expansion into previously lost areas, mostly in the southern and south-eastern parts of the continent, and gives hope for its continued comeback [1,7].

Nevertheless, various threats still present a real danger to the species in the region. These include a reduction in food availability due to the lack of carcasses of domestic livestock and regional reductions in populations of wild mammals (e.g. wild ungulates). Direct mortality caused by humans (whether intentional or not), particularly from poisoning, is also still a major issue, and lead poisoning remains a prevalent yet poorly reported threat. Moreover, the continued expansion of wind farms and the subsequent increase in collisions with wind turbines, electrocution from power-lines and habitat loss are a growing concern. Nest abandonment can also occur as a result of human disturbance. Due to climate change, the number of wildfires in Mediterranean forests is increasing, thus increasing breeding habitat loss [1,6–8,26,27].

Potential future threats include accidental poisoning by ingestion of certain veterinary non-steroidal anti-inflammatory drugs (NSAIDs) from livestock carcasses. NSAIDs have caused high mortality rates in vulture populations in Asia and one confirmed Cinereous vulture death in Spain in 2020. In addition, outside of Europe, it is suspected that low and fluctuating temperatures may be the cause of many brood losses. Therefore, changes in air temperatures resulting from climate change may also be a potential future threat to the species [1,6,28].

The ongoing recovery of the Cinereous vulture population is therefore still very dependent on the continuation of existing conservation actions in the form of anti-poisoning strategies, food supplementing, reintroductions and monitoring. Moreover, the implementation and upholding of policies and policing against disturbance and persecution, the insulation of unprotected power lines, and awareness-raising about the species are all still very much needed. Further work could be done to help Cinereous vultures, such as the restoration of populations of wild ungulates and European rabbits (*Oryctolagus cuniculus*), which would help increase feeding opportunities [6,8].

Cinereous vultures also need appropriate habitat to breed, the availability of which could be improved with adequate habitat protection. Such habitats also need to be increasingly protected from wildfires. In addition, further efforts in increasing and extending research and monitoring work are crucial to better identify and understand the current and potential future threats that affect this species. Of particular importance are threats related to the decline in abundance of prey species, the impact of wind farms and energy infrastructure, as well as improving knowledge on current levels of illegal poisoning. Conservation actions protecting the Cinereous vulture from these threats would benefit other species too, such as eagles and falcons, as well as other large scavenger species [6,8].

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Spanish imperial eagle

Aquila adalberti

The Spanish imperial eagle (*Aquila adalberti*) is a large, long-lived, sedentary raptor endemic to the western Mediterranean region. It is one of the rarest birds of prey globally, and at present occurs exclusively in the Iberian Peninsula (Figure 1b). The species can occupy various habitats, from alluvial and wetland habitats through plains to hills and mountains, but most of the breeding population inhabits areas with patches of Mediterranean forest and dehesas. It is also increasingly found in farmland with high densities of European rabbits (*Oryctolagus cuniculus*), which form its most important prey species, so much so that the Spanish imperial eagle's population size and abundance is inherently linked to the availability of European rabbits. Occasionally, it will also hunt pigeons, reptiles and waterbirds, and opportunistically feed on wild ungulate carcasses. The Spanish imperial eagle tends to occupy very large territories, and nests mainly in the crown of trees, away from human activity[1,5,6].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
	VU			+1,313%	+40%
Forest, Shrubland, Grassland, Wetlands (inland)[1]	Global: Vulnerable (2021)[2] Europe: Vulnerable (2020)[1]	Global: Increasing (2021)[2] Europe: Increasing (2020)[1]	Global: 1,080* (2021)[2] Europe: 1,080* (2020)[1]	Increasing, +1,313% 1974–2017**	Increasing, +40% 1980s–2010s[3,4]

Historical distribution and abundance

During the 19th century, the Spanish imperial eagle was common throughout Spain and its range extended from Portugal in the west to Morocco in the south. However, between 1850 and the middle of the 20th century, the species experienced a dramatic reduction in its population size and range. Until the first half of the 20th century, this was probably due to the use of poison, shooting for predator control, and the demand for museum specimens, which together caused the largest decline in the species' population. Thereafter, the crash in European rabbit populations during the 1950s, due to myxomatosis, greatly diminished the Spanish imperial eagle's already highly impacted population. This left the Spanish imperial eagle close to extinction, with only 30 breeding pairs remaining in the wild by 1960. By 1974, a year after the species became legally protected, its Iberian range had declined by 90%, with only the central and southern parts of its distribution remaining occupied, while it had entirely disappeared from Portugal. From then on, however, thanks to conservation efforts started in the 1960s, the population has started to recover slowly[1,5,6].

Recent changes in abundance and distribution

In the 1990s, the Spanish imperial eagle's population continued to increase, although its rise faltered following an outbreak of viral haemorrhagic disease in European rabbits, in the middle of the decade. The decline in its main prey also caused the species to increasingly forage outside of protected areas, exposing it to increased contact with poisoned baits. This was followed by a period of stagnation from the mid to late 1990s which coincided with, and was probably caused by, an increase in the illegal use of poison for predator control in game breeding areas. Then, from 2000 until recently, there was another increase in the species' population thanks to further conservation efforts, and the species is estimated to have increased by approximately 167% between 2007 and 2018. In the past few years, the Spanish imperial eagle population appears to have plateaued, at least partly due to an increase in persecution, poisoning and electrocution events[5,6].

The species' population size has increased almost continuously in Europe since the 1960s (Figure 2), with the number of pairs breeding in Spain increasing from 317 pairs in 2012 to approxi-

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

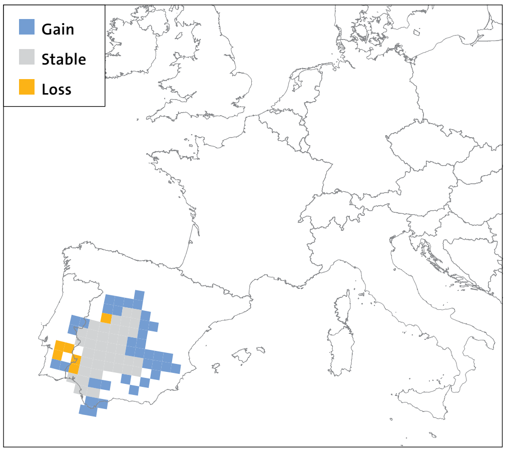


Figure 1a. Change in range of the Spanish imperial eagle between the 1980s [9] and 2010s [4] as per the EBBA2.

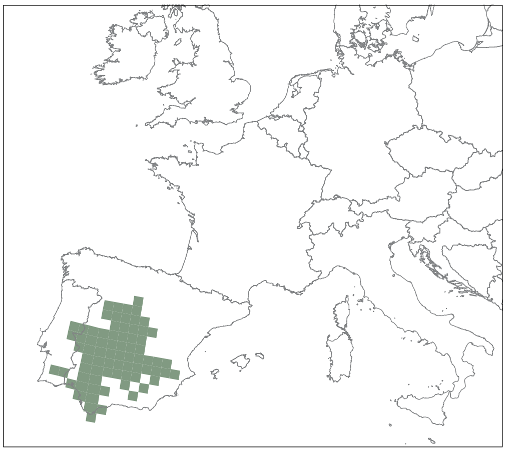
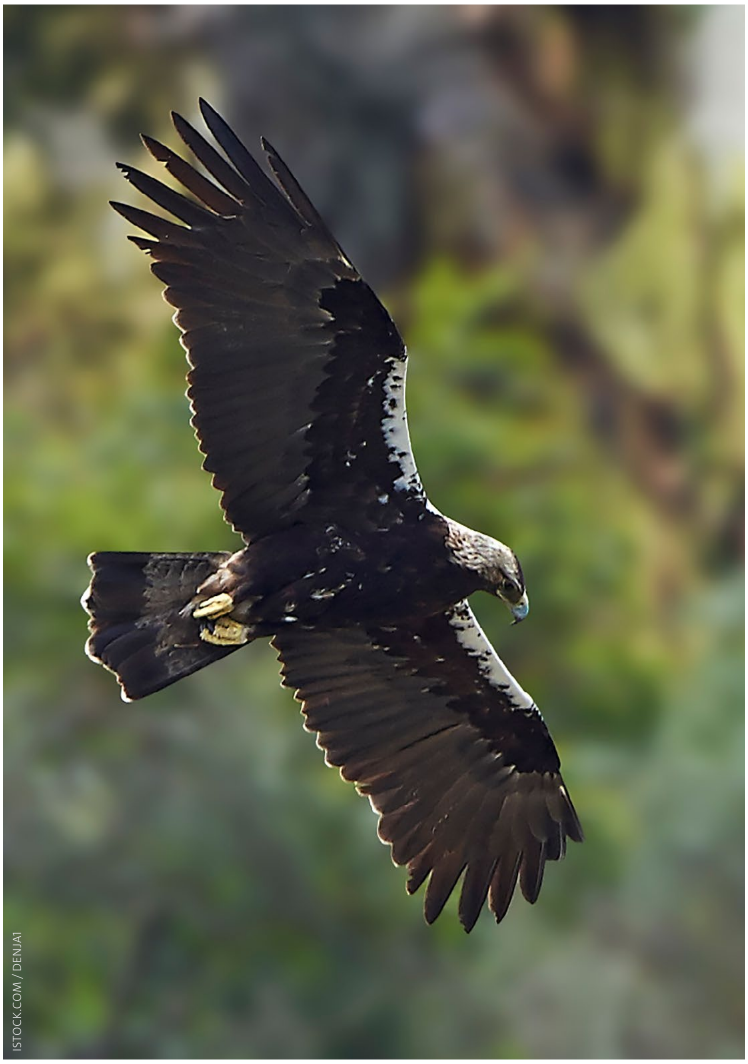


Figure 1b. Current distribution of the Spanish imperial eagle across Europe (2010s) [4].



mately 520 pairs in 2018. After more than 20 years of absence, breeding resumed in Portugal in 2002, with the Portuguese population reaching 17 pairs by 2019. As a result of population growth across the Iberian Peninsula, a rising number of dispersing immature birds have been recorded in North Africa, especially in Morocco, where the species became extinct as a breeding species in the first half of the 20th Century [1,5–8].

Despite this impressive recovery and some increases in the Spanish imperial eagle's distribution since the 1970s (mainly due to successful recolonisation), the species' range has not increased greatly. By 2012, it was still occupying less than 20% of its mid-19th century range, being largely restricted to mountainous forest areas and some protected private land areas in the plains. Since then, it has started to recolonise more parts of its former range (e.g. the Beticas Mountains) (Figure 1a). It is likely that the recent slowing in the Spanish imperial eagle's recovery is due to a combination of saturation of occupied areas, and an increase in previously existing threats, combined with the recent emergence of new threats [1,5–8].

DRIVERS OF RECOVERY

Habitat management has been critical for the recovery of the Spanish imperial eagle, including management to improve food availability and supplementary feeding programmes. Measures to prevent electrocution have included the modification of power cables and the insulation of electricity pylons in both Spain and Portugal; in 2008 a law was passed in Spain for the protection of birds against collision and electrocution by power lines, with best practices for new power line construction or modification. Nest monitoring has reduced human disturbance and consequently improved reproductive success. The species is also a good candidate for reintroduction, as habitat availability is not a limiting factor. Indeed, reintroductions have or are taking place in several regions, including in Doñana and Cádiz in Spain [1,5,6].

In addition, the species has significantly benefitted from protection under international, national and regional legislation over the entirety of its range, aided by the fact that a large proportion of the total breeding population (around 60%) occurs within protected areas. A European Action

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix I) • Bern Convention (Appendix III) • CMS (Appendices I and II) • Raptors MoU (Annex II)
Global threats	• Housing & urban areas • Annual & perennial non-timber crops • Wood & pulp plantations • Renewable energy • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities • Work & other activities [2]
European threats	• Housing & urban areas • Wood & pulp plantations • Renewable energy • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Recreational activities • Work & other activities • Viral/prion-induced diseases • Habitat shifting & alteration [1,13]

Plan for the conservation of the Spanish imperial eagle, initially published in 1996, and subsequently updated in 2008, has helped coordinate conservation action [1,5,6,14].

Communication with stakeholders and awareness raising are an important tool for this species' conservation. As an example, the Soaring Land Stewardship Network (created by SEO/BirdLife as part of the preceding Flying High Programme) targeted the conservation of Spanish imperial eagles and lasted from 2006 to 2015. This network involved national authorities, local communities and private landowners, and focused on habitat management, species conservation, awareness raising and information activities across the species' entire range in Spain. Other awareness raising work is ongoing, in both Spain and Portugal, particularly regarding private land where the species breeds, seeking to improve habitat management [1,5,6].

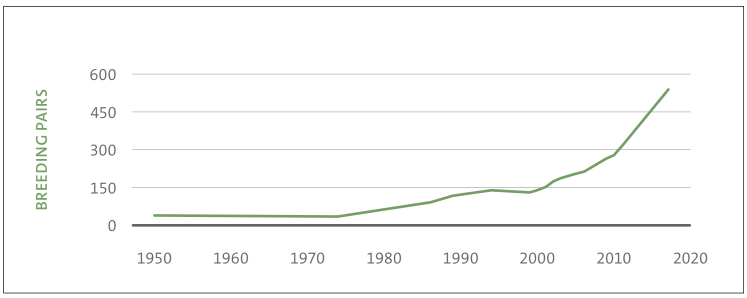


Figure 2. Estimated number of Spanish imperial eagle breeding pairs in Europe [1,6,10–12].

BENEFITS OF COMEBACK

The Spanish imperial eagle's main prey species is the European rabbit, and therefore the presence of eagles in a landscape can help keep rabbit populations in check. Moreover, the Spanish imperial eagle is a charismatic species, which has the potential to attract tourism to the regions in which it is present. It faces similar threats to other bird of prey, such as other eagle species, hawks, vultures and falcons, and so, the conservation of the Spanish imperial eagle, particularly relating to actions mitigating the threats of electrocution and illegal poisoning, is likely to be very beneficial to many other species.

OUTLOOK

Spanish imperial eagle populations have made a good recovery over the past few decades, mainly due to an increased survival rate among adults, as persecution and poisoning have been greatly reduced. It is therefore probable that the species could continue to increase and expand back into more of its former range. However, its population growth appears to be reaching a plateau, likely due to a recent increase in non-natural deaths, which, combined with the philopatric nature of this species, may act to prevent them from expanding into new areas. Indeed cumulatively, these new threats are predicted to cause a decline in the species' Spanish population in the near future, and as such it was assessed as Vulnerable in the Spanish Red Data Book in 2021 [7,8].

The main ongoing threats to Spanish imperial eagles are electrocution from power lines, and poisoning. Electrocution, despite effective mitigation measures, may be more of an issue for immature birds, which disperse further (as far as Morocco, where the risk of electrocution is higher). Occurrences of poisoning are mainly accidental, and relate to game and livestock protection, but intentional poisoning is increasing once again, and is often related to commercial hunting reserves. The enforcement of anti-poisoning legislation is not currently effective, and although attitudes towards the Spanish imperial eagle have improved, persecution remains an issue, with several individuals having been shot in both Spain and Portugal in recent years. Accidental shooting and ingestion of lead pellets from hunting activities are also an issue. The reduction in adult survival caused by these threats, combined with the possible saturation of available habitats in some parts of its Spanish range, appears to be inhibiting further population recovery [1,5–8].

Habitat fragmentation (mainly resulting from infrastructure development), as well as habitat degradation and loss (mainly due to agricultural intensification and urbanisation) lead to increased disturbance and conflict with humans. This affects breeding success and dispersal, potentially limiting the recolonisation of the bird's historic range [1,5,6].

In addition to these ongoing threats, the future of Spanish imperial eagles remains closely linked to the availability of its preferred prey species, the wild European rabbit, and Spanish imperial eagles may once more experience decline if European rabbits undergo another outbreak of disease. A reduction in the availability of their prey may also be an emerging issue where solar farms are installed in the Spanish imperial eagle's habitat. Spanish imperial eagles are also susceptible to collisions with wind turbines. Although these have not yet been observed to be a significant threat for the species, the issue may increase in the future, as more solar and wind farms are installed within its breeding range. Moreover, the highly aggregated distribution of the Spanish imperial eagle increases its risk of being affected by stochastic, yet more and more regular, natural disasters such as wildfires [1,5,7,8].

To counter these ongoing and potential threats, it is essential to keep monitoring the population and continue with the conservation actions taken so far. Regional conservation plans should be updated regularly with the most up-to-date information on the species' distribution. Current and new breeding sites, as well as key dispersal areas should be protected and maintained. The installation of wind farms should be avoided in key areas for the species, as should that of solar farms in areas with important European rabbit populations. Awareness raising and collaboration between different stakeholders is essential, be it relating to land use, new transport or energy infrastructure, the promotion of land stewardship for the species, or the prevention of persecution and disturbance [1,5].

Unfortunately, all these conservation efforts are limited by funding, which, especially in the case of the insulation of power lines, could become a significant constraint in the future, and may contribute to slowing the species' recovery. At present, the recovery of the Spanish imperial eagle is still dependent on intensive management and conservation efforts, all of which requires resources [1,5,6]. Lack of funding could therefore be seen as a threat in itself.

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Eastern imperial eagle

Aquila heliaca

The Eastern imperial eagle (*Aquila heliaca*) is a large, long-lived bird of prey, occurring in central and eastern Europe and Asia. It is essentially a lowland species, which is nowadays commonly found occupying higher altitudes as a result of persecution and habitat loss, particularly in the Caucasus, Altai, and other parts of central Asia. Eastern imperial eagles breed in large trees, in mountain or alluvial forests, in open landscapes, along rivers and very rarely on rocks or shrubs in semi-deserts or steppes. They hunt in open areas and wetlands by preying on small mammals such as Sousliks (*Spermophilus* spp.), Hares (*Lepus* spp.) and Hedgehogs (*Erinaceus* spp.), the abundance of which its distribution depends on – but they may also prey on birds and reptiles or feed on carrion. Farmland, especially traditional pasture, is one of the most important foraging habitats for the species[1,5–9].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
	LC			+520%	-10%
Forest, Shrubland, Grassland, Wetlands (inland), Artificial/ Terrestrial[1]	Global: Vulnerable (2016)[2] Europe: Least Concern (2020)[1]	Global: Decreasing (2016)[2] Europe: Increasing (2020)[1]	Global: 5,000* (2016)[2] Europe: 4,800* (2020)[1]	Increasing, +520% 1993–2018**	Decreasing, -10% (1980s–2010s)[3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The historical limits of the species' distribution in Europe are not known. However, it is certain that the Eastern imperial eagle was more abundant in the past and ranged over a much larger part of Europe in the 19th century than its current distribution accounts for. This was the case in the Balkans, where it used to occur in high densities, as well as in southern Poland, and possibly, the south-eastern parts of Germany. During the 20th century, its population declined dramatically as a result of persecution, poisoning and habitat loss. By 1960, its distribution had contracted eastwards to just the Carpathian Basin and some parts of the Balkan Peninsula[6,9,10].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Since its rapid decline in the second half of the 20th century, the Eastern imperial eagle is currently patchily distributed in Europe (Figure 1b). Its range spans from the Carpathian Basin in the west, through the Balkan Peninsula and southern Ukraine, to Lake Baikal in European Russia in the east, and Turkey and the Caucasus in the south. Wintering birds are also found in southern Turkey. While the populations from central Europe, the Balkans and Anatolia are usually resident, immature birds may occasionally reach the Middle East or northeast Africa, and others may migrate southwards during the winter[5,6].

The species' distribution in the Carpathians started to expand in the 1990s (Figure 1a), but the Balkan population, although stable, has remained small and scattered. Population increases, as well as range expansions westwards and northwards, have been observed, seemingly as a direct result of targeted conservation efforts. New breeding areas have been identified in Czechia and Austria since the late 1990s and in Siberia since the late 2000s, indicating that the species is bouncing back from its previous declines[6,9].

Overall, the quality of population monitoring, especially in Russia, which currently holds most of the European population, has improved greatly in the past decades. Some of the reported population increase and range expansion in eastern Europe is now attributed to improved monitoring, although current data still indicate growth in this region[1,6]. The Balkan population is small and fragmented. It is increasing in Bulgaria and North Macedonia,

* Mature individuals.

** Change calculated using the minimum population size estimated as start year.

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix I) • Bern Convention (Appendix III) • CMS (Appendices I and II) • Raptors MoU (Annex I)
Global threats	• Wood & pulp plantations • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Work & other activities [2]
European threats	• Annual & perennial non-timber crops • Wood & pulp plantations • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Work & other activities • Agricultural & forestry effluents [1,20]

with currently 30–40 pairs each. Serbia and Greece only have very small but stable populations of a few pairs each. The species has disappeared from Cyprus and Moldova, while Croatia only holds one pair. Improved monitoring is needed to assess the bird's status in the Caucasus, where trends are unknown; the population in Armenia may have risen from one pair to currently 10 pairs, while in Turkey, the trend also appears to be going up. Robust monitoring indicates that the population in the Carpathian Basin has grown significantly since the early 1990s, and the central European population (mainly in Hungary and Slovakia) appears to have been increasing recently as a result of conservation efforts [1,5–7,11].

The current population of the Eastern imperial eagle in Europe is estimated at approximately 1,900–3,000 breeding pairs and is increasing overall (Figure 2).

DRIVERS OF RECOVERY

Targeted conservation actions, particularly in Hungary and Bulgaria, have enabled the recovery of Eastern imperial eagle populations. Hungary has become one of the species' main European strongholds outside of Russia, and consequently has contributed to a steady increase of the Eastern imperial eagle's population size and range across the entire Carpathian Basin [6].

Targeted conservation actions have included: introducing a ban on the use of poisoned baits and anti-poison campaigns, insulation of power lines, nest surveillance and protection, and breeding and feeding habitat protection and management. Habitat protection and management, for example, involves the setting-up and promotion of agri-environmental schemes, which maintain pastures and appropriate grazing regimes. In addition, the protection of non-arable features in agricultural

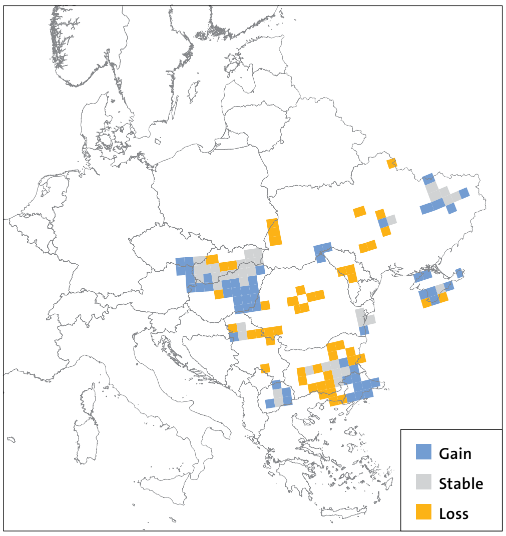

Figure 1a. Change in range of the Eastern imperial eagle between the 1980s [12] and 2010s [4] as per the EBBA2.

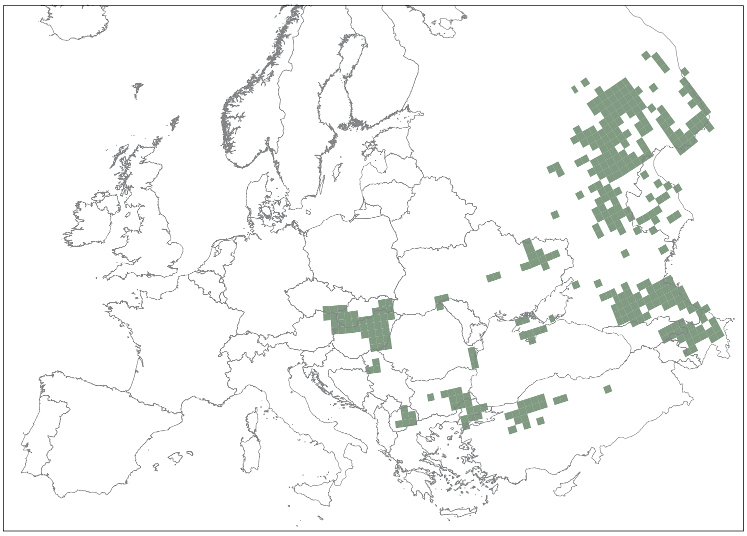

Figure 1b. Current distribution of the Eastern imperial eagle across Europe (2010s) [4].

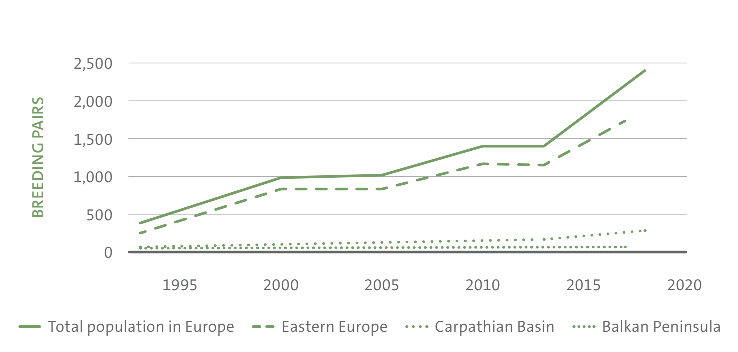

Figure 2. Estimated number of Eastern imperial eagle breeding pairs in Europe[1,13–19].

land, the purchase, protection and management of good foraging habitat, and the reintroduction and restocking of prey species such as Souslik, have significantly contributed to the species' recovery. These actions are also supported by supplementary feeding, nest guarding, the construction of artificial nests and the rehabilitation and release of birds confiscated from illegal trade. Awareness raising has also played a role in educating people and changing their attitude towards the species[6,7].

Nevertheless, threats are still very present across the Eastern imperial eagle's overall European range, and it is important to note that current local increases may be partly due to immigration from populations further east as well as increased fecundity and survival[5]. The Eastern imperial eagle remains dependent on targeted conservation measures for its continued stability and recovery in the region.

The Eastern Imperial eagle is listed in CITES, the EU Birds Directive, the Bern Convention, the Convention on Migratory Species (CMS) and the Raptors Memorandum of Understanding (Raptors MoU). Moreover, outside of the EU, it is nationally protected in Armenia, Azerbaijan, Georgia, Turkey, Ukraine and Northern Macedonia[1,5–7].

In addition, an Eastern Imperial Eagle Working Group was established in 1990, and a series of plans were created to help the conservation of the species. A European Action Plan was published in 1996 (with its implementation reviewed in 2010), Regional Action Plans have been published for the Balkan Peninsula and for the Southern Caucasus in 2004 and 2006, respectively, and Management Guidelines were published for Hungary and for Slovakia in 2005 and 2007, respectively[1,5,16,19,21–24]. These various groups and plans all contribute to building a collaborative international platform aimed at ensuring that the species makes a successful comeback in Europe.

BENEFITS OF COMEBACK

Eastern imperial eagles are top predators. In a healthy environment, their preying on small to medium-sized mammals helps keep those species' populations in check, constituting an important role in local food webs. As one of its prey species are the Sousliks (including the endangered European souslik (*Spermophilus citellus*)), in some regions the Eastern imperial eagle's conservation can be linked to that of this small group of mammal species. The conservation of the Eastern imperial eagle can therefore also help the recovery of the Sousliks and other species which use the same habitats.

Moreover, Eastern imperial eagles are impressive birds, which can attract ecotourists to areas where they are present, thus generating revenue for local communities.

OUTLOOK

After steep declines in the past, the Eastern imperial eagle's population has stabilised in most of Europe, thanks to targeted conservation measures. Local increases are predicted to keep the overall population growing. In addition, the species has recently shown ability to adapt to the prey species currently available, and therefore to changing conditions[8]. However, the Eastern imperial eagle is still very much conservation-dependent and the continuation of these actions is crucial for its recovery.

Threats to the species are still very much present in Europe. Persecution and accidental poisoning are key issues. In the past decade, the occurrence of persecution incidents has significantly increased, with more than 80 Eastern imperial eagles poisoned in Hungary alone in 10 years. Moreover, the loss and alteration of feeding habitats, especially the conversion of pastures, due to land use changes and unsuitable agricultural practices, and the subsequent decline of prey species, are key factors limiting breeding and feeding opportunities. Additional threats to current, historical and potential breeding sites exist due to intensive forestry in the mountains, the shortage and continued removal of large indigenous trees in the lowlands, and to agricultural expansion and intensification. In Bulgaria, for example, the strong intensification of agricultural practices, financially stimulated by subsidies from the EU Common Agricultural Policy, has resulted in the loss of foraging habitats, becoming a serious threat to the species in recent years [1,5–7,11,25,26].

The Eastern imperial eagle is sensitive to human disturbance, which means its breeding range can be highly restricted by human presence, activity and infrastructural development. In Turkey, a large proportion of nesting areas are being threatened by intensive infrastructural development and habitat loss. It is also threatened by nest robbing and illegal trade, and by electrocution by power lines. In Bulgaria, approximately one third of non-natural deaths recorded between 1992 and 2019 were caused by electrocution, while in Russia, a quarter of the Altai region's population died as a result of electrocution on powerlines during the 2009 breeding season. Moreover, as nesting sites become scarcer, competition with other species that use similar nesting habitats such as the Greater spotted eagle (*Clanga clanga*) is likely to increase. Together, these threats might cause the species' population to decline, as is expected in Russia for example [1,5–7,11,25,26].

Therefore, to ensure the continued recovery and long-term survival of the Eastern imperial eagle in Europe, targeted conservation actions, along with appropriate management of farmland and preservation of traditional land use, must be put in place across the whole of the species' range. Increased law enforcement and public awareness efforts about the protection of the species and its habitats, illegal trade and the impact of poisons, are required. The insulation of power lines and enforcing the protection of large trees in open land and old woodland, along with implementing beneficial forestry practices, are also very important. Moreover, increased monitoring and survey efforts could strengthen knowledge on sites and routes used during the breeding, passage and wintering seasons [1,5,6].

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White-tailed eagle

Haliaeetus albicilla

The White-tailed eagle or Sea eagle (*Haliaeetus albicilla*) is a large raptor found across the Palearctic, from Greenland and Iceland in the west, through to the Pacific coast and Japan in the east. It occurs in a variety of habitats near open expanses of water, lakes, river valleys, and coastal areas. The species nests on old growth trees in wooded areas, on cliffs, or, more rarely, on pylons or towers, or even on the ground, generally away from human disturbance. White-tailed eagles are territorial, and pairs are usually sedentary, although birds in northern and eastern parts of the range migrate south in winter, travelling to continental Europe and even as far as southern Asia. White-tailed eagles are known for feeding on fish, but they also prey on birds and mammals from either marine, freshwater or terrestrial habitats. Carrion is also an important source of food, especially during the winter [1,6,7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Forest, Grassland, Wetlands (inland), Marine Neritic, Marine Intertidal, Marine Coastal/Supratidal, Artificial/Aquatic & Marine [1]	Global: Least Concern (2021) [2] Europe: Least Concern (2020) [1]	Global: Increasing (2021) [2] Europe: Increasing (2020) [1]	Global: 34,600* (2021) [2] Europe: 25,000* (2020) [1,3]	Increasing, +445% 1970–2018**	Increasing, +194% 1980s–2010s [4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Historically, the White-tailed eagle was present throughout Europe, with its distribution extending down to western and southern Europe and reaching as far as North Africa. Between the 1800s and the 1970s, its population declined dramatically, first due to persecution, and then due to the bioaccumulation of organochlorine pesticides. The latter caused high rates of breeding failure, resulting in severe declines until the 1970s. This was particularly the case in the Baltic Sea region where organochlorine pollution levels were very high. By contrast, the Norwegian population, which utilises food resources from the northern Atlantic, was not as badly affected [6,7]. The declines over the past two centuries have led to severe contractions in the species' range, resulting in its disappearance from many countries, such as Czechia in the 19th century, the United Kingdom and Denmark in the first part of the 20th century, and Austria, Slovakia and Ireland in the second half of the 20th century [6,7].

The declines over the past two centuries have led to severe contractions in the species' range, resulting in its disappearance from many countries, such as Czechia in the 19th century, the United Kingdom and Denmark in the first part of the 20th century, and Austria, Slovakia and Ireland in the second half of the 20th century [6,7].

STAFFAN WIDSTRAND / REWILDING EUROPE

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

Following the introduction of legal protection and the ban on harmful organochlorine chemicals, coupled with targeted conservation

* Mature individuals.

** Change calculated using the minimum population size estimated as start year.

actions, the White-tailed eagle has shown a spectacular recovery. Over the last few decades, its population size has increased and population trends continue to be positive in almost all countries in Europe, while its range is gradually expanding to the west.

The species has recolonised many areas from which it had become extinct, either naturally as the population increases (such as in Austria, where it returned as a breeding species in 1999) or in some cases with the help of reintroduction programmes[1,3,7].

Currently, the bulk of the European population is in Norway and the countries surrounding the Baltic Sea, while most of the remaining population is found in the countries along the river Danube, with smaller numbers in Greenland and Iceland, as well as western Europe (in the British Isles, the Netherlands and France). Its large range, however, is patchily populated, and the species'

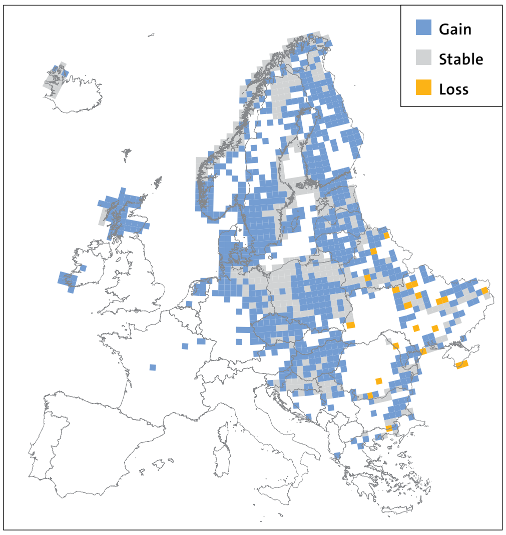


Figure 1a. Change in range of the White-tailed eagle between the 1980s[8] and 2010s[4] as per the EBBA2.

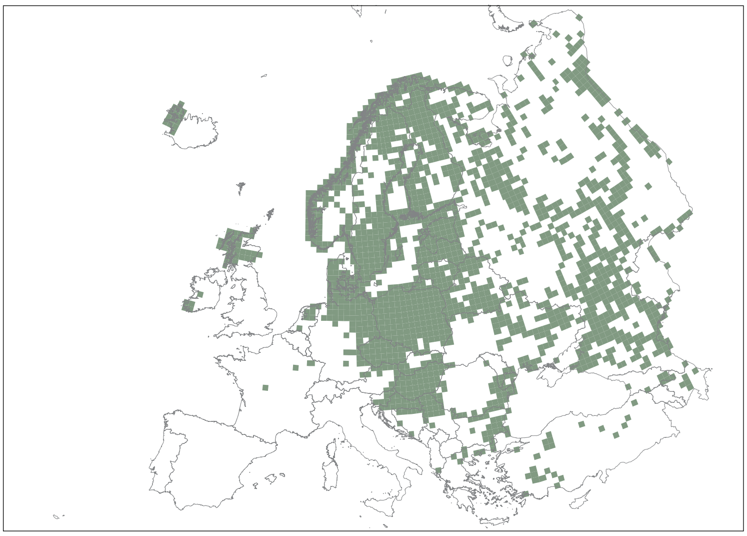


Figure 1b. Current distribution of the White-tailed eagle across Europe (2010s)[4].

absence in large parts of southern Europe could be due to ongoing threats, such as persecution and poisoning[1,4,7].

The current population of White-tailed eagles in Europe is estimated at approximately 12,500 pairs and is increasing overall[1,3].

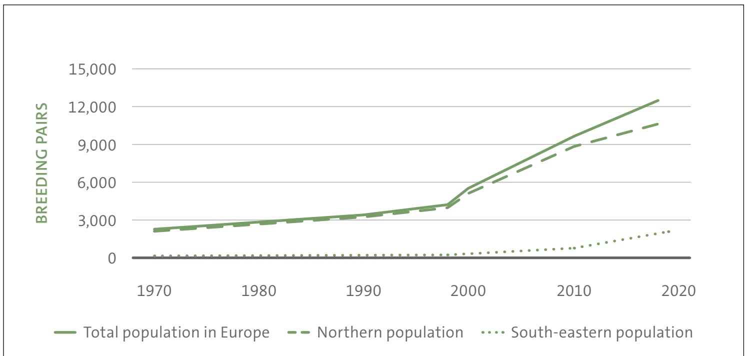
DRIVERS OF RECOVERY

The comeback of the White-tailed eagle can be attributed to several drivers, most importantly the ban of DDT and other harmful chemicals from the agriculture and forestry sectors since the early 1970s, and improved legal protection from persecution (intentional poisoning, shooting, trapping or disturbance), together with effective implementation and enforcement of these protections[1,6,7].

In addition to these main drivers, other conservation actions have helped the species' recovery. Reintroductions have led to its increased presence in Czechia, Germany, and the British Isles. However, these programmes have sometimes been met with resistance due to concerns over livestock predation, and therefore awareness raising, good communication and collaboration with stakeholders remain as key factors in the continued success of these programmes[1,3,6,7].

Public awareness campaigns might be of growing importance as the species is expanding naturally into more areas of its former range, including in Germany, Denmark and the Netherlands. Campaigns against the use of illegal poison baits have been one of the most important factors for its recovery in some countries, such as in Austria[1,3,6]. Supplementary winter feeding, which increases the chances of survival for juvenile White-tailed eagles, artificial nest construction, on-site protection of nests from disturbance, as well as habitat protection and monitoring, have all played important roles in this species' recovery. Less directly, nature restoration projects, such as those occurring on the March and Danube in Austria, have also had a positive impact on the White-tailed eagle population[1,3,6,7].

Figure 2. Estimated number of White-tailed eagle breeding pairs in Europe, and separately in the northern population (including Norway and states around the Baltic Sea) and the smaller south-western population (including Danube countries and the Balkans)[1,3,7,9–13].



THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix I) • Bern Convention (Appendix II) • CMS (Appendix I) • Raptors MoU (Annex I)
Global threats	• Annual & perennial non-timber crops • Wood & pulp plantations • Renewable energy • Hunting & trapping terrestrial animals • Recreational activities • Viral/prion-induced diseases • Industrial & military effluents • Agricultural & forestry effluents[2]
European threats	• Housing & urban areas • Tourism & recreation areas • Annual & perennial non-timber crops • Wood & pulp plantations • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Recreational activities • Work & other activities • Industrial & military effluents[1,14]

Legal tools which have supported these drivers of recovery include the EU Birds Directive, CITES, the Bern Convention, the Convention on the Conservation of Migratory Species (CMS) and the Raptors MoU. These protections have all been in place for some decades, helping the recovery of this species. In 2011, Danube Parks published an Action Plan for the conservation of the White-tailed sea-eagle within the region's protected areas, which helps guide and coordinate the species' conservation[6,12].

BENEFITS OF COMEBACK

The White-tailed eagle is an apex predator, and as such it plays a role in the ecosystem by contributing to the control of its prey species' population sizes. Although White-tailed eagles are not always very favourably perceived (as demonstrated by ongoing persecution), with more awareness raising and visibility due to its increasing population, the species can become a popular local draw for tourists. As an example, the Scottish Island of Mull (United Kingdom) has approximately 22 pairs of White-tailed eagles that attract 5 to 8 million pounds sterling in visitor spending each year[15,16]. In addition, conservation actions aimed at the White-tailed eagle could benefit other species in its range which face similar threats, such as collision with overhead cables and electrocution from pylons, or poisoning from lead ammunition or toxic chemicals, especially in wetlands.

OUTLOOK

This White-tailed eagle has made a good recovery in Europe so far. Reintroduction programmes have had considerable success and the species is naturally expanding back into its historical range in some areas. Continued population growth and expansion are therefore expected. However, the species is still affected by ongoing threats, which, if not mitigated, may have an effect on its comeback. These include habitat loss and degradation, particularly in wetlands subject to drainage and land use change, as well as some loss of suitable nesting sites due to modern forestry practices. Human disturbance, especially as a result of forestry operations and access, persecution (especially shooting), accidental poisoning (from pesticides, lead ammunition and poisoned bait) and collision with wind turbines and overhead cables, all add to the list of threats. Large scale future development of wind power plants may have a potentially high impact on White-tailed eagle populations over the long term. As more eagles adapt to nesting closer to cities, the frequency of collisions with traffic also increases. Adding to these anthropogenic threats, the species is also occasionally affected by outbreaks of the avian influenza virus [1,6,7,15].

Therefore, it is important to continue with those conservation measures that are already in place and to ensure that more action is taken to secure this species' recovery. Such measures should focus on increasing the level of community engagement in and around areas where the species is present or will be reintroduced, aiming to lower the risk of persecution. It is also important to prevent the loss of nesting and hunting habitat from modern forestry practices, as well as from the encroachment of human development, through careful pre-emptive spatial planning. The latter is also important for wind turbines, ensuring these are not installed in breeding areas to lower the risk of collision, especially given the current push at national and international levels to increase the production of renewable energy. Consideration for the species' presence should also be given when installing new power lines, while insulation of pylons should continue. The use of lead-free ammunition should also be encouraged, and current legislation against illegal actions such as shooting, nest robbing or disturbance, and the use of poisoned baits should be enforced and strengthened where such threats still occur. The cumulative effect of toxic chemicals is still being observed in the species (e.g. in Germany) and therefore more consideration should be given to the impacts of hazardous chemicals on the natural environment when undertaking risk assessments for their us[e 1,3,6,15].

Fortunately, recent developments in policy may already be helping to ensure some of these threats will soon be tackled. These include the recent ban in EU countries on using lead ammunition in wetlands, and the national and EU commitments to protect and/or restore large proportions of land [3,17,18].

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Red kite

Milvus milvus

The Red kite (*Milvus milvus*) is a medium-sized bird of prey with a relatively small global population; it is endemic to the Western Palearctic and almost entirely restricted to Europe. The species breeds in broadleaf or coniferous woodlands near open areas such as heathland, farmland or pasture. In winter, it can also be found in treeless habitats, wasteland, scrub and wetlands. Red kites can also visit gardens at the edges of towns. They are mostly scavengers, feeding on carcasses, including of livestock and roadkill, but will also take small to medium-sized mammals, birds (especially nestlings), and sometimes herptiles or invertebrates. They can also be found feeding off residential and slaughterhouse discards[1,3,6,7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Forest, Grassland, Artificial/Terrestrial, Shrubland[1]	Global: Least Concern (2020)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2020)[2] Europe: Increasing (2020)[1]	Global: 78,000* (2021)[3] Europe: 70,300* (2020)[1]	Increasing, +69% 2000–2016**	Increasing, +23% (1980s–2010s)[4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Red kite's current range spans from the United Kingdom and Sweden in the north, through Latvia to Russia in the east, down to the Balkan Peninsula in the southeast and through to the Iberian Peninsula in the southwest (Figure 1b). Outside of Europe, it is only found breeding in a small relict population in Morocco[3,6,7].

The distribution of the Red kite before the 20th century used to be much larger than its current one. Red kites suffered severe declines in the 19th and early 20th centuries, mainly due to intensive persecution, resulting in a restricted and highly fragmented distribution. By the end of the 19th century, they had become extinct in Norway and Denmark and had disappeared from their wintering grounds in Turkey. In the 1960s, the intensification of agriculture and reduction of livestock also added pressure on the Red kite population, and the species declined globally until the 1970s, including completely disappearing from Hungary. After the 1970s, some populations started recovering, the overall trend stabilised, and the species started to recolonise parts of its range, including Denmark and Belgium, expanding north into Latvia and Lithuania in the 1980s and returning to Hungary in 1990. Nevertheless, severe range contractions continued in Spain and Portugal, as well as in central and eastern Europe (e.g. Slovakia and Italy)[1,3,6,7].

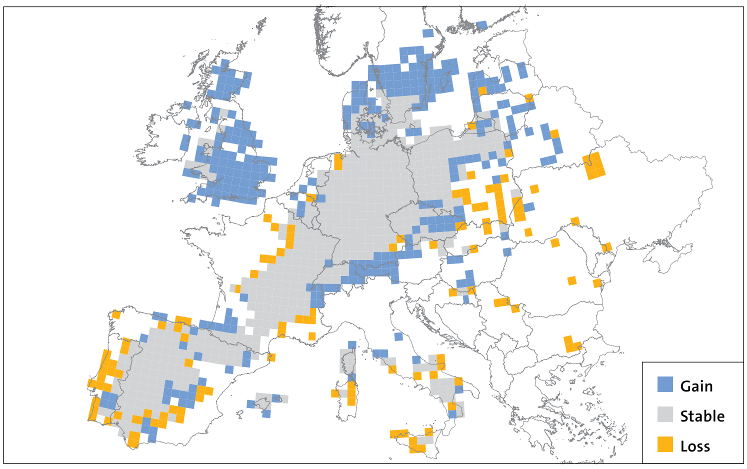


Figure 1a. Change in range of the Red kite between the 1980s[8] and 2010s[5] as per the EBBA2.

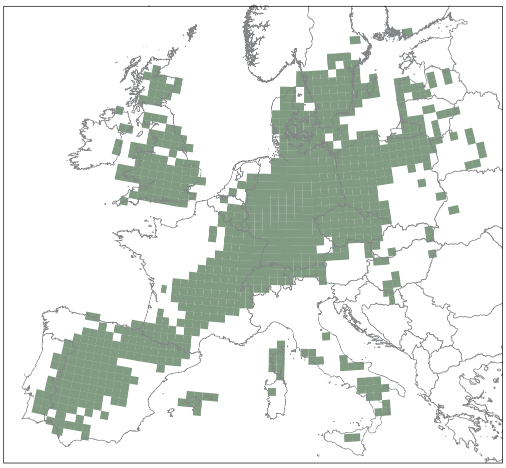


Figure 1b. Current distribution of the Red kite across Europe (2010s)[5].

JUAN CARLOS MUÑOZ / WILD WONDERS OF EUROPE

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

After a period of stability and slight improvement in the 1980s, the Red kite started to decline again at the start of the 1990s, especially in its strongholds (in Germany, France and Spain). This was due to accidental and deliberate poisoning from pesticides and persecution, as well as to habitat loss from land use changes and agricultural intensification. These declines continued until the early 2000s but were, to some extent, offset by increases occurring in countries such as the United Kingdom, Sweden, Poland and Switzerland. Nonetheless, the remaining distribution was highly fragmented and discontinuous, which led to a Red kite population decline of almost 20% between 1990 and 2000 in Europe[3,6,7].

Since then, however, the Red kite has made a spectacular comeback. Recent declines in a few countries have been compensated for by increases in most. The largest population in Europe, in Germany, has stabilised, while the United Kingdom's population has continuously and significantly increased in recent decades, reaching approximately 4,400 pairs in 2016, an increase of about 400% from 2008[1,6].

Large increases have also been seen in other countries, e.g. in Sweden and Poland, with rates of increase reaching 70% in 2007–2018 and 84% in 2008–2018, respectively. In Switzerland, the population has been increasing since the 1990s. Conversely, in France, the population decreased by a quarter between 1998 and 2011, although the current trend appears to be increasing and recovering; in Spain, the trend has stabilised after a continued decline until at least 2014. Successful reintroductions have increased populations in Italy, and the trend in the country overall is increasing. Smaller populations, such as in Belgium or Denmark have also experienced impressive recoveries[1,3,6].

The current population of Red kites in Europe is estimated at approximately 35,000 pairs, and accounts for more than 99% of the species' global population. Overall in Europe, the population of Red kites has been increasing at a rate that itself has been going up, with the species estimated to have increased by approximately 40% between 2008 and 2018 (Figure 2)[1,3].

There has been a shift in distribution towards central and northern Europe (Figure 1a), and individuals are wintering in their northern European breeding grounds more frequently or moving only depending on resource availability. This has led to an increase of the population size wintering outside of Spain, which could be reducing occurrences of poisoning during this season and partially contributing to the increases in countries where the species is currently resident[3,6,7].

* *Mature individuals.*

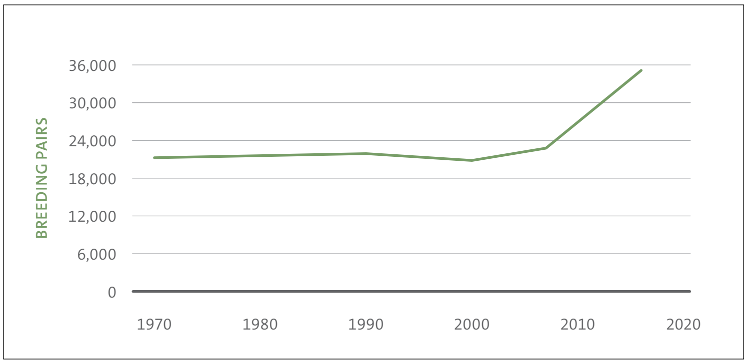
** *Change calculated using the minimum population size estimated as start year.*

Although legal protection and targeted conservation efforts have been instrumental in enabling the successful and ongoing recovery of the species, poisoning remains the greatest threat, particularly in southern Spain and France. Local declines are still being observed, not only in these countries, but also in Portugal and Germany [6,7].

DRIVERS OF RECOVERY

Red kites have benefitted from legal protection, monitoring and targeted conservation actions, including awareness raising, across most of their distribution. An EU species Action Plan for the Red kite was published in 2009 and National Action Plans are in place in several countries. A highly successful reintroduction project has been ongoing in the United Kingdom since 1989, and more recently similar successful projects have started in other countries, such as Italy and Ireland. The latter recorded a first breeding attempt in 2009, and the number of breeding pairs in the country reached 63 in 2018. Research and monitoring also plays an important role, with ongoing research in Germany on the impact of wind farms on the species, and radio and satellite tagging in Spain, Switzerland, and France [1,3,6,7,9].

Figure 2. Estimated number of Red kite breeding pairs in Europe [1,9–12].



Internationally, the species is legally protected through the EU Birds Directive, CITES, Bern Convention and the Convention on Migratory Species. These have all now been in place for some decades, helping to explain the long-term increase in this species' population.

BENEFITS OF COMEBACK

Red kites are mainly scavengers, and therefore they participate in the disposal of carrion, a role in the ecosystem which is particularly important [14], especially where other scavengers such as vultures may not be present. This disposal of carrion may limit the spread of diseases within an ecosystem, but also to domestic animals and humans. The increase of the species in the landscape also increases this impact and can help save resources that might otherwise have to be invested to replicate this service.

In addition, being an easily recognisable species, as it becomes more common and well known in Europe, it may help raise awareness and popularity for birds of prey generally, restoring some of the connectedness people feel with the natural world. The Red kite's protection from persecution could also benefit other raptor species within its range, especially where it involves measures to reduce poisoning.

OUTLOOK

Despite declines in many countries extending into the 21st century, the Red kite has made a spectacular comeback in Europe thanks to all the conservation efforts made to enable its recovery. It is likely that carrying capacity within its range still exceeds its present numbers and therefore its population can be expected to keep growing.

Threats to this species still exist however, with the main one being poisoning. As facultative scavengers, Red kites are particularly affected by the illegal use of poison to control foxes, wolves, corvids, etc., but also by secondary poisoning from pesticides and the consumption of poisoned rodents. Rodenticides are used to control vole outbreaks in agricultural areas and scavengers feed on the poisoned carcasses. This is a major ongoing threat for Red kites (and other birds of prey), particularly in Spain and France, where the migratory populations winter, but also in Portugal and Germany. In Spain, it has been estimated that between 430 and 1,800 individuals are illegally killed annually. Illegal killing (mainly through poisoning but also shooting) is also a serious threat in the United Kingdom, especially in Scotland where it has been demonstrated to hamper the population's recovery [1,6,7,15].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix III) • CMS (Appendix II) • Raptors MoU (Annex I)
Global threats	• Annual & perennial non-timber crops • Livestock farming & ranching • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Agricultural & forestry effluents [2]
European threats	• Annual & perennial non-timber crops • Livestock farming & ranching • Renewable energy • Roads & railroads • Hunting & trapping terrestrial animals • Logging & wood harvesting • Utility & service lines • Problematic native species/diseases • Agricultural & forestry effluents [1,13]

Additionally, the species is also affected by declines in food availability due to a reduction in grazing livestock and loss of breeding and foraging habitat. The main reason is agricultural intensification, which results in chemical pollution, homogenization of landscapes and ecological impoverishment, which in turn also leads to further reduction in food availability for the species. Collision with wind turbines is emerging as another serious threat to the species, adding to other threats such as electrocution from power lines, hunting, trapping and nest robbing, traffic collisions and deforestation [1,6].

Another possible emerging threat for this species is poisoning from the use of veterinary Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), such as Diclofenac which has been authorised for use in some European countries in the past decade. These drugs have had devastating effects on other scavenger species elsewhere in the world, particularly affecting vulture populations in Asia, and their increased use has the potential to greatly impact scavenger species in Europe. Indeed, Diclofenac could directly contribute to declines in Red kite populations [16,17].

Therefore, in order for the Red kite to continue its successful recovery, it is essential to tackle these threats, as well as to continue existing conservation efforts (such as monitoring and reintroduction projects). This includes reducing and regulating the use of pesticides and rodenticides, increasing the enforcement of protection laws to reduce persecution, and increasing awareness campaigns and engagement with stakeholders such as farmers and landowners. Research should continue on the impact of changing land-use practices, while more woodland areas need to be protected. National and international agricultural policies also need to be changed, if further habitat loss is to be avoided. This would also be hugely beneficial to many other species in the region. The continued management of habitats for the Red kite, such as maintaining low intensity managed grassland, should be ensured. It is also important that national legislation and policies relating to livestock farming and animal by-products consider their impact on scavengers, both through ensuring sufficient food availability and through the use of alternatives to potentially dangerous veterinary NSAIDs [1,6,7,16].

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Lesser kestrel

Falco naumanni

The Lesser kestrel (*Falco naumanni*) is a small migratory bird of prey, found all the way from Spain in the west through the Mediterranean region to central Asia and southern Russia, Mongolia, and northern China. It typically congregates at roosting sites in the pre-migratory period, and travels in flocks during migration, often with other falcon species. It winters mainly in sub-Saharan Africa, although some populations only migrate to southern Europe or northern Africa. As a colonial breeder, the Lesser kestrel naturally nests in cavities in cliffs, clay banks or sometimes in old corvid nests, but is often found in or near human settlements, making use of hollows or caves in walls and roofs of old buildings, ruins, stone heaps or quarries. Lesser kestrels forage in open areas, particularly in lowland steppe-like habitat, grassland and extensively farmed land. They prey on a variety of insect species, as well as small vertebrates on occasion, including small birds, mammals and reptiles [1,6,7].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Savanna, Grassland, Rocky areas (e.g. inland cliffs, mountain peaks), Desert, Artificial/ Terrestrial [1]	Global: Least Concern (2021) [2] Europe: Least Concern (2020) [1]	Global: Stable (2021) [2] Europe: Stable (2020) [1,3]	Global: 103,500* (2021) [2] Europe: 64,800* (2020) [1,3]	Increasing, +248% 1990–2018**	Decreasing, -25% (1980s–2010s) [4,5]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Lesser kestrel used to be one of the most abundant birds of prey in the Western Palearctic, its range extending up to approximately 55°N. However, during the second half of the 20th century, it suffered severe declines throughout Europe. This was primarily due to habitat loss and degradation caused by land-use changes, particularly land abandonment, urbanisation, afforestation and agricultural intensification, often driven by European policies, that together led to a reduction in both their prey base and nesting opportunities. In particular, the use of pesticides, especially DDT during 1940s–1970s, caused a drastic reduction in prey and an increase in poisoning of the species [1,6,7].

The western European population almost halved every ten years from 1950 onwards, while rapid declines were observed in wintering populations in South Africa, beginning in the 1970s. The species also disappeared from the Russian Urals and the western and central parts of the Balkan Peninsula, while there was range contraction in most parts of Europe. In total, the population size of the Lesser kestrel declined by 95% between the 1960s and first half of the 1990s [1,6,7].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

From the mid-1990s onwards, due to targeted and intense conservation efforts, such as the provision of artificial nests and the restoration of breeding colonies, the Lesser kestrel population in the southwest of Europe increased substantially, especially in Spain and Italy. However, this recovery was not reflected over the whole of Europe, with the species becoming extinct in Austria, Hungary, Poland, Czechia, Slovenia, Croatia and Bulgaria by the start of the 21st century, leading to a further contraction of its range [5–7]. Currently, the Lesser kestrel population is considered stable. Although it now has a predominantly Mediterranean distribution, it is recovering some of its former range in countries such as Croatia, Bulgaria, European Russia, Portugal, Italy and France, indicating potential for further expansion in the future [1,7]. Nonetheless, despite ongoing conservation efforts, recent studies show rapidly declining population numbers in Spain [3], one of the species' strongholds in Europe. This trend, observed since the start of the 21st century and considered to be due to agricultural intensification, may impact the overall European species'

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Appendix II) • CMS (Appendices I and II) • Raptors MoU (Annex I)
Global threats	• Housing & urban areas • Annual & perennial non-timber crops • Livestock farming & ranching • Renewable energy • Utility & service lines • Hunting & trapping terrestrial animals • Other ecosystem modifications • Agricultural & forestry effluents • Droughts • Temperature extremes [2]
European threats	• Housing & urban areas • Annual & perennial non-timber crops • Livestock farming & ranching • Utility & service lines • Agricultural & forestry effluents • Droughts [1,14]

population status in the future.

DRIVERS OF RECOVERY

Since the 1980s, the restoration and management of Lesser kestrel breeding colonies (including the introduction of protection measures (from disturbance as well as destruction), the provision of artificial nests, breeding schemes and the release of captive-bred birds into existing populations) have helped secure and reinforce local populations, with notable success in in southwestern Europe. Reintroduction projects, like that occurring in Bulgaria, can also help restore the species' historical range [6,7].

In order to guide conservation efforts for the species, a European Action Plan has been published in 2010 [12]. Research and management of the species, its sites and habitats have been carried out in France, Spain, Portugal, Gibraltar, Italy, Greece and Bulgaria. In addition, new measures are being tested to counteract recently emerged threats, e.g. tilling the soil around the base of wind turbines to reduce the risk of collisions [1,6].

Unfortunately, despite the Lesser kestrel being legally protected across Europe, the level of enforcement and on-the-ground protection varies between countries and needs to be improved. Awareness raising and education are key to prevent the destruction of nesting sites, particularly from the neglect, careless refurbishment or demolition of buildings [6,7].

In addition, despite conservation efforts having driven an increase in this species since the 1980s, the lack of suitable foraging habitat remains as a limiting factor for population growth and expansion. The species is most successful when it has a diversity and abundance of prey, with colonies or roosting sites located near suitable foraging habitats. Agricultural and forestry policies are pivotal for the availability of suitable habitat and prey for Lesser kestrels, and measures such as low pesticide and herbicide use, rotational cereal cultivation practices and traditional low-intensity pastoral systems have the potential to make a big positive difference. For example, in Castro Verde, in Portugal, a local ban on afforestation combined with the use of agri-environmental schemes has secured the persistence of the largest population of Lesser kestrels in the country [6,7].

BENEFITS OF COMEBACK

Lesser kestrels are mainly insectivorous, being preyed upon themselves by reptiles, mammals, birds of prey and corvids [15]. Considering the continued decline in insect populations [16], this species could potentially serve as an indicator of higher concentrations of insects and perhaps healthier ecosystems.

OUTLOOK

From its steep declines in the second half of the 20th century, this species has experienced a significant comeback in the past four decades. However, its range has contracted over the same period, and its population is no longer growing significantly. In addition, if the causes of localised declines are not remedied, the continuation of the sharp declines seen in Spain may lead to a decreasing trend in Europe. There is some hope for the future though, as conservation actions continue and some, mainly small, populations are increasing, suggesting range

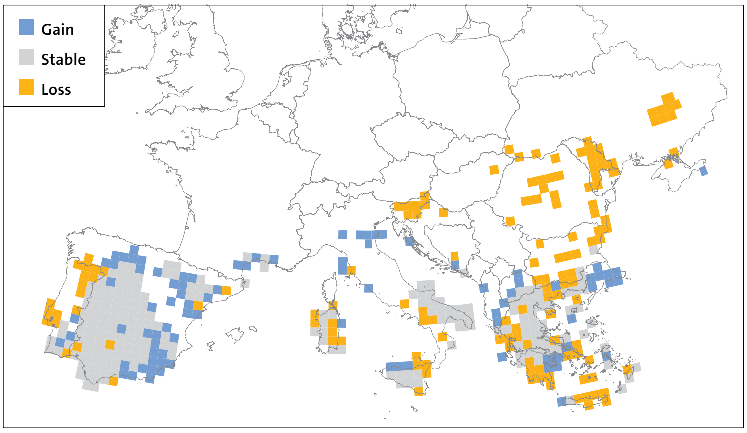

Figure 1a. Change in range of the Lesser kestrel between the 1980s [8] and 2010s [5] as per the EBBA2.

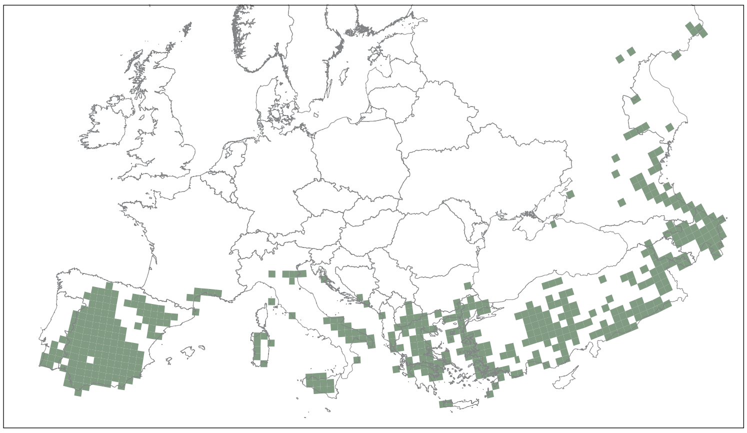

Figure 1b. Current distribution of the Lesser kestrel across Europe (2010s) [5].

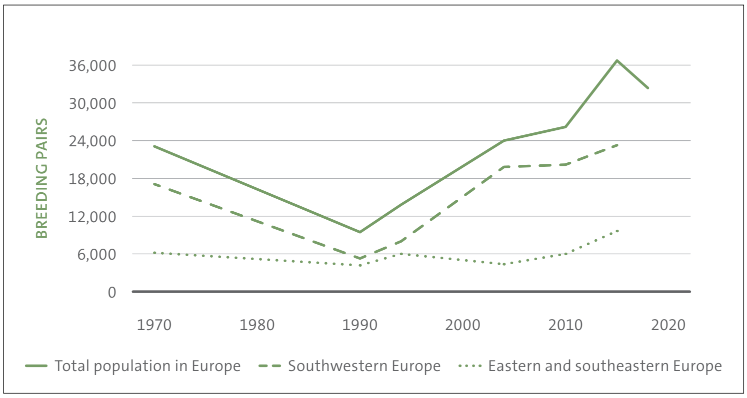

Figure 2. Estimated number of Lesser kestrel breeding pairs in Europe, and separately in southwestern Europe, and eastern and southeastern Europe [1,3,9–13]

expansion is possible in the future [1,5]. This can only happen, however, if current threats continue to be tackled at a greater scale.

The main cause of the Lesser kestrel's decline – habitat loss and degradation – is still ongoing. The cause is land use change, mainly driven by European agricultural and forestry policies, resulting in abandonment of extensively grazed grasslands and extensive dry cereal cultivation, or their conversion to intensive agriculture, afforestation or urbanisation. This diminishes the amount and diversity of prey available to the species during both breeding and non-breeding seasons. The application of pesticides on intensive farmland further exacerbates the reduction of prey, which during the breeding season can result in chick starvation, or direct poisoning of the parents, and to reduced juvenile survival in wintering and staging areas. Decreasing nest site availability is still an issue, which limits the potential for future population growth. Indeed, in some areas, nests are deliberately destroyed due to sanitary concerns or noise conflicts. Collision with power cables or wind turbines may pose an additional threat [3,6,7,17].

Adding to this, the weather can influence population dynamics, especially in the wintering grounds, where low rainfall can decrease locust population explosions and hence lower prey availability for Lesser kestrels. In the breeding season, higher chick mortality has been observed during periods of unusually high temperatures. It is therefore expected that climate change will increase the pressure on Lesser kestrel populations [6,7].

Overall, the promotion of biodiversity-friendly agricultural and forestry policies, the use of agri-environmental schemes, habitat management and the limitation of pesticides all remain key for the recovery of the Lesser kestrel population in Europe and recolonisation of its former range. Existing legislation needs to be further implemented into national urbanisation policies and adequately enforced. National Action Plans are needed to guide the creation of suitable policies and conservation actions [6,7].

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BIOSPHOTO / ALAMY STOCK PHOTO

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SAKER FALCON

Falco cherrug

The Saker falcon (*Falco cherrug*) is a large, partially migratory bird of prey, occurring widely across the Palearctic, from central Europe to western China, where it prefers open grassy landscapes such as steppe habitats or shrublands. Saker falcons reuse old nests of other birds such as those of eagles, hawks or corvids, located usually in single trees, woodlands, cliffs or, increasingly, on electricity pylons. They mate for life, and pairs tend to stay together even outside of the breeding season. Adults are mostly resident, although some birds from central Europe migrate towards the Mediterranean in the autumn; juveniles are more migratory, with individuals from the European population reaching Egypt, Libya or even Niger. The Saker falcon has a very agile flight and is capable of rapid acceleration, which enables it to hunt close to the ground. It preys on medium-sized rodents such as sousliks (*Spermophilus* spp.) or, if rodents are unavailable, on birds, particularly the Domestic pigeon (*Columba livia domestica*)[1,2,5–10].

HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Shrubland, Grassland, Wetlands (inland), Artificial/Terrestrial, Marine Intertidal[1]	Global: Endangered (2021)[2] Europe: Endangered (2020)[1]	Global: Decreasing (2021)[2] Europe: Decreasing (2020)[1]	Global: 19,070* (2021)[2] Europe: 1,100* (2020)[1]	Increasing, +90% 1990–2020**	Decreasing, -18% 1980s–2010s[3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

Although reliable data are not available before the 1980s, enough is known to deduce that, before the 19th century, the Saker falcon used to be much more widespread across the central and south-eastern parts of Europe. From the mid-1900s onwards, the species experienced significant declines across the whole of its European range. These were mainly the result of persecution and habitat loss and degradation (mainly for agriculture). Electrocution, trapping and nest robbing for falconry also had important negative effects, especially on already declining populations, even causing local extinctions. As a result, the species' distribution has become fragmented, especially in south-east Europe. For example, in Bulgaria, Saker falcons used to be common and widespread before the 1930s, but the species' range has contracted since 1945. In Ukraine, the population suffered significant declines since the 1950s and dropped to only 30–40 pairs in both Ukraine and Hungary by 1980. In Austria, by the 1970s, the species was on the brink of extinction[1,5,6].

RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

In the late 20th century, populations underwent shifts in their distribution within the European region (Figure 1b), due to changing land use and habitats. Indeed, habitat change has been a key driver for shifts in the species' demography and distribution, mainly due to its effect on the population sizes and distribution of its prey species (i.e. sousliks). In particular,

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix II) • Bern Convention (Annex II) • CMS (Appendices I and II) • Raptors MoU (Annex II)
Global threats	• Housing & urban areas • Annual & perennial non-timber crops • Wood & pulp plantations • Utility & service lines • Hunting & trapping terrestrial animals • Dams & water management/use • Other ecosystem modifications • Agricultural & forestry effluents • Other threat [2]
European threats	• Housing & urban areas • Annual & perennial non-timber crops • Wood & pulp plantations • Livestock farming & ranching • Utility & service lines • Hunting & trapping terrestrial animals • Dams & water management/use • Agricultural & forestry effluents • Habitat shifting & alteration [1,18]

the abandonment of pastoralism in the foothills and mountains within its range, following the end of the communist regime, had a major negative effect on these prey species. This caused Saker falcon territories in these areas to be abandoned in favour of lowland agricultural habitats, where the species has expanded, occupying (or more likely re-occupying) new areas, particularly in central Europe. In eastern Europe, Saker falcons declined in the forest steppe, but they persisted and possibly increased in the southern steppe [1,6,9,11].

From the 1980s onwards, due to conservation efforts, the species' population in Europe stabilised and started to recover. This recovery was mainly driven by large increases in Hungary, Slovakia and Austria, which hold most of the population around the Carpathian Basin (Figure 2), and it is from this area that the Saker falcon has expanded to other countries (Figure 1a). In Ukraine, the population had stabilised, but has recently declined again, and the population in Bulgaria is considered close to extinction [6].

In recent years, the Saker falcon's populations are no longer experiencing the growth seen at the end of the 20th and start of the 21st centuries. This is partially due to localised declines, such as those seen in Ukraine, previously one of its main strongholds in Europe, and Czechia. However, this slowdown is also due to the previous rapid increases of the recovering population, which have recently stabilised in Hungary and Slovakia. The national populations in these countries seem to have reached current carrying capacities, supporting 164 and 36 pairs respectively in 2020.

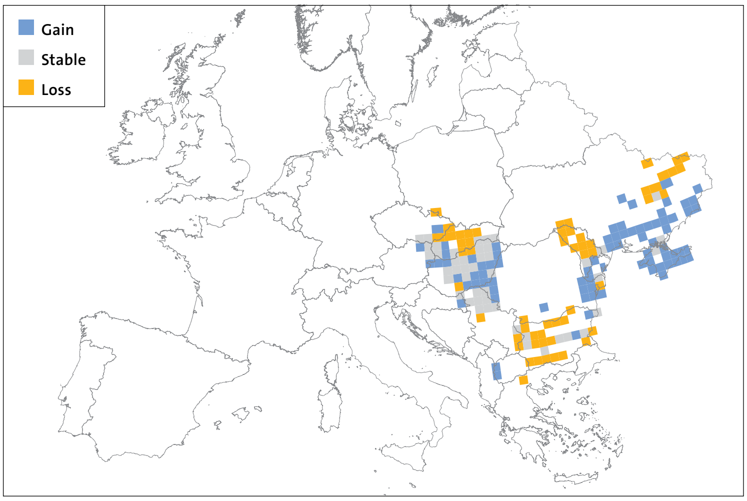

Figure 1a. Change in range of the Saker falcon between the 1980s [13] and 2010s [4] as per the EBBA2.

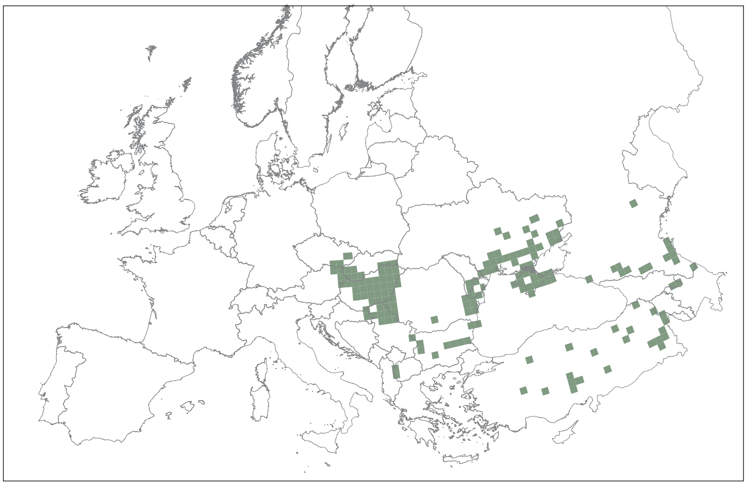

Figure 1b. Current distribution of the Saker falcon across Europe (2010s) [4].

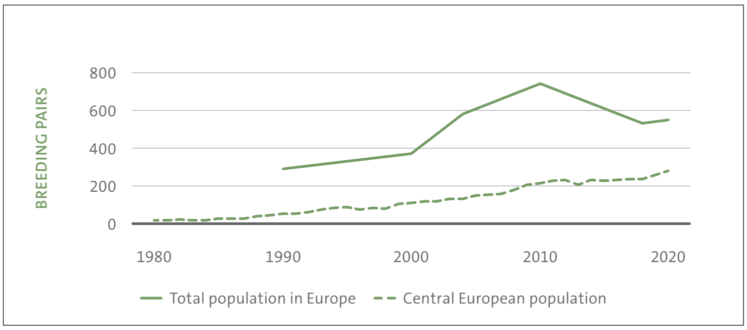

Figure 2. Estimated number of Saker falcon breeding pairs in Europe [1,6,12,14–17].

The population in European Russia, which was considered to have been extirpated by the start of the 21st century, is now known to be extant, although it is considered to be declining. Improved knowledge and changes to country borders have contributed to this change [1,4,6,11].

Although there are knowledge gaps concerning population sizes in the eastern part of its European range, the Saker falcon population is currently estimated at 550 pairs in Europe [1,12].

DRIVERS OF RECOVERY

A lot of work has been done to conserve this species in the region, particularly in central Europe, with significant success. The Saker falcon has shown evidence of recovery, particularly in the Carpathian Basin, as a direct result of active conservation efforts, legal protection and illegal trade controls (implemented in the 1990s). In 2011, a Saker Falcon Task Force was established, which resulted in the production of a Global Action Plan in 2014, and this continues to help guide and coordinate Saker falcon conservation efforts. Conservation measures have included ensuring safe breeding sites through *in situ* nest protection, particularly in the 1980s, as well as the provision of artificial nests, which has played a key role in the recovery of populations, particularly in central Europe. Other measures have included the insulation of power lines to prevent electrocution, ensuring enough food is available through habitat management (e.g. through agri-environment schemes) and population management of key prey species, and communication with key stakeholders and awareness raising [5,6,8,11].

Population management and reintroductions have also contributed to the recovery of the species in some countries. In Hungary, for example, intensive protection and management have produced a rise in the population size, and in Bulgaria, a captive-breeding and release programme to restore the extirpated population is ongoing, with the first recent breeding of the species in the wild being confirmed in 2018 [1,5,19]. The reintroduction of sousliks in some areas is also likely to have benefitted the species. In addition, new research programmes in many parts of the species' range have begun to establish more baseline data to inform the actions listed above. In 2015, an information portal and online survey was launched to continuously gather data on the species, which should also help raise awareness about it [1,5,20].

The combination of all these efforts in Europe have had positive results and have been essential to the Saker falcon's conservation. In the meantime, Saker falcons are adapting to their changing habitats. increasingly they are using nests located on electricity pylons, and thus finding new places to nest where possibilities were previously limited. In Hungary, intensive agricultural areas currently hold some of the highest breeding pair densities, and over 90% of the population uses artificial next boxes, indicating that the species can utilise such habitats given adequate prey and nest site availability. Many nests in central and eastern Europe are now located in such nest boxes on electricity pylons. In addition, currently most of the European population mainly preys on avian species, thus eliminating its historical dependence on sousliks and other small mammals [5–7,9,11].

BENEFITS OF COMEBACK

Saker falcons may contribute to the top-down control of populations of their main prey species, e.g. medium-sized rodents. As apex predators they can also act as an indicator species, as their breeding success can be directly linked to the population size of their prey species. However, this relationship has been thrown out of balance as many souslik species are in decline, especially the European souslik (*Spermophilus citellus*) which was categorised as Endangered on the IUCN Red List in 2019 [9,11].

Nevertheless, the successful conservation of the Saker falcon, and particularly related measures which aim to restore populations of its small mammal prey species or protect its natural habitats, could potentially benefit the conservation of threatened sousliks in the long term. In addition, the European range of the Eastern imperial eagle (*Aquila heliaca*) overlaps with that of the Saker falcon, and as its diet also used to include sousliks - the conservation and management of habitat for each of these species can benefit the other.

The Saker falcon is also valued culturally. It is the national bird species of Hungary, where it has cultural importance as an agent in Magyar mytholog[y 6].

OUTLOOK

The Saker falcon has made a good comeback at the end of the 20th and start of the 21st centuries, due to intense conservation efforts. Despite this, its current distribution is still fragile and fragmented, and is still declining in eastern Europe [1,11].

Although it has shown adaptability to change, the main issues the species faces today are nesting and foraging habitat loss due to land-use change, and deaths from energy infrastructure. In some areas, the population is still affected by the loss of steppes and dry grasslands to agricultural intensification, the establishment of tree plantations, or the abandonment of traditional pastureland and sheep pastoralism. It is also likely that the amount of nest site availability limits Saker falcon populations, as a result of the removal of trees in agricultural areas, but also of old nest destruction [1,5,7].

Electrocution from power lines is a big contributor to this species' decline. Moreover, the development of wind farms in Romania has led to the destruction of Saker falcon nests. Although persecution and nest robbing are not as prevalent as they were in the past, and now only occur rarely, persecution is still a critical threat. This is usually from deliberate shooting/poisoning by pigeon keepers, as well as from unintentional poisoning through agriculture or hunting activities (e.g. rodenticides, poisoned baits, lead ammunition), which still occurs in some areas (indeed the use of poisoned bait has increased in the Carpathian Basin in the past decades), all contributing to the decline of an already pressured population [1,5–7,11,21].

In addition, the Saker falcon population in eastern Europe is still affected by the decline in small rodent prey availability, particularly that of sousliks. Although the reasons behind the declines of these ground squirrels in the region are not yet known, it has been suggested that their populations could be affected by climate change [11]. However, Saker falcons are finding alternative avian prey species (particularly in central Europe), and so, the impact on the species may not be critical in the long-term.

For the Saker falcon to continue its comeback, existing conservation measures will have to be sustained and indeed extended, to ensure there is scope for further recovery and recolonisation. A more holistic approach, considering other species and wider ecosystems, would likely increase the chances of success. The presence of suitable and safe nesting and foraging habitats remains a critical factor, and therefore the continued and increased management and protection of these sites is especially crucial. Increasing awareness and ensuring the review, implementation and enforcement of legal protection, policies and trade regulations of the species is also vital, as is the continued study of this species to understand key threats and their impact on its population [1,5,6].

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PEREGRINE FALCON

Falco peregrinus

The Peregrine falcon (*Falco peregrinus*) is a partially migratory raptor, and one of the most widespread in the world , occupying all continents except Antarctica. It tolerates wet and dry, hot and cool climates, and uses a diverse array of habitats. These mainly comprise cliffs, rocky areas, grassland or agricultural land, but also temperate forests, wetlands and other inland waters and coastal habitats, as well as some urban habitats. Peregrine falcons prey almost exclusively on birds, especially pigeons and doves (*Columbidae* spp.)[1,5,6].

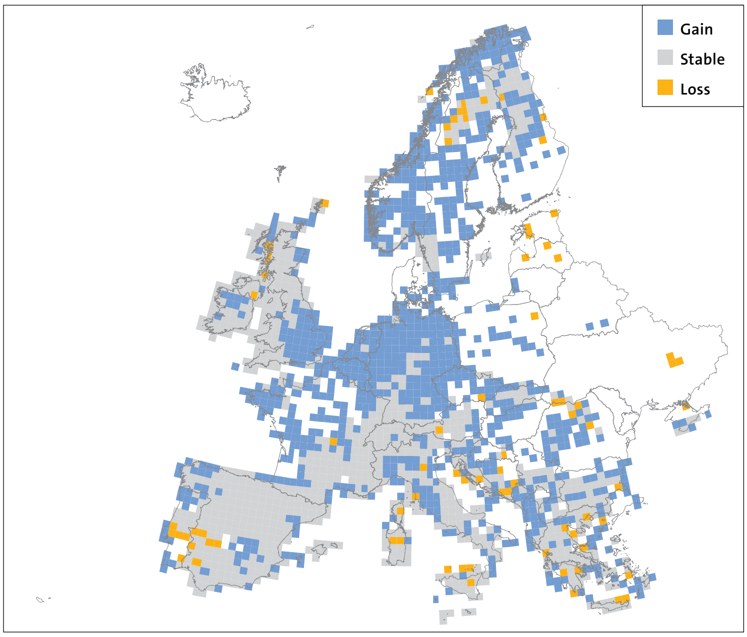
HABITAT	RED LIST STATUS	RED LIST POPULATION TREND	POPULATION SIZE	CHANGES IN POPULATION SIZE	CHANGES IN DISTRIBUTION
Forest, Savanna, Shrubland, Grassland, Wetlands (inland), Rocky areas (eg. inland cliffs, mountain peaks), Desert, Marine Intertidal, Marine Coastal/Supratidal, Artificial/Terrestrial[1]	Global: Least Concern (2021)[2] Europe: Least Concern (2020)[1]	Global: Increasing (2021)[2] Europe: Increasing (2020)[1]	Global: 344,300* (2021)[2] Europe: 41,300* (2020)[1]	Increasing, +261% 1970–2017**	Increasing, +88%, 1980s–2010s[3,4]

HISTORICAL DISTRIBUTION AND ABUNDANCE

The Peregrine falcon occurs all over Europe (with the main exception of Island) (Figure 1b), with its range extending between the tundra in the north and the Iberian Peninsula in the south-west, and between the Mediterranean coast, the Balkans and the Caucasus in the south, to Greenland in the west and the Russian Urals in the east[1,6].

Historically, Peregrine falcon populations in Europe were stable, but serious declines occurred in the 1960s and 1970s, due to harmful organochlorine-based pesticides used in agriculture (e.g. DDT). These chemicals, accumulated in their prey species, were ingested by Peregrine falcons and became concentrated in their bodies (biomagnification) resulting in reduced breeding success, as adult and embryo mortality and eggshell breakage increased[5,6]. Illegal nest robbing and persecution, driven mainly by conflicts with gamekeepers or with pigeon fanciers, as well as being illegally shot for recreational purposes, also added more pressure to the already declining species' population. As a result, the species disappeared from many areas in the region, particularly in central and eastern Europe, including the tree-nesting population in Germany and Poland, which decreased from c. 4,000 pairs to none, prior to recent conservation efforts. It also suffered very high declines in northern and western parts of the continent , disappearing from large areas of France and Scandinavia[4,6].

Figure 1a. Change in range of the Peregrine falcon between the 1980s[9] and 2010s[4] as per the EBBA2.



RECENT CHANGES IN ABUNDANCE AND DISTRIBUTION

After a period of decline, following the introduction of national bans on organochlorine-based pesticides, improved protection from persecution and

* *Mature individuals.*

** *Change calculated using the minimum population size estimated as start year.*

nest robbing, and extensive reintroduction efforts, the Peregrine falcon has recovered worldwide. By the mid-1980s, its population in many parts of Europe had reached pre-decline levels and has increased even more since then (Figure 2)[6].

The Peregrine falcon's population size in Europe has continued to gradually rise thanks to long-term conservation actions targeted at reducing pollution and persecution. Recolonisation has occurred in numerous areas across Europe and elsewhere (Figure 1a), and Peregrine falcons are increasingly expanding into new habitats, including cities and other urban areas. In Hungary, Peregrine falcons have started to occupy nest boxes installed on power line pylons originally intended to support the endangered Saker falcon (*Falco cherrug*) population. The competition over nesting sites may however pose a threat to the local Saker falcon population, 90% of which now breed in such nest boxes. In central and eastern Europe, the European Peregrine Falcon Working Group was formed and efforts to restore the species' contracted range are underway. After a successful reintroduction programme, the tree-nesting population in Eastern Germany has been re-established, increasing from 37 pairs in 2011 to 64 pairs in 2017[5–8]. The current Peregrine falcon population in Europe is estimated at around 20,600 pairs[1].

DRIVERS OF RECOVERY

The ban on the use of organochlorines in agriculture and increased legal protection have significantly helped Peregrine falcons recover in Europe. Reintroduction efforts have enabled the recolonisation of lost sites in countries such as Austria, Czechia, Germany, Hungary, Slovakia, Switzerland, Sweden, and Poland, as well as the colonisation of Moscow by reintroduced birds[6].

The size of many Peregrine falcon populations in Europe is now higher than it was before the organochlorine crisis, and the species is expanding its range in both natural and urban environments. The latter provide suitable breeding habitat and feeding opportunities (e.g. Feral pigeon (*Columba livia domestica*)) and have therefore also contributed to the recovery of the species in Europe[5,6].

Legal tools which have supported these drivers of recovery include the EU Birds Directive, CITES, the Convention on Migratory Species (CMS) and the Bern Convention. They have all been in place for some decades, helping the recovery of the species.

However, Peregrine falcons still face numerous threats, such as persecution (mostly by pigeon fanciers), disturbance, electrocution, or collisions with energy infrastructure and buildings. Gaps

DUNCAN SELBY / ALAMY STOCK PHOTO

still exist in our knowledge about the species, and how to improve the effectiveness of conservation actions. To facilitate such work, the European Peregrine Falcon Working Group was established[1,5,6].

BENEFITS OF COMEBACK

Peregrine falcons contribute to the control of prey species populations, such as that of Feral pigeons, in both rural and urban environments. Given that pigeon excrement is corrosive, and their carcasses may harbour disease, hunting and scavenging by apex predators such as the Peregrine falcon in urban environments may contribute to reducing city maintenance and healthcare costs. In the

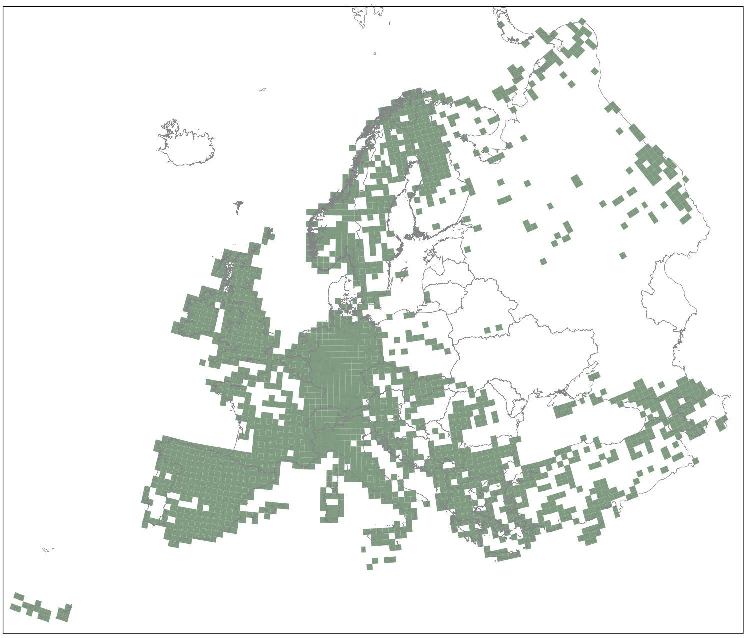


Figure 1b. Current distribution of the Peregrine falcon across Europe (2010s)[4].

THREATS AND PROTECTION	
Legal protection	• EU Birds Directive (Annex I) • CITES (Appendix I) • Bern Convention (Appendix II) • CMS (Appendix II) • Raptors MoU (Annex I)
Global threats	• Livestock farming & ranching • Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Logging & wood harvesting • Recreational activities • Work & other activities • Fire & fire suppression • Industrial & military effluents • Agricultural & forestry effluents • Temperature extremes [2]
European threats	• Renewable energy • Roads & railroads • Utility & service lines • Hunting & trapping terrestrial animals • Recreational activities • Work & other activities • Agricultural & forestry effluents [1,16]

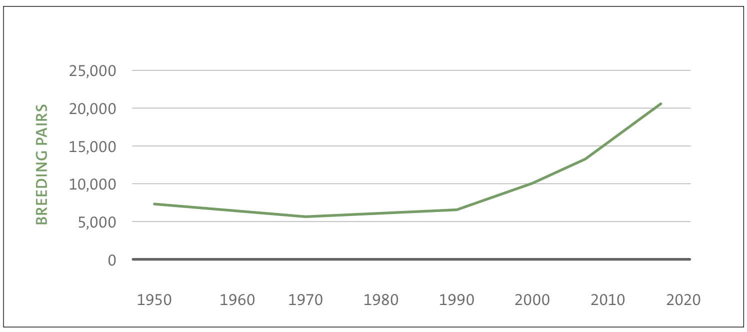
countryside, the Peregrine falcon's presence can help control and have a scaring effect on the population of grain-eating birds (e.g. Woodpigeon (*Columba palumbus*)), considered in some circumstances to be an agricultural pest. In addition, the presence of Peregrine falcons in an ecosystem can deter or suppress more generalist predators (e.g. small mammals, corvids, etc.), thus benefitting less preferred and non-prey species [17,18].

In deterring such predators, Peregrine falcons may in turn benefit other conservation efforts, and, as a charismatic flagship species, they may also have some socio-economic benefits by attracting tourists and bird watchers.

OUTLOOK

Peregrine falcon populations in Europe have made an impressive recovery since the 1980s and continued growth in their range and numbers is expected in the future, as well as continued expansion into urban environments. Nevertheless, the forest-nesting population in central and eastern Europe is still very small and further conservation action, in the form of continued reintroductions and monitoring, is still very much needed. The maintenance of public goodwill in cities and in the countryside, the upholding of policies and policing against persecution, as well as the implementation of recovery measures and breeding and nesting site protection, should secure the species for many generations to come. In countries such as Switzerland, Peregrine falcons "have only survived and recovered due to conservation efforts" [19], illustrating the need for such actions to be sustained in the long term.

Figure 2. Estimated number of Peregrine falcon breeding pairs in Europe [1,10–15].



Given the wide range of suitable habitats, extensive European and global ranges, and clear adaptability of the species, climate change may be less of an issue for Peregrine falcons in comparison to other bird species. In addition to sustained action against persecution and pesticide control, the tackling of more recent threats would be beneficial to the species. This could include activities specifically aimed at Peregrine falcons, such as awareness raising to prevent unintentional human disturbance, or action aimed at other species which positively affects Peregrine falcons too (e.g. measures to prevent bird electrocutions or collisions with energy cables or wind turbines) [1,5,6].

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BRUNO D'AMICIS/REWILDING EUROPE

Synthesis and outlook

A SYNTHESIS OF THE STATUS AND TRENDS OF RECOVERING EUROPEAN SPECIES

Understanding the mechanisms behind species recoveries is critical to inform broadscale conservation and management actions for the restoration of ecosystems. There are many examples of recoveries among species of birds, mammals and other taxa (e.g. Deinet, *et al.*[1],Tucker, *et al.*[2]; www.conservationoptimism.org). These increases in abundance or distribution have been driven by a variety of factors, including policy and legislative frameworks, species management and conservation activities, as well indirect factors such as shifts in land-use. However, even for recovering species, a variety of pressures remain, acting at different levels on different groups; we need to improve our understanding of these pressures, and how they act to limit the comeback of recovering species.

In this section we synthesise information from the species accounts within this report, to better understand the status of selected recovering birds and mammals in Europe. We explore their changes in abundance and distribution, and investigate the reasons for, and limitations to, the comeback of these species. This will help us understand how to maximise wildlife comeback across Europe, achieve conservation targets, and facilitate the re-establishment of functional ecosystems, facilitating efforts to restore nature at scale. Using a combination of data reported under the EU Birds (Directive 2009/147/EC) and Habitats (Council Directive 92/43/EEC) Directives (together referred to hereafter as the Nature Directives)[3] and from the Living Planet Index Database[4], we also present a quantitative assessment of the impact of pressures and conservation measures on recovering European birds and mammals in this report. Details of how the following data were compiled and analysed are described in the Methods (Appendix 1).

Glossary of terms used in this synthesis (see Methods in Appendix 1 for full details)

Term	Definition referring to mammals and reptiles	Definition referring to birds
"Average change in relative abundance"	The average rate of change among populations for a species from the baseline year (usually 1960) to the most recent year (usually 2016), expressed as a percentage. This refers to relative change among populations of different sizes and is not the absolute change in numbers of individuals.	
"Overall population change"		Percentage change in absolute numbers of birds since the start of recovery. Change was calculated from the minimum population estimate during the time period for which data were available for each species (marking the beginning of population recovery).
"Average annual growth rate" "Annual population change" "Annual population growth rate"	The average rate of change among populations for a species per year. This refers to relative change among populations of different sizes and is not the absolute change in numbers of individuals each year	Average annual percentage change in birds from the beginning of population recovery to recent times (the year of which ranges from 2016 to 2021).
"Range change"	Represents the difference between a species' past range and the present range; calculated using geodesic area in km^2.	Number of comparable 50x50km squares (sq) in which breeding evidence (possible, probable or confirmed) was observed for the species in the 1980s and the 2010s, and the percentage change between these.
"Pressures"	Main pressures from human activity currently affecting mammal populations. This information is from the population data source and has usually been recorded at the local scale.	Main pressures from human activity currently affecting bird species in Europe. Data is from the IUCN European Red List of Birds and Article 12 of the Birds Directive, as well as other sources used in the bird species accounts.
"Reasons for recovery" "Conservation measures"	Main conservation activities that have been reported as driving the recoveries in mammal populations. This information is from the population data source and has usually been recorded at the local scale.	Conservation measures recorded for the relevant bird species used to enable their recovery. Data is from the IUCN European Red List of Birds and Article 12 of the Birds Directive, as well as other sources used in the bird species accounts.

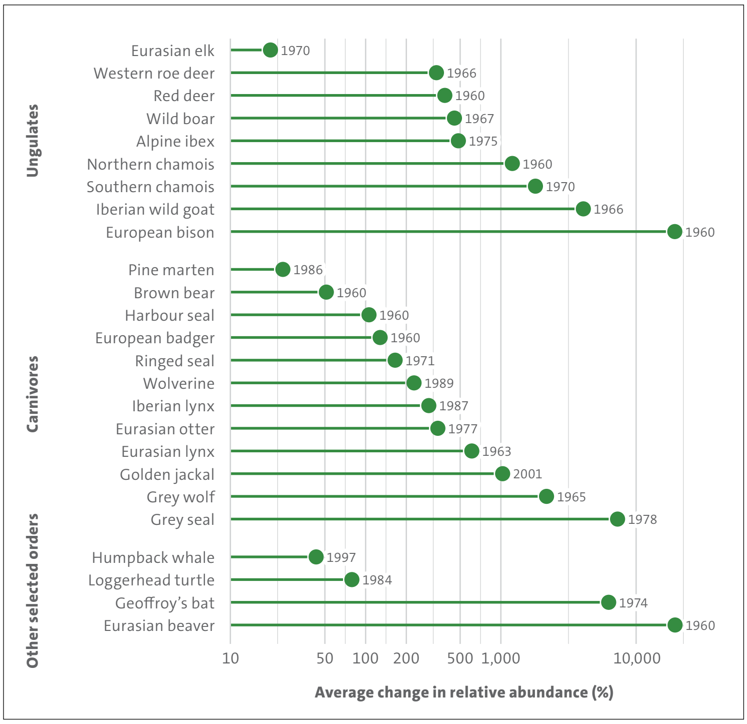

Figure 1. Change in relative abundance over recent monitored period (~1960 to 2016) for the 24 mammal species and one reptile covered in this study. These trends were calculated over the period for which data were available. Calculated trends had an average duration of 43 years starting from 1960 and ending in 2016 in the longest case (dates indicate the start year of calculated trends).

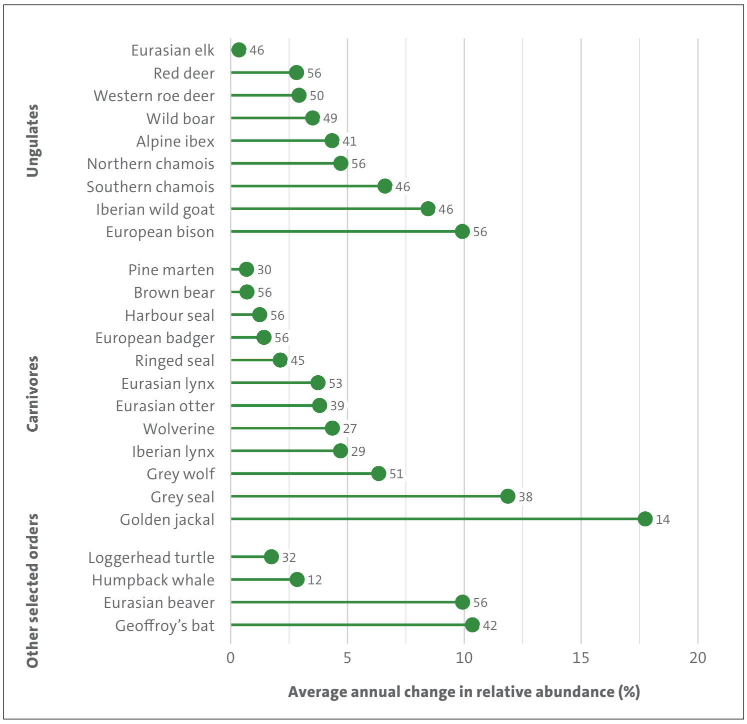

Figure 2. Average annual growth rates for the 24 mammal species and one reptile covered in this study. Annual average growth rates were calculated over the period for which data were available. Calculated indices had an average duration of 43 years, starting from 1960 and ending in 2016 in the longest case (numbers next to points indicate duration in years of the index calculated for that species).

Overview of the species accounts

POPULATION CHANGE

Following the same process as the Wildlife Comeback in Europe 2013 report, in addition to the species previously reported on, we selected species on the basis that they had "all undergone a recovery after a period of serious decline" (Deinet, *et al.*[1]). This resulted in 13 new species (six mammals, six birds and one reptile species) being included, for a total of 50 species for this 2022 study.

Given the basis for their selection, it is not surprising that we continue to see overall positive abundance trends for most of these species (Figure 1). However, we note that some species show recent declines in range size (affecting one mammal and five bird species; see Tables 1 and 2), and some species' populations may currently be declining despite recovery from historical lows (e.g. Audouin's gull (*Larus audouinii*), White-headed duck (*Oxyura leucocephala*), and some Eurasian lynx (*Lynx lynx*) populations). This highlights that caution is needed in assuming the recoveries reported here will continue. It is also worth noting that contractions in range size may occur despite increases in population size, as when well-protected core populations increase while unprotected peripheral populations vanish. There is a high degree of variation in overall and average annual rates of population recovery across species (Figures 1–4). In some cases, this reflects the different monitoring periods from which data are available, but it may also reflect regional differences in species trends and variations in the reproductive strategy and generation length of different species.

MAMMALS AND REPTILES

For the 24 mammals and one reptile included in this report, relative abundance increased by between 17% (Eurasian elk *Alces alces*) and over 16,000% (Eurasian beaver *Castor fiber*) (Figure 1). Herbivore species increased more on average than carnivores but increases across the studied species were greater than the vertebrate average for the wider region[5]. Among the herbivore species, Eurasian beaver and European bison (*Bison bonasus*) showed the largest increases, while Eurasian elk showed the smallest. Among the carnivores, Grey seal (*Halichoerus grypus*) and Grey wolf (*Canis lupus*) showed the largest increases, while Pine marten (*Martes martes*) and Brown bear (*Ursus arctos*) showed the smallest. Humpback whale (*Megaptera novaeangliae*) and Loggerhead turtle (*Caretta caretta*) also showed small increases. Similar patterns are seen in average annual growth rates (Figure 2), but we note that Golden jackal (*Canis aureus*) had the largest annual average growth rate.

BIRDS

The population sizes of the 25 bird species covered in this report are estimated to have increased by an average of 470% overall (Figure 3), ranging from 34% (Black stork *Ciconia nigra*) to more than 5,000% (Barnacle goose *Branta leucopsis*) since the beginning of their recovery. The annual population growth rates (Figure 4) show some additional variability between species, due to differences in the year of lowest population size from which population recoveries are measured, but with a smaller overall range. On average, their populations are estimated to have increased by 3.8% per year, ranging from 1% (Audouin's gull) to more than 7% (Eastern imperial eagle *Aquila heliaca*) per year. There is little evidence for systematic variation in the rates of recovery of species between bird groups, with raptors, waterfowl and other waterbirds all including a range of species whose populations have increased at different rates and to different extents.

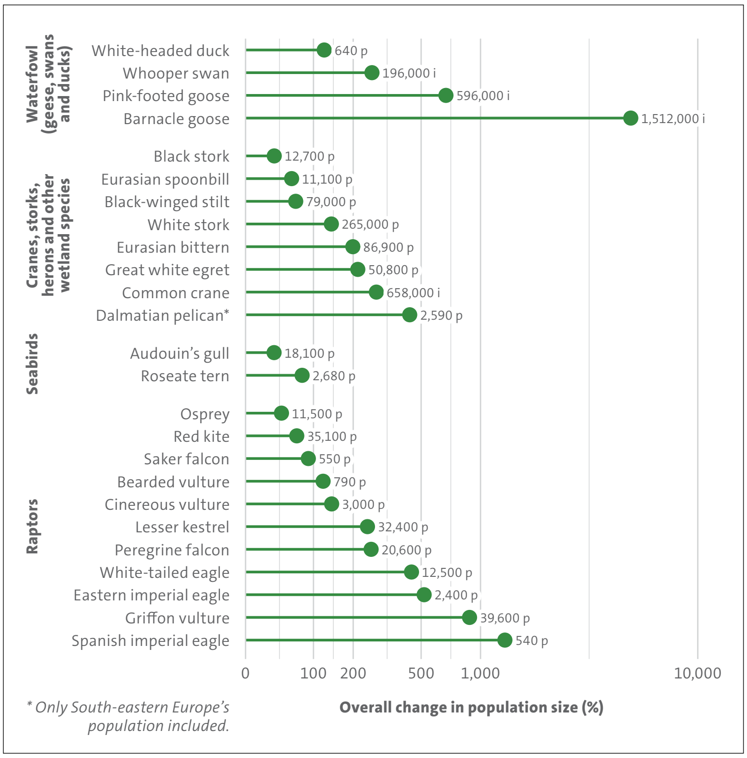

Figure 3. Overall change in population size (%) for the 25 bird species in Europe covered in this study. Change was calculated from the minimum population estimate during the time period for which data were available for each species (beginning of population recovery). Numbers next to points show the current population size in Europe as number of breeding pairs (p) or individuals (i).

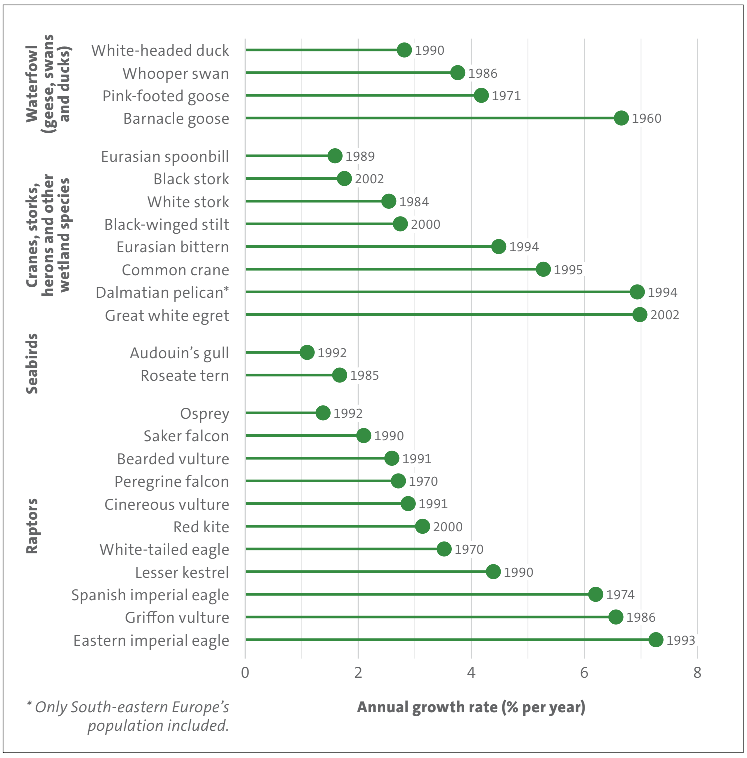

Figure 4. Annual growth rate (% increase per year) in Europe of the 25 bird species in Europe in this study, from the beginning of population recovery (start year indicated beside bars) to the most recent available data (which range from 2016 to 2021).

RANGE CHANGE

MAMMALS AND REPTILES

Species increasing in abundance often also increase in range. However, for mammals this was more complex to assess owing to the difficulties of sourcing reliable and comparable historical distribution data (Table 1. See Deinet, *et al.*[1] for discussions on challenges of historical data). While most species in this report are assessed to be generally increasing in range ("Trend from past", Table 1), expert assessment suggested that only 12 species offered sufficiently accurate range data for both past and present periods to reliably assess distributional change (Figure 5). Of these species, all but one (Eurasian otter *Lutra lutra*) were increasing in range. However, the decline in the Eurasian otter range was small (–4.2%), and of equivalent magnitude to small increases in Pine marten and Eurasian badger (*Meles meles*), and such small changes (of less than ~5%) may indicate broadly stable populations. Overall, the Eurasian beaver showed the largest increase in range, having expanded its past range by 835%, followed by the European bison, which expanded by almost 400% (Table 1).

It is notable that less accurate information was available for many mammal species than for birds. Range data for past (1950s/1960s) distributions tends to be less accurate and hard to compare with more modern, spatially refined data. There is also no current grid-based atlas for mammals such as is available for birds[6]. Here we focused on those species where expert opinion agreed that range change calculations were appropriately supported by available data. Even so, differences in methods used to derive range data (e.g. from historical maps or from more recent habitat modelling) may still have introduced inaccuracies to calculations. Techniques to reconcile these problems are still needed. For now, abundance change data appears to provide us with more comprehensive and robust metrics of mammalian comebacks.

Changes in spatial distribution data still provide us with interesting information on the spatial pattern of recoveries and declines across Europe. Comparing the number of species (species richness) in past (1950s/1960s) and present (2010–2020) distributions helps highlight those areas where recoveries are more apparent and those areas where declines are still evident (Figures 6 and 7).

Table 1. Past and present distribution areas for the 24 mammal and one reptile species covered in this study, including percentage range changes and overall trends. Past: 1955–1971. Present: 2010–2020. † Indicates species for which past range data was insufficiently accurate to reliably estimate percentage changes, but overall trends are given where possible. For more details, see species accounts.

Order	Species	Common name	Past		Present			
			Year	Area (km²)	Year	Area (km²)	Range change from past	Trend from past
Artiodactyla	*Alces alces*	Eurasian elk	1955	4,083,654	2010	5,356,340	31.2	+
Artiodactyla	*Bison bonasus*	European bison	1971	4,872	2020	24,304	398.8	+
Artiodactyla	*Capra ibex*	Alpine ibex	1960	4,353	2020	19,233	341.9	+
Artiodactyla	*Capra pyrenaica*	Iberian wild goat	1967	25,469	2020	91,664	†	+
Artiodactyla	*Capreolus capreolus*	Western roe deer	1955	4,671,179	2016	6,042,334	29.4	+
Artiodactyla	*Cervus elaphus*	Red deer	1955	1,423,306	2018	4,433,073	211.5	+
Artiodactyla	*Rupicapra pyrenaica*	Southern chamois	1955	38,870	2020	15,276	†	+
Artiodactyla	*Rupicapra rupicapra*	Northern chamois	1930	234,792	2020	191,356	†	+
Artiodactyla	*Sus scrofa*	Wild boar	1955	3,308,249	2018	7,153,257	116.2	+
Carnivora	*Canis aureus*	Golden jackal	1960	86,432	2018	372,709	331.2	+
Carnivora	*Canis lupus*	Grey wolf	1960	871,695	2018	1,577,607	†	+
Carnivora	*Gulo gulo*	Wolverine	1955	1,985,429	2015–18	2,075,496	†	+
Carnivora	*Halichoerus grypus*	Grey seal	1964	2,470,427	2016	2,041,483	†	+
Carnivora	*Lutra lutra*	Eurasian otter	1955	8,901,392	2020	8,530,256	-4.2	-
Carnivora	*Lynx lynx*	Eurasian lynx	1950s	365,337	2018	935,020	155.9	+
Carnivora	*Lynx pardinus*	Iberian lynx	1960	60,960	2018	5,602	†	+
Carnivora	*Martes martes*	Pine marten	1955	7,337,443	2016	7,754,847	5.7	+
Carnivora	*Meles meles*	European badger	1955	7,208,647	2015	7,589,711	5.3	+
Carnivora	*Phoca vitulina*	Harbour seal	1956	1,627,904	2016	1,974,279	†	+
Carnivora	*Pusa hispida*	Ringed seal	1964	2,757,738	2016	3,111,889	†	+
Carnivora	*Ursus arctos*	Brown bear	1955	3,140,567	2017	3,906,599	†	+
Cetacea	*Megaptera novaeangliae*	Humpback whale			2020	6,062,394		
Chiroptera	*Myotis emarginatus*	Geoffroy's bat	1955	1,386,610	2016	2,729,139	†	+
Rodentia	*Castor fiber*	Eurasian beaver	1955	225,632	2021	2,109,849	835.1	+
Testudines	*Caretta caretta*	Loggerhead turtle			2020	5,869,114	12	


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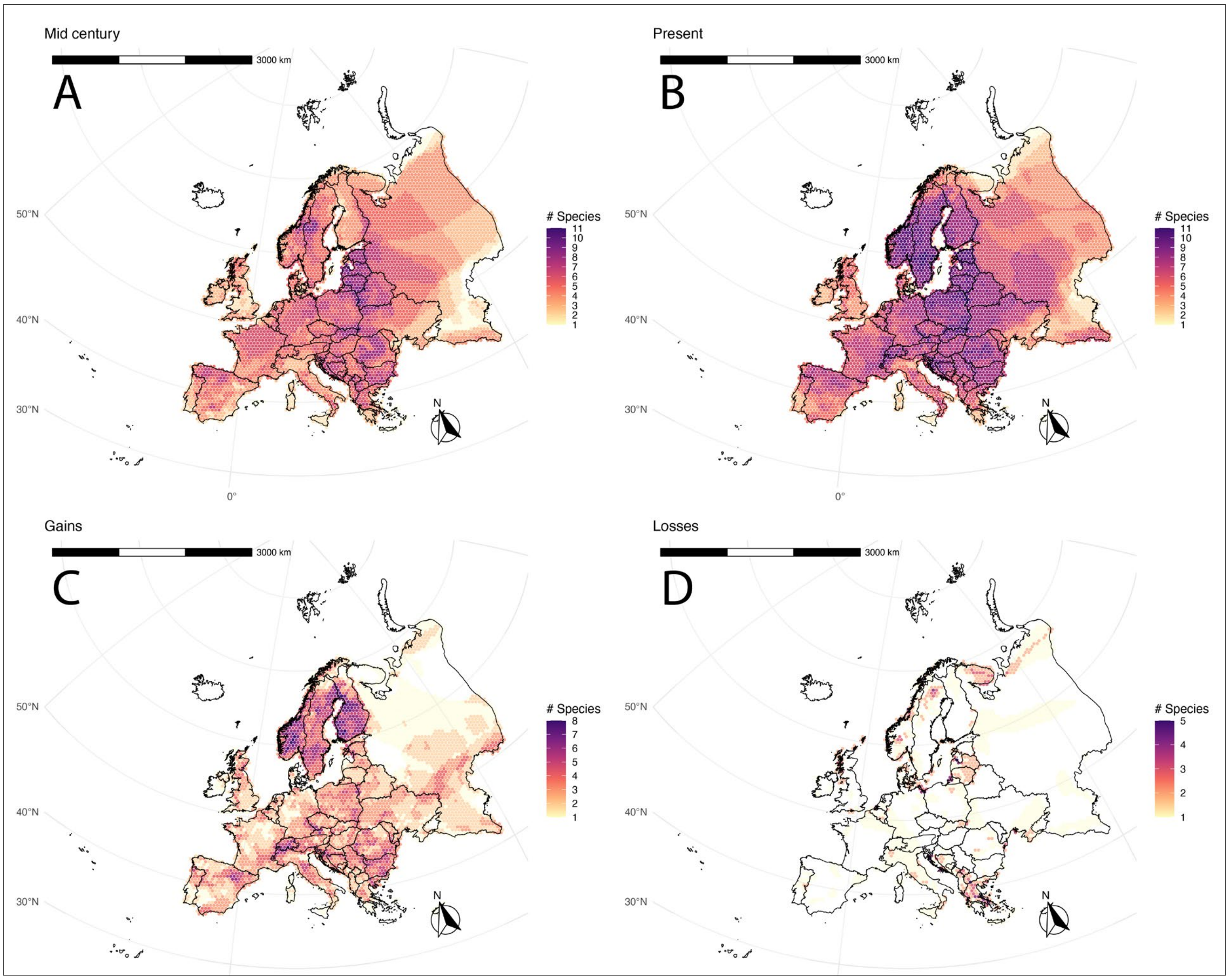

Figure 6. Mammalian species richness patterns for the period (A) 1950s–1960s, and (B) present day. Note that this dataset comprises only the 24 mammal species which were the focus species of the study (see species accounts). Spatial occurrence of distribution gains and losses, between 1950s/60s and present day, expressed as number of species gaining (C) or losing (D) distribution in that area. Note that C and D only include the 12 mammal species for which reasonable range data was available for past and present ranges (see Table 1).

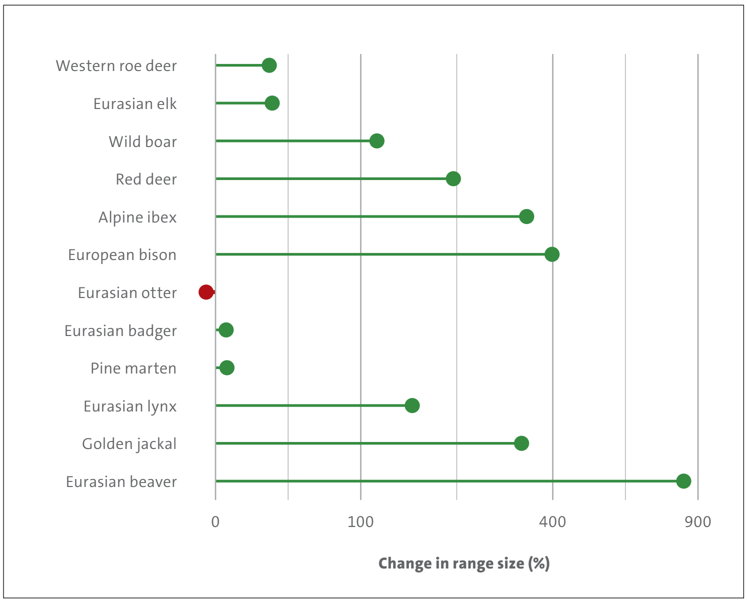

Figure 5. Overall percentage change in range size for the 12 mammal species in the study for which reliable distribution data was available over the monitoring period. See individual species accounts for context.

Most of the mammal species in this study were thought to have increased in range over this period (Table 1) with range expansions occurring across most of Europe (Figure 6C). Range contractions were much more spatially constrained (Figure 6D), occurring particularly in southern and south-eastern regions. Range expansions were more widespread in ungulates (Figure 7A) with carnivore expansions more noticeable in Scandinavia and southern Europe (Figure 7C). Contractions were less common in ungulates, limited to a few regions in the Balkans and north-western Russia (Figure 7B), while carnivore contractions were clearer and more widespread (Figure 7D).

BIRDS

Distributional changes were more varied for the bird species selected in this study. While 19 of the 25 species have expanded their ranges since the 1980s, six have contracted their ranges (Table 2). Increases in distribution ranged from 7% for

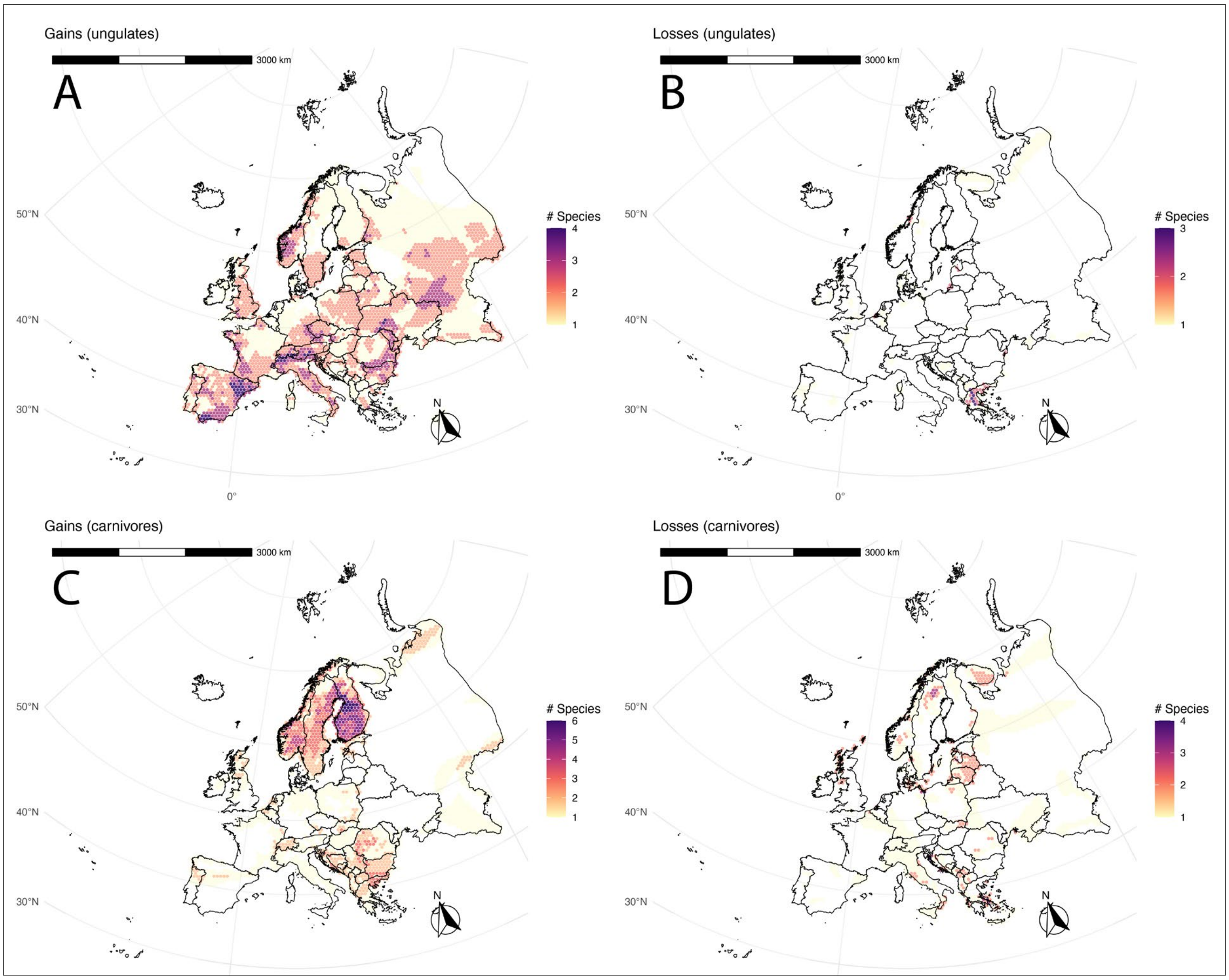

Figure 7. Spatial occurrence of distribution gains and losses for mammals, between 1950s/60s and present day, expressed as number of species gaining [ungulates (A), carnivores (C)] or losing distribution area [ungulates (B), carnivores (D)]. Note that these figures only include the 12 mammal species for which reasonable range data was available for past and present ranges (see Table 1).

Osprey (*Pandion haliaetus*) to 585% for Barnacle goose. Declines in range size ranged from −10% for Eastern imperial eagle to −39% for Roseate tern. Exploring the spatial distribution of these species' range changes across Europe highlights many areas of increased species presence (Figure 8). Increases in the number of species present are also apparent across much of northern and central Europe, with declines in south-eastern Europe, following a similar pattern to mammal declines. It is worth noting that some of the species with observed contractions in range nonetheless increased in abundance. For example, the Roseate tern (*Sterna dougallii*); its range has contracted into fewer island colonies, but these are well protected and thus have increasing populations. For the Saker falcon (*Falco cherrug*), the same phenomenon is likely due to well-protected and conserved populations in some parts of Europe (e.g. in Hungary, Slovakia and Austria) offset by declines elsewhere (e.g. in eastern and south-eastern Europe).

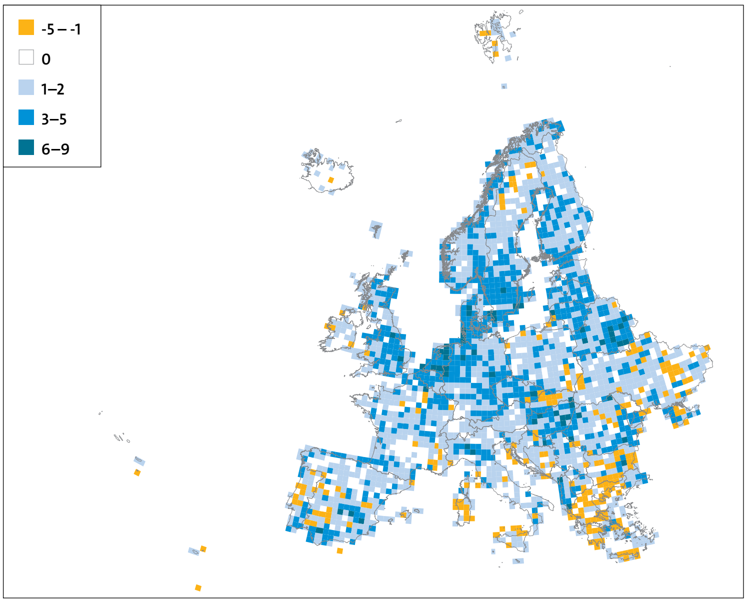

Figure 8. Change in number of species per 50 km square between 1980s and 2010s (considering the set of 25 bird species that are the focus of the study). Distributional data from the EBBA1 [7] and EBBA2 [6].

Order	Species	Common name	EBBA1 (sq)	EBBA2 (sq)	Change since EBBA1	Trend since EBBA1
Charadriiformes	*Sterna dougallii*	Roseate tern	38	27	–39%	–
Accipitriformes	*Aegypius monachus*	Cinereous vulture	62	131	–26%	–
Falconiformes	*Falco naumanni*	Lesser kestrel	332	490	–25%	–
Anseriformes	*Oxyura leucocephala*	White-headed duck	24	57	–20%	–
Falconiformes	*Falco cherrug*	Saker falcon	117	162	–18%	–
Accipitriformes	*Aquila heliaca*	Eastern imperial eagle	99	369	–10%	–
Accipitriformes	*Pandion haliaetus*	Osprey	678	1,000	7%	+
Accipitriformes	*Gyps fulvus*	Griffon vulture	201	352	14%	+
Ciconiiformes	*Ciconia ciconia*	White stork	1,218	2,042	21%	+
Accipitriformes	*Gypaetus barbatus*	Bearded vulture	58	188	23%	+
Accipitriformes	*Milvus milvus*	Red kite	631	788	23%	+
Pelecaniformes	*Botaurus stellaris*	Eurasian bittern	891	1,899	24%	+
Anseriformes	*Anser brachyrhynchus*	Pink-footed goose	56	75	27%	+
Ciconiiformes	*Ciconia nigra*	Black stork	727	1,307	29%	+
Gruiformes	*Grus grus*	Common crane	781	1,758	33%	+
Accipitriformes	*Aquila adalberti*	Spanish imperial eagle	44	74	40%	+
Pelecaniformes	*Pelecanus crispus*	Dalmatian pelican	14	72	67%	+
Charadriiformes	*Larus audouinii*	Audouin's gull	40	94	67%	+
Falconiformes	*Falco peregrinus*	Peregrine falcon	931	2,113	88%	+
Anseriformes	*Cygnus cygnus*	Whooper swan	416	991	98%	+
Charadriiformes	*Himantopus himantopus*	Black-winged stilt	395	1,094	103%	+
Pelecaniformes	*Platalea leucorodia*	Eurasian spoonbill	88	283	165%	+
Accipitriformes	*Haliaeetus albicilla*	White-tailed eagle	389	1,751	194%	+
Pelecaniformes	*Ardea alba*	Great white egret	159	907	419%	+
Anseriformes	*Branta leucopsis*	Barnacle goose	48	397	585%	+

Table 2. Number of 50 x 50 km squares (sq) in which breeding evidence (possible, probable or confirmed) was observed for the species in EBBA1 (1980s) and EBBA2 (2010s), and the percentage change between these. Note: change since EBBA1 is not calculated using all the squares in which the species has been reported to be present in either EBBA1 or EBBA2; calculations were restricted to a large subset of squares in which intensity of fieldwork was sufficient and comparable between the two atlases.

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SPOTLIGHT 2

Biodiversity monitoring and data gaps

The value of monitoring species cannot be overstated. It is needed to understand how and why biodiversity is changing, how to prioritise conservation efforts and to gauge the impact of interventions[1]. Although technology and modelling are improving our understanding of the natural world, collecting primary data is still essential to inform and ground truth these approaches[2]. The results from this report are built on monitoring data for 50 species – some from studies running for over 50 years. Without such consistent monitoring over time, this synthesis would not have been possible.

Europe is one of the regions of the world where species monitoring has been more widespread and long-term, as shown by the bias towards this region in many biodiversity databases[1,3]. Regular systematic bird monitoring started in some countries in the 1970s or even earlier, and for many mammals, abundance trends are available from 1960 onwards, and occasionally even earlier. Bird and mammal atlases for Europe have been produced since the 1990s, but for some species groups field guides were produced in the 1950s and 1960s, with historical maps as far back as 1500–1900 (for the Iberian lynx *Lynx pardinus*).

However, gaps in our knowledge of European species remain, due to the lack of consistent monitoring over time for establishing trends, or the complete absence of data from some countries. The pattern of data availability is uneven, with certain species better monitored than others. One of the factors behind the focus on birds and mammals in this report is the taxonomic bias towards these groups when it comes to the monitoring of vertebrate species in Europe[1]. Reptiles (with one exception), amphibians and fishes are not included, in part because these groups are more highly threatened, and evidence of comeback is sparser in recent decades[4]. However, the relative lack of monitoring for these taxa also means that establishing abundance and distribution trends for many species would be challenging. We feature the first reptile species, the Loggerhead turtle, in this report to highlight other taxa and the paucity of monitoring for these equally important groups.

This unevenness in data availability is brought about by several factors. It is understood to be partly driven by taxonomic bias in the EU Nature Directives, which steer much of the biodiversity monitoring effort in many European countries[5]. Even so, not all species listed are necessarily monitored comprehensively. Of the native species reported on under the EU Birds Directive, a third of the Article 12 data (country-level reporting on bird population sizes and short- and long-term trends) is based on complete surveys, just over a third is based on partial or limited data, one fifth is from expert opinion and 13% have no data available[6]. The available capacity within countries to conduct monitoring varies; across much of Europe there is limited funding (especially long-term), and a lack of standardisation, coordination, infrastructure and trained capacity to implement monitoring schemes[5,7].

However, there are other possible explanations behind this pattern, including the influence of societal preferences[3]. Charismatic species, or those which are of more interest to people culturally, either for recreation or other uses, are more likely to be monitored and be the focus of research or conservation attention[3,8]. Reintroductions in Europe were found to be highly heterogenous across all mammal species, with two-thirds of reintroduction efforts focusing on three species – the Alpine ibex (*Capra ibex*), Eurasian beaver and European bison[9]. Of the mammal species, the largest number of populations monitored were for carnivores and large ungulates; these populations were more likely to be recorded as being utilised by people and have management interventions in place. They are some of the more charismatic species but are often also of interest to monitor for reasons of mitigating conflict with people (e.g. Grey wolf, Eurasian badger and Red deer *Cervus elaphus*).

Monitoring elusive species or those found within challenging environments also presents a barrier to collecting long-term biodiversity data. The Pine marten is an elusive species for which there is little abundance or distribution data across Europe beyond a few local studies, although the use of camera traps for monitoring is one way this is being tackled[10]. Marine species tend to be harder to monitor than their land-based counterparts and research activity in the seas and oceans has lagged behind as a result[11]. Species which use

terrestrial locations for breeding (e.g. seals and sea turtles) can be more easily monitored but even these groups sometimes lack data, as evidenced in this report. It was not possible to calculate decadal trends for the Humpback whale due to a lack of long-term abundance data and we had no range change data to show changes in distribution. The need for research and monitoring of the Humpback whale in Europe has been highlighted in the species account.

What does the state of monitoring in Europe mean for understanding wildlife comeback and the process of rewilding more broadly? One remaining gap is the need for studies to monitor how ecosystem composition and function responds to changes in species composition. Another is clear recommendations for best practice for monitoring rewilding activities. Whilst reintroductions of vertebrates may be closely monitored, evaluating wider impacts on ecosystems and the value of rewilding beyond the larger-bodied species is important to understand[12,13]. Likewise, a similar bias to species monitoring in general is found in monitoring rewilding processes, with efforts largely focused on terrestrial ecosystems, and there is an urgent need to evaluate rewilding processes in aquatic habitats and underground ecosystems[14]. In order to understand the complex effects of changes in species assemblages in processes such as trophic rewilding, carefully designed monitoring is advocated[15,16]. Frameworks are now being developed to monitor natural processes in rewilding sites, seeking to understand changes in ecological integrity and to what extent there is a continued need for human interventions in these landscapes[16,17].

The work of practitioners alongside research institutions is needed to establish long-term

monitoring elements in rewilding projects to fill this knowledge gap[18]. Centralised databases should also be developed to share information on species which cross boundaries. For example, there is a call for cooperation to record hunting, vehicle collisions and damage payments relating to wild ungulates in Europe[19] and, similarly, to centralise data collection on entanglement of Humpback whales with fishing gear[20]. Continent-wide initiatives have been initiated to try to fill data gaps: EuropaBON is a network which has identified where data are missing and the barriers to monitoring in Europe. They note the key solutions to fill the gaps are funding, capacity building, technology, coordination and standardisation[5]. Embedding monitoring into policy is another promising strategy. For example, aquatic monitoring has improved under the auspices of the Water Framework Directive which helped with standardisation of monitoring practices[5].

Citizen science approaches can tackle skills gaps, identified as one of the barriers to monitoring, by training volunteers and encouraging development of local participatory schemes to monitor species and exchange knowledge. The results of the second European Breeding Bird Atlas which feature in this report would not have been possible without the input of tens of thousands of volunteers[21]. Whilst there are many citizen science initiatives across Europe, some still suffer the same biases as other monitoring schemes[5] and may not target the under-represented taxa and regions. Expanding the taxonomic coverage of species monitoring is essential as we lack trend information for many of these understudied taxa which may be under threat[22].

Since the 2013 report, we have been able to gather data on more species and increase the number we feature in the 2022 report. The Pine marten is one species in this report not featured previously due to a lack of data. We have also boosted the data set for species featured in the 2013 report; for example, we were able to produce an abundance trend for the Golden jackal data for which data was previously insufficient. Techniques for assessing range have advanced since 2013, especially with the use of modelling probability of occurrence for bird species using environmental predictors such as climate and landcover[21]. Even with these advances, we were only able to obtain sufficiently accurate data to estimate distributional changes for 60% of the mammal and reptile species featured. Significant gaps remain and monitoring, especially of ecological processes, should be at the heart of rewilding approaches if we are to fully understand the effects of species resurgence on the ecosystems they inhabit and the trends in European wildlife overall.

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SERGIO PITAMITZ

Drivers of recovery and limits to growth

For the recovering species included in this report, we also explored how ongoing pressures may be limiting recoveries or, conversely, how conservation measures may be contributing to growth.

We used data reported by EU Member States under Article 12 of the Birds Directive for analysis on the trends of, pressures to and conservation measures for bird species, and data from the Living Planet Index Database for trends of, pressures to, and conservation measures for mammal species. This allowed us to explore relationships between abundance trends, range change and key variables capturing pressures and conservation measures (see Gray *et al.* for details [1]).

We found that, even for recovering species, increases in population size and range were lower where there were more pressures acting upon populations, but that these species were doing better when more conservation measures were present (see Figure 9). Recovering bird species were generally doing less well (in long-term trends in both range and populations size) when they were reported to be facing a greater diversity of pressures. For mammal species, we found that increases in abundance were less positive where the population was in use by people (for example, recreational hunting) or where there were known pressures impacting the population. The same mammal populations also show more positive increases in abundance when conservation management is in place.

These results emphasise the importance of continuing to reduce pressures on wildlife (such as habitat loss, legal or illegal hunting, invasive species and climate change), even for those species that are known to be "coming back" across Europe, and of continuing to enhance those conservation measures that are currently in place.

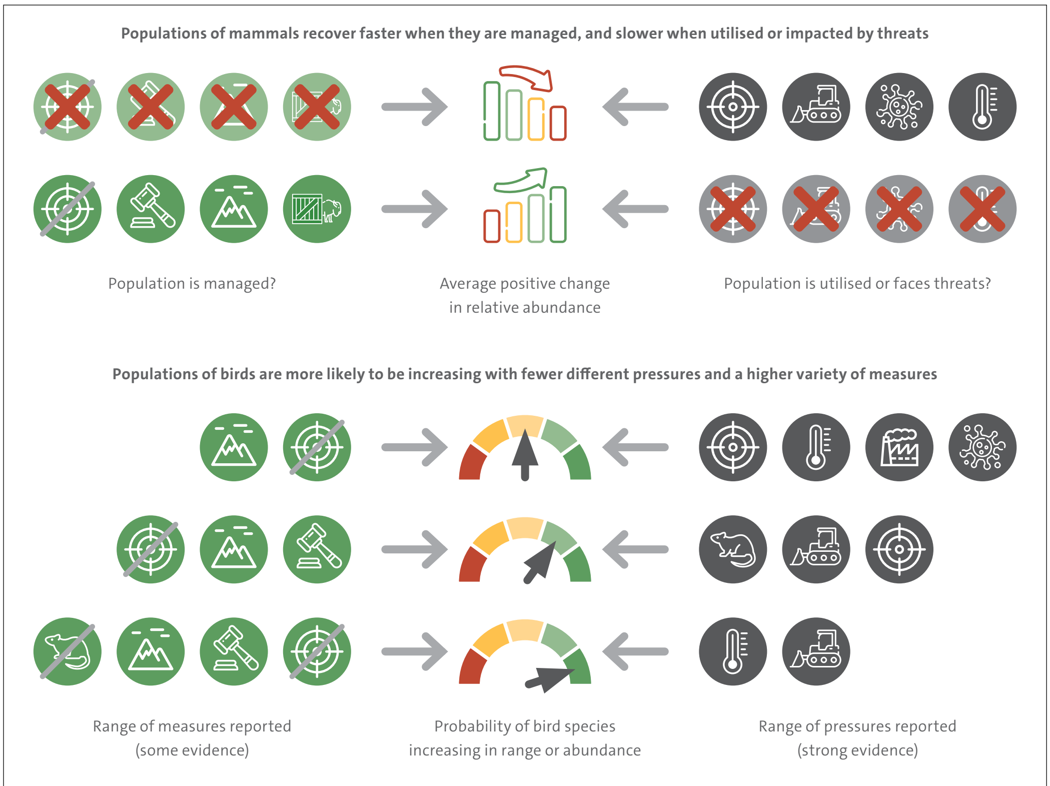

Figure 9. Infographic outlining the relationship between ongoing anthropogenic pressures and a range of conservation measures on the rate and probability of recoveries among mammal and bird species in Europe. For mammals, black circles illustrate pressures or evidence of use by people and green circles represent conservation management options in different categories. For birds, black circles represent pressure types and green circles represent a range of conservation measures. The categories themselves are not part of the analysis; rather they reflect the variety of different types of pressures or conservation measures. For mammal species (top), the presence of pressures (black circles) was associated with faster declines in abundance, while the presence of management action (green circles) was associated with more positive changes in abundance. For bird species (bottom), a larger variety of pressures (black circles) was associated with lower probabilities of increases in abundance or range size in the long-term, while a larger range of conservation measures (green circles) was associated with higher probabilities of long-term increases in abundance or range-size. (Adapted from results in Gray *et al.* [1])

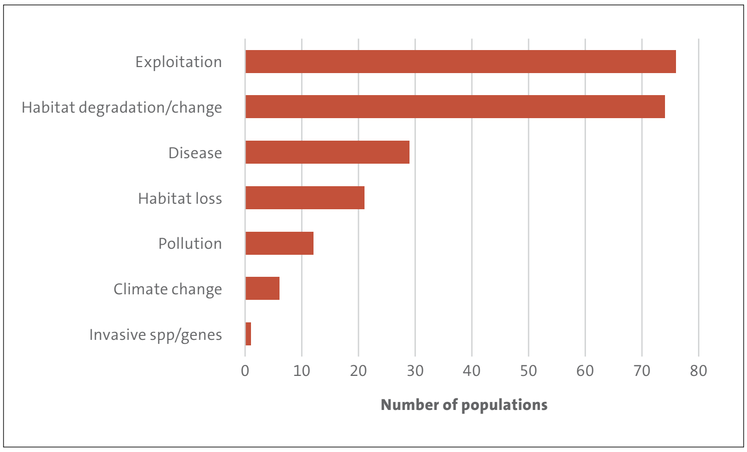

Figure 10. Summary of pressures on mammal populations. For each population, pressures were recorded, based on descriptive information from the original data source (see Appendix 1 Methods). Up to three pressures were recorded per population, as this is the maximum number of different pressures that populations usually face. Pressure information was available for 134 populations of the 24 mammal species (not all data sources provided information on pressures).

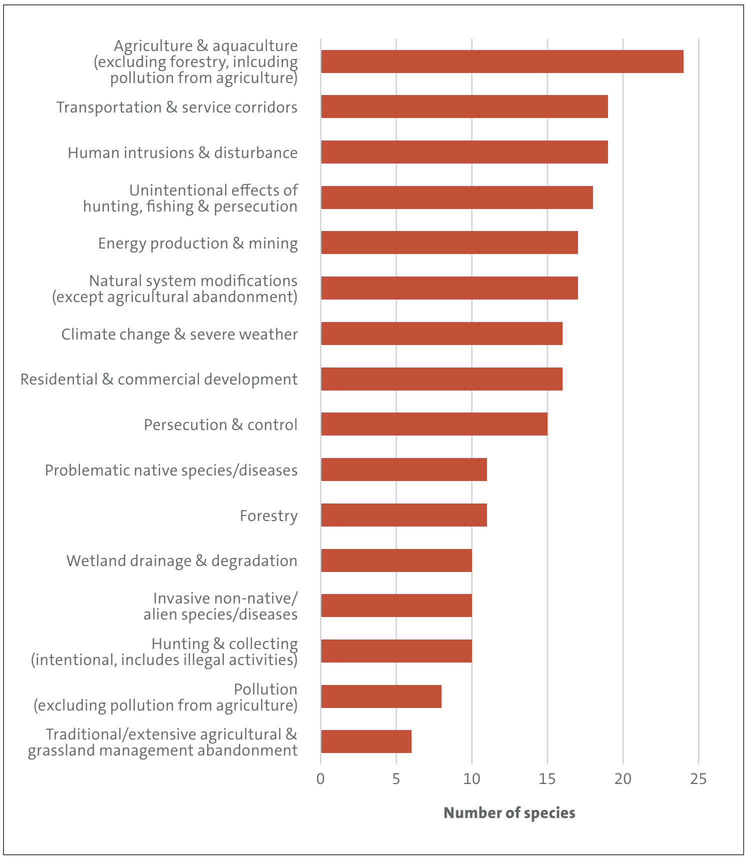

Figure 11. Summary of main pressures currently affecting the selected bird species in Europe.

Ongoing pressures

As outlined above, even for recovering species in Europe, ongoing pressures can reduce the likelihood of recoveries and lead to lower rates of population growth. Based on the information gathered for the accounts in the previous chapter, the species covered in this report continue to face a range of pressures that have driven historical declines and may still constrain populations (Figures 10 and 11).

MAMMALS

For mammals, where pressure data is available at the population level, the most frequently identified pressures were *Exploitation* (76 of the 134 populations) and *Habitat degradation/change* (75 populations, see Figure 10). The least frequently reported pressures for these populations were those related to Invasive species (one population) or *Climate change* (six populations). It should be noted that recorded pressures may be influenced by changes in awareness about the importance of different pressures (e.g. awareness of climate change impacts may change over time).

BIRDS

For birds, where greater detail is available regarding pressures, the most frequently identified pressures were those associated with *Agriculture and aquaculture (excluding forestry, but including pollution from agriculture)*, affecting 24 species. Pressures associated with *Transportation or service corridors* and *Human intrusions or disturbance*, as well as the *Unintentional effects of hunting, fishing & persecution* were also frequent, each affecting 18 or 19 species (Figure 11). The least frequently identified pressures were associated with the abandonment of *Traditional/extensive agriculture and grassland management*, although this was still identified for six species.

Reasons for recovery

MAMMALS

For mammals (Figure 12), the many of the most frequently reported reasons for recovery were those associated with species management, including *Harvest management* (such as limiting the amount of legal hunting permitted) and *Reintroductions and translocations* which was identified for 101 (of 137) populations. Respectively, these activities either reduce the number of individuals removed from a population or boost the numbers of a population by adding new individuals, either from captive breeding or from other wild populations. The top reason recorded was one of the more passive reasons behind increases: *Natural expansion and recolonisation* (usually when suitable habitat has become available and/or the species is protected in a new region). This and similar factors, such as *Species ecology*, were identified for 80 populations in total. Reasons associated with land/water protection or restoration were less frequently reported (fewer than five populations).

BIRDS

For bird species (Figure 13), the most frequently recorded driver of recovery was *Legal protection (e.g. from shooting, egg collecting etc. & disturbance)*, recorded for all 25 species, followed by *Site/habitat protection* recorded for 18 species and *Habitat management and restoration*, recorded for 17 species. Less frequently recorded reasons included *Compensation/subsidies* (four species) and *Invasive/problematic species control* (three species).

Summary

In this section we have synthesised the changes in abundance and distribution of selected mammals and birds in Europe and explored the reasons behind their resurgence as well as the main pressures that some of these species still face. We have also revealed that recovery is not continuing for all species and that species can face limits to their range and population increases, especially when they face varying geographic pressures or do not have uniform conservation measures in place. How does this story fit into the large-scale story of wildlife recovery in Europe? We now put these results in context and consider the relevance of wildlife comeback at the ecosystem scale, alongside the growing pressure from climate change, followed by a synthesis of the benefits and challenges of coexistence between nature and people.

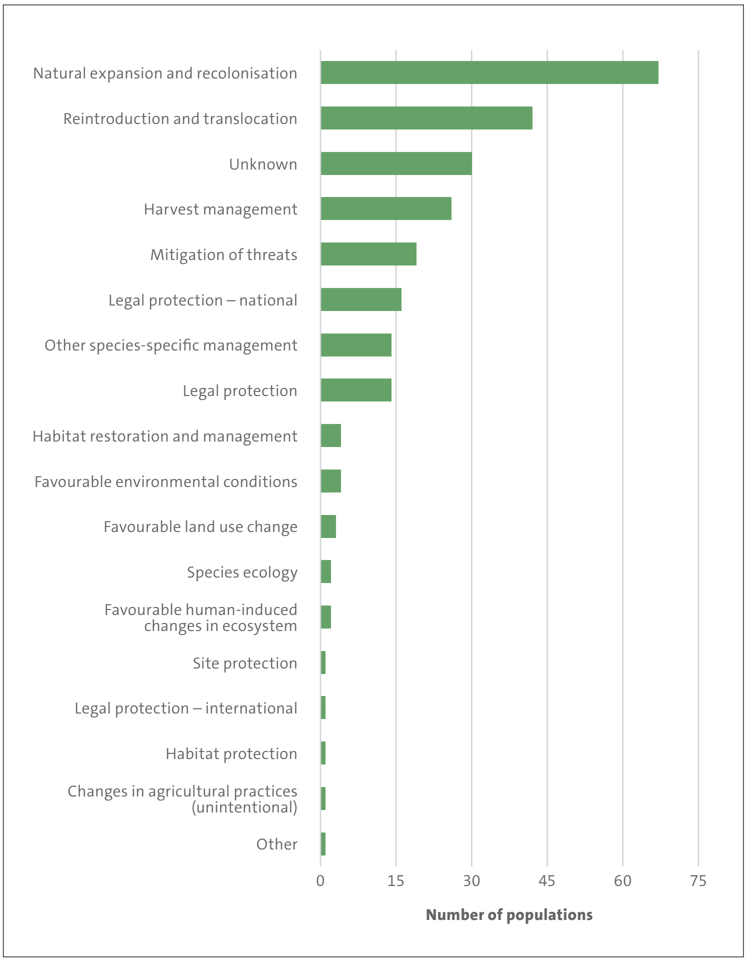

Figure 12. Summary of reasons for recovery recorded for mammal populations. For each population, any reasons for recovery were recorded, based on descriptive information from the original data source (see Methods). Reasons for recovery were available for 137 mammal populations of the 24 mammal species (not all data sources provided information on reasons for recovery).

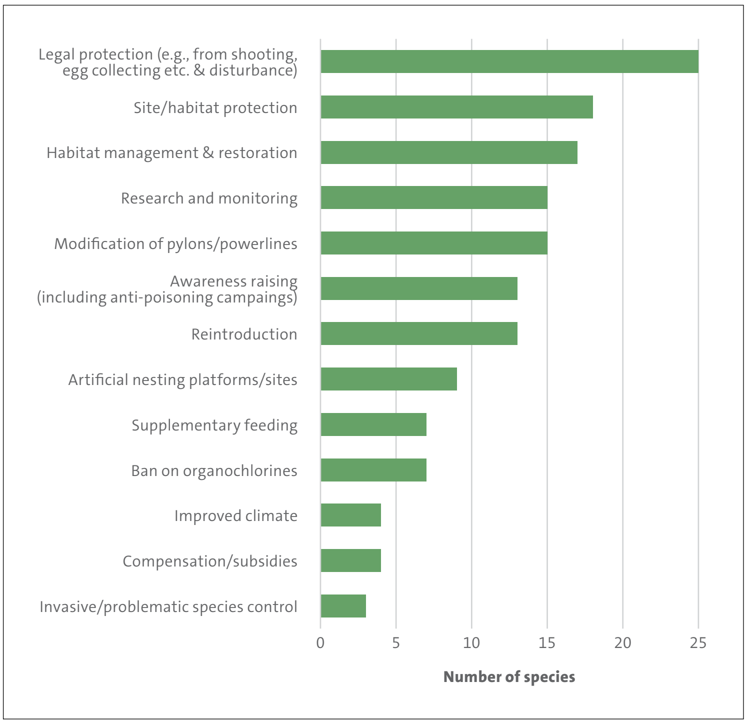

Figure 13. Conservation measures and the number of bird species (out of the 25 included in this report) whose recoveries were influenced by each measure.

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Ecosystem lens – the benefits of rewilding in Europe

An increase in ecosystem health and the restoration of ecosystem processes can occur as a direct result of active rewilding approaches, or indirectly in a landscape where passive rewilding has occurred, creating increased wildness and autonomy over ecological processes and functions.

The goals of rewilding approaches may differ; the objective might be to restore an ecosystem to a point with high fidelity to a historical baseline (e.g. Pleistocene rewilding) or it might be to restore an ecosystem to a self-regulating state, without excluding people (in both urban and non-urban landscapes) (see Table 1 within Spotlight 1). In either case, the benefits of enhancing ecosystem health are increasingly recognised as paramount to the halting and reversal of the global biodiversity and climate crisis – prioritised internationally within the targets of the UN Decade on Restoration[1] (see Spotlight 6 on policy). Through rewilding, the broader restoration of ecosystem health can provide increased ecosystem services (both cultural and regulatory), including flood prevention and carbon storage to support climate change mitigation and adaptation (see Spotlight 3 on climate change).

The interactions and processes between species assemblages and their environment underpin functioning ecosystems and the services they provide (explored in Deinet, *et al.*[2]). In Europe, where ecosystems have been heavily reduced, degraded, and in some cases extirpated as a result of human activities, a priority for many rewilding initiatives has been restoring species assemblages, reinstating trophic cascades through actively restoring wildlife populations and allowing space for nature to regenerate by itself. In supporting the resurgence of keystone species, policies, legislation and practices are implemented which have the added benefit of supporting healthy populations of non-target taxa (e.g. increases in plant biomass and increased abundance within arthropod communities[3]) and improve the health of the wider landscape[4,5].

Various European rewilding initiatives are working to restore species assemblages, using keystone species to recover some ecosystem functions. These initiatives include the use of species analogues for extinct megaherbivores, e.g. free-ranging bovines for Aurochs (*Bos primigenius*) and wild horses for extinct European wild horses (*Equus ferus*), as well as reintroductions of the European bison. Through grazing and browsing behaviours, these large herbivores promote structural diversity and cyclic dynamics (both temporal and spatial) in vegetated (woody) landscapes, ranging from grasslands to closed-canopy forest, and all stages in between (which can reduce the risk of wildfires), while trampling and defecation can encourage nutrient cycling and soil carbon capture[6]. With agricultural land abandonment trends in Europe continuing, this approach could prevent succession taking over grasslands and maintain high diversity open habitats[7,8]. Moreover, wild ungulate populations can divert carnivores from livestock predation where conflicts might otherwise occur. Where wild ungulates are overgrazing or damaging crops, a predator can be effective at moderating their population, reducing management costs[9,10].

Similarly, vultures provide an array of ecosystem services. They are some of the most efficient terrestrial scavengers and play a key role in maintaining the function of ecosystems, providing a vital nutrient and energy cycling link in the food chain. In doing so, they also help regulate populations of opportunistic scavenging mammals (e.g. Red foxes (*Vulpes vulpes*) or Feral dogs (*Canis familiaris*)), by reducing the amount of carrion available, and may also limit the spread of diseases, such as rabies, within these species[11]. By quickly disposing of carcasses, vultures also provide a useful and sustainable service to humans, as carcass disposal otherwise requires substantial resources, incurring the emission of greenhouse gasses due to decomposition, the processing of carcasses, manual removal and transport[12]. In Cyprus, studies have shown that the carcass disposal services provided by Griffon vultures (*Gyps fulvus*) alone could reduce the greenhouse gas emissions from transport and incineration by between approximately 40% and 60%[13,14].

Further investigation and empirical studies exploring rewilding approaches are urgently needed to quantify the exact impacts upon ecosystem services and support effective large-scale implementation[4,15,16]. An important way to do this is to set up effective monitoring systems and protocols in areas where rewilding is already happening, to better inform future rewilding initiatives[17,18].

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SPOTLIGHT 3

Climate change and nature-based solutions

We know that climate change is happening at an alarmingly rapid rate, exacerbated by human activities and that we are running out of time to make the changes needed to prevent irreversible damage to the ecosystems upon which we depend[1–3]. Climate change and biodiversity loss are interlinked, occurring across all biomes (terrestrial, freshwater and marine) and they share common human drivers of change[4].

Since our 2013 report, studies have confirmed that climate change and land-use change influence mammal and bird population abundance trends[5], and that delayed impacts of these pressures on species are common[6,7]. Given improvements in our understanding of both these drivers and the linkages between ecosystem processes, restoration ecology and rewilding, we have a chance to make impactful changes, with nature as part of the solution[8].

Within Europe, climate change is impacting upon many species' ranges (some are shifting their ranges northwards[9]). It is also reducing the availability of certain habitats (e.g. species dependent on sea ice face an uncertain future as their habitat shrinks – see Box 1). For other species, climatic changes have facilitated an expansion in their ranges. The Golden jackal, previously a Mediterranean or southern European species, is now being observed in north-western Europe[10]. Changes in timings around breeding seasons and migratory periods have also been observed within bird communities[11,12] as well as shifts in species' ranges[13]. Increased frequency of droughts and decreases in precipitation in some areas, rises in sea level and increased wave exposure (e.g. on coastal bird or seal colonies) are predicted to be the most impactful climate change-related pressures on European biodiversity[14,15].

BOX 1

The Ringed seal on thin ice?

Whilst the Ringed seal (*Pusa hispida*) is featured within this report as a comeback species (see species account), long term predictions considering the impacts of a warming climate on the sea ice on which it depends mean its future is not secure[26,27].

The four European subspecies of the Ringed seal (the Arctic ringed seal *P. h. hispida*, the Baltic ringed seal *P. h. botnica*, the Ladoga ringed seal *P. h. ladogensis* and the Saimaa ringed seal *P. h. saimensis*) breed on land-fast ice and are ice-dependent for most of their life cycle[28]. As the climate warms, sea temperatures rise and the sea ice thins, making it more likely to break up and disintegrate. A reduction in the quality and extent of this habitat will decrease Ringed seal breeding success. Not only do the lairs where they breed and rear pups require adequate snowfall, if sea ice breaks up early, pups can become separated from their mothers, upon which they are dependent for survival for their first month[28].

As well limiting reproductive success, indirect impacts through the reduction of prey availability (e.g. a reduction in the population density of Arctic cod (*Boreogadus saida*)) are predicted in line with increases in sea temperature and ocean acidification[29].

Taking these into account, it is estimated from population modelling that the species will decline in abundance by between 50% and 99% by the year 2100[30]. For Arctic-dwelling European seals like the Ringed seal, climate change is the biggest current threat to the species[27]. However, in the near future it is predicted that climate change will be the most pervasive threat to seals worldwide[31,32].

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Whilst the exact impacts of climate change on European species are uncertain[16], 16 bird and 11 mammal species within our study have climate change listed as a threat within their species account outlooks (including all three seal species). Moreover, climate change is noted as one of the top three threats for seabirds globally[3]. Wetland-dependent species such as waterbirds may also be highly impacted, suffering from habitat loss exacerbated by increased droughts and rising sea levels[13]. For example, the Black-winged stilt (*Himantopus himantopus*), whilst it appears to be expanding its range northwards[17,18], may be affected by increased droughts, drying up its preferred ephemeral wetland habitats. The effects of climate change are not limited to birds and mammals. Overall, European biodiversity will be affected directly by climatic alterations or through knock-on effects; e.g. insectivorous species whose life cycles lose synchrony with their invertebrate prey species[19]. Our flagship reptile, the Loggerhead turtle, has high thermal sensitivity and as temperatures increase, the sex ratio of egg clutches and recruitment success are likely to be impacted[20]. Changes in phenology and shifts in nesting site selection towards the northwest Mediterranean have already been observed in the Mediterranean population[21,22].

In response to the global climate crisis, ambitious targets have been set at the global and European scale (under the European Green Deal for Nature and the EU Biodiversity Strategy 2030)[23]. In order to achieve these targets, large scale carbon sequestration through the restoration of ecosystem functionality will be a crucial part of the response[4,24]. An increase in the Natura 2000 network of Protected Areas (both terrestrial and marine areas) targeting areas of high climate value is also proposed in the EU Biodiversity Strategy[25]. Selection of these supplementary Natura 2000 sites will need to consider interactions between climate change and adverse land use given their complex effects upon species[16] and allow for increased connectivity between them.

A nature-based solution to mitigate climate change

Reforestation, afforestation and other plant-focused (e.g. mangroves[33], seagrasses) nature-based solutions are more commonly associated with carbon trapping and climate mitigation pathways[24,34]. However, animals with their functional roles are a key part of the carbon cycle too – contributing to and removing carbon from the environment through their interactions with vegetation and the soil (or seabed) and natural behaviours (e.g. predator-prey dynamics, scavenging, or herbivores trampling and compacting the soil and redistributing nutrients or influencing plant biomass spatial distribution through grazing habits)[35,36]. This concept is also known as “Animating the Carbon Cycle,” (ACC)[37].

It has been suggested that using these natural processes by encouraging species recovery or trophic rewilding and cascades[38] could, within the right context, be a viable way to increase rates of carbon trapping and contribute towards balancing out national carbon budgets[36,39]. For example, the recovery of wildebeest (*Connochaetes sp*) populations within the Serengeti ecosystem, and the associated reduction of wildfires, is estimated to store between 0.0001–0.008 Gts of carbon per year[40]. There are opportunities for the ACC concept to be deployed in every ecosystem. Marine fauna, for example, play a role in “blue carbon” capture[41], facilitating the “biological carbon pump” and nutrient cycling through the movement of organic matter vertically in the water column[42,43].

Benefits of the ACC approach

- Avoids focusing climate mitigation purely on vegetation-based approaches, short-term carbon storing and encourages whole ecosystem approach to carbon persistence[44].
- Ready for implementation across any ecosystem (avoids the delays of developing new technological-based carbon capture solutions).
- Scalable to suit the needs of an ecosystem and resources available.
- Co-benefits include restoring ecosystem functions and environmental processes, wildfire reduction, nutrient cycling and species recovery[45].

Challenges to explore

- We have knowledge gaps – Getting the carbon “budget” in check for each landscape will take more empirical research. Guidance and recommended practice will need to be developed to avoid an unintentional carbon source[34].
- The ACC balance is context specific[39]. For example, the impact of predators within the carbon cycle and whether they tip the balance from source to sink, can differ depending on which ecosystem they are in[46].
- If an increase of animals is proposed within a landscape, there are a multitude of social and ethical factors to consider as well as the costs and ensuring the restoration of ecosystem processes overall (see section on People and nature co-existence).

Amplifying the ACC with megafauna

Within Europe we have seen the comeback of some megafauna species (e.g. the European bison and Grey wolf)[47] and evidence suggests these larger animals can be particularly effective at trapping carbon within the soil and within their biomass[34]. We don't have many studies from the European region to draw from but studies from the tropics and the Americas demonstrate that this is an area which merits further exploration within Europe.

Megafrugivore species (e.g. elephants) transport and disperse the large fruits of hardwood trees (which tend to be taller and denser, and more effective as carbon stores), thereby increasing the recruitment success and geographic spread of these tree species, in turn increasing the carbon storage potential of such forests[39]. Disturbance of forest understories by Forest elephants (*Loxodonta cyclotis*) in central African rainforests significantly impacts the accumulation of aboveground biomass and carbon storage[48]. However, these species have suffered population declines and the declines in the megafrugavores specifically, is estimated to have caused a knock-on loss to the carbon storage potential of tropical forests by 2–12%[49].

Aside from aboveground carbon storage, terrestrial megaherbivores have an influential effect on belowground carbon storage processes considered crucial for long-term carbon stores[44]. This emerging research area is of particular interest for ecosystems which have poor aboveground carbon storage capacity (e.g. grasslands). Grazing, trampling, digging and other behaviours can reduce the chances of wildfires and create opportunities for persistent belowground carbon stores within the soil[44].

Megafauna carnivores (e.g. Grey wolf) also have an important part to play in the ecosystem carbon dynamic. Where they can initiate trophic cascades, they can be the regulating agents of megaherbivores, moderating pressure on plants and helping to keep the carbon balance in check[39]. In the Canadian range of the Grey wolf, their impact on the North American moose (*Alces alces*) population within a boreal forest is estimated to facilitate 0.05–0.15 Gt of carbon sequestration annually[46].

Within the marine biome, whales (especially baleen whales, such as the Humpback whale, featured in this report, and the Sperm whale *Physeter macrocephalus*) have been noted as key players within the marine ecosystem and carbon cycle[50,51]. Throughout each whale's life, it captures thousands of tons of carbon, and at the end of its life cycle it takes the carbon stored in its body to the seabed. Every year, 30 thousand tons of carbon are deposited at the ocean floor by eight species of baleen whale[52].

We know that ecosystems which support intact assemblages of large mammals sequester large amounts of carbon[53]. Thus, by encouraging the restoration of megafauna within ecosystems we have the potential to facilitate a multitude of natural carbon regulating mechanisms. As with other aspects of rewilding, there are a lack of empirical studies which have monitored and evaluated ACC with megafauna, and the outcomes will undoubtedly be landscape and context specific. The European region holds the world's largest coordinated network of Protected Areas and has already provided species of megafauna (e.g. European bison, Red deer and Grey wolf) with opportunities to recover[39]; whether the region can capitalise on all the natural climate storage opportunities available (faunal, floral and otherwise) will become of increasing importance as we head towards the deadlines for climate commitments.

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People and nature coexistence

The inextricable link between people and nature is widely seen as central to biodiversity conservation[1]. People have long influenced and continue to shape the natural world[2] while benefitting from the many goods and services that nature provides[3].

In an unprecedented two years of the COVID-19 pandemic, many people have reconnected with nature with positive outcomes, reducing feelings of isolation and enjoying the discovery of nature on their doorsteps[4,5]. Nature is now more commonly seen as inclusive of people and not restricted to wilderness areas, with increasing recognition of urban green spaces as important refuges for people and non-human species[6]. Alongside these benefits, there are challenges to achieving coexistence of people and nature, with this topic being fundamental to understanding the potential impact of wildlife comeback in Europe. Some of the most important factors in determining rewilding success are the presence of socio-economic benefits to local people[7].

One such example is the market for wildlife watching and photography from hides in Europe which offers opportunities for observing and photographing species at close range (see Figure 14). The map shows an overview of providers of hide locations, and major companies selling such offerings across the continent at the time of publication[8]. This growing industry can bring local economic development, and employment to local communities, landowners and reserve managers who can benefit from wildlife comeback. It is expected this market will grow in the coming years as nature photography and wildlife watching increases in popularity[9].

In this section, we outline the benefits and challenges of wildlife comeback in relation to people (as presented in the first Wildlife Comeback in Europe report[10]). We explore how wildlife comeback can be enabled by legal capacity; how large carnivore species can both adapt within modern Europe and bring back traditional shepherding practices from times gone by. Finally, we describe how rewilding approaches sit within European legal and policy frameworks.

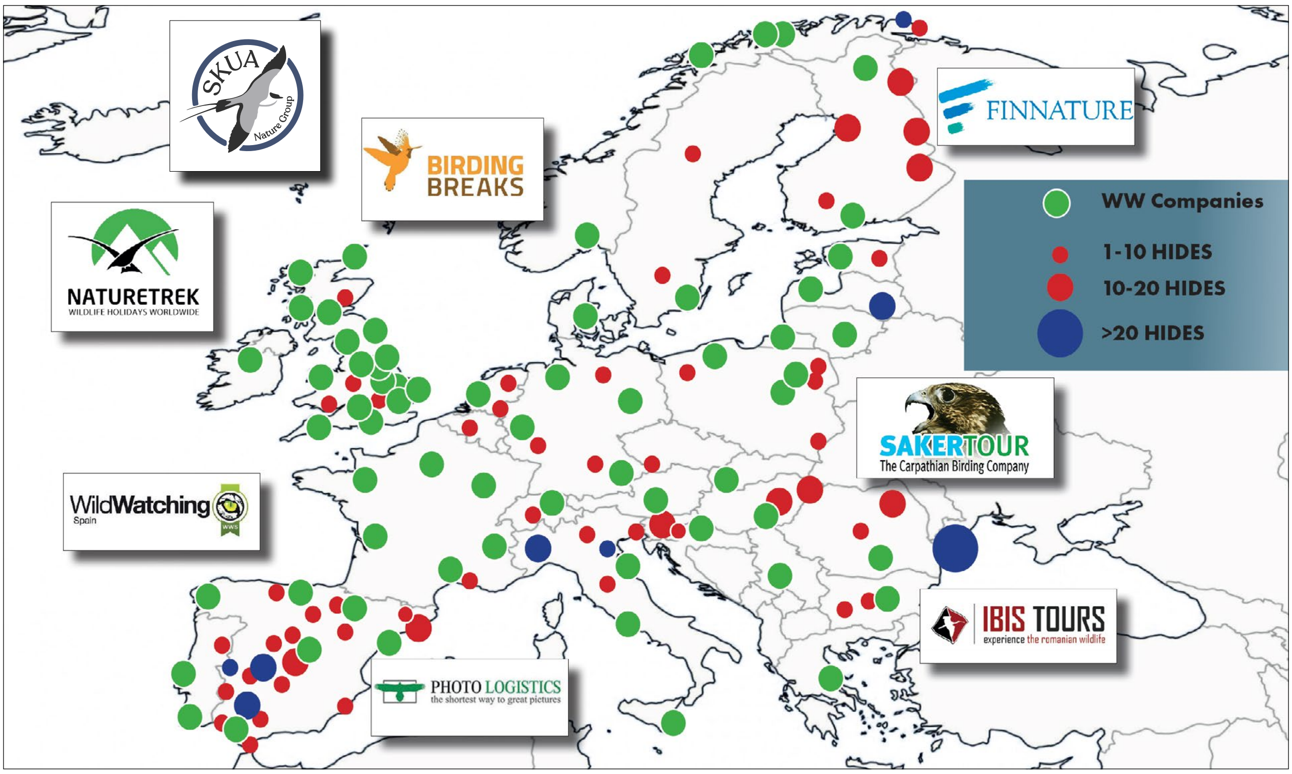

Figure 14. Wildlife economies in Europe. This map showing all the companies that offer wildlife watching from hides in Europe in 2022[8].

Table 3. Summary of benefits and challenges of wildlife comeback. Adapted from Deinet, *et al.*[10]

Benefits of wildlife comeback – A summary		
Category	**Description**	**Examples**
Economic: wildlife watching	Wildlife comeback can provide an increase in income from wildlife watching and other related tourism Income can be generated from activities such as birdwatching, photography, tours and using services locally These activities can provide alternative livelihoods in rural areas where unemployment can be high It can also allow direct or indirect marketing opportunities for traditional products Presence of a charismatic species can be especially beneficial in attracting tourists However, there is a risk of disturbance to wildlife by increased tourism	Expenditure on tourism and recreation supported by Natura 2000 sites was €50–85 billion (2011 EU study)[11] In 2017, one in five visitors to Iceland went whale watching, where Humpback whales were one of the main cetaceans to be spotted[12] White-tailed eagles (*Haliaeetus albicilla*) are thought to be the top bird species in UK for tourism (on the Isle of Mull alone, eagle tourism generates between £4.9 million and £8 million per year)[13] Vultures attract many tourists, particularly birdwatchers and wildlife photographers, around their breeding sites and at feeding stations, which can significantly contribute to the revenue in the local area (potentially over 600,000 euros in Cyprus alone)[14] Concerns exist that the rise in Harbour seal (*Phoca vitulina*) watching tourism is affecting the species' behaviour[15]
Economic: hunting/fishing	Increased wildlife numbers in Europe will benefit hunters who will enjoy access to more animals and/or higher densities Some advocates of hunting highlight the maintenance of economic, social and cultural values as a benefit However, impacts on animal behaviour from hunting may reduce opportunities for wildlife watching	In Europe, 25 million anglers spend about €25 billion per year and 7 million hunters spend €16 billion[16] The hunting of Eurasian elk (*Alces alces alces*) holds cultural significance in Finland. The economic value of this hunted elk meat was estimated at €61 million in 2010[17] In Greece, the Balkan chamois (*Rupicapra rupicapra balcanica*) avoids areas where poaching occurs or hunting of other species is allowed, reducing opportunities for chamois watching in those areas[18]
Economic: restoration of natural processes	The restoration of natural processes as a result of wildlife comeback such as herbivory, carnivory and scavenging can shape and maintain a landscape without people actively managing it A self-supporting ecosystem can reduce land management costs and resource demands	By allowing the recolonisation of wild grazers, afforestation can be prevented, and high species diversity of open habitats can be maintained without the provision of grazing livestock[19] Restoring wild ungulate populations has been suggested as a necessary intervention to maintain large predatory mammal species in sufficient numbers, and to minimize predation on livestock. E.g. restoring Western roe deer (*Capreolus capreolus*) to Portugal has enabled the return of the Iberian wolf (*Canis lupus signatus*) to be tolerated in the area[20] The return of Eurasian beavers and their dam-building behaviour can restore useful natural processes to waterways which would be costly to recreate artificially, such as water filtration and the reduction of bank erosion[21]
Economic: certification	Provides market-based funding for wildlife conservation – reduces conflict with species and generates income	'Bear-friendly' local products marketed in Croatia[22] Rewilding edition of Portuguese wine, in collaboration with Rewilding Portugal[23]
Cultural and societal: cultural value	The relationship between human culture and nature is dynamic and there is recognition at policy level of the importance of nature for people Wildlife comeback can contribute to conservation of natural and cultural heritage of Europe – reigniting cultural links from the past	The European Landscape Convention was established in 2000 to identify and protect landscapes that are important to people[24] The Saimaa ringed seal (*Pusa hispida saimensis*) holds cultural importance in Finland. As the country's only endemic mammal, it has become a symbol of national and local identity[25]
Cultural and societal: wellbeing	Nature can contribute to physical and mental health and the enhancement of education opportunities	Almost 30 case studies from the EU demonstrate the benefits that wildlife can have on physical and mental health, even at the local scale, e.g. a Danish study of 1,200 people found that 90% of respondents considered green spaces important for their health and mood[26]

Challenges of wildlife comeback – A summary		
Category	**Description**	**Examples**
Disease	Challenge of disease risk to wildlife, livestock and humans as a result of increasing interaction between these groups with inadequate biosecurity, poor animal husbandry, biodiversity loss as drivers Return of wildlife to areas managed for livestock production increases risk of direct and indirect disease transmission and the role of wildlife as a reservoir for disease vectors Artificial increase in urban wildlife populations could increase zoonotic disease spread Effective disease surveillance and education on disease prevention is key Current evidence suggests that naturally functioning ecosystems generally reduce prevalence of infectious diseases, so wildlife comeback not necessarily a universal risk	Density of Western roe deer and incidence of Lyme's disease correlated in space and time in Denmark[27] In most European alpine areas, wild Caprinae overlap in range with domestic herds, and this close contact can facilitate cross-transmission of diseases, such as infectious keratoconjunctivitis and sarcoptic mange[28] Incidence of West Nile Virus in humans was lower where bird diversity was higher in eastern USA[29] Studies show that tick-borne diseases (like Lyme disease) increased due to the absence of carnivores[30]
Native/non-native	There is much debate in science and beyond about what constitutes native and non-native species, and the extent to which this dichotomy should be prioritised in conservation This has implications for which species should be encouraged or assisted in their recoveries	For the Fallow deer (*Dama dama*), historical range is hard to determine, and therefore it is difficult to distinguish where it should originally be considered native, especially as some introductions happened as early as the Phoenician period[31] Climate change can facilitate unassisted range expansion beyond a traditional 'native' range – milder winters and reduced snow cover may be contributing factors to the northward spread of the Golden jackal across Europe[32]
Space for wildlife	Many species have large ranges, undergo seasonal migration, and/or cross borders, so species recovery strategies need to consider large, connected areas and cooperation between countries Connectivity also important for ensuring safe passage of wildlife across roads and railways	There is a transnational conservation plan in place for the Harbour seal in the Wadden Sea[33] Norway and Sweden are collaborating on transboundary monitoring schemes for the Wolverine (*Gulo gulo*) and Arctic fox (*Vulpes lagopus*) populations which traverse the border between these two countries[34,35] The Oder Delta rewilding project, involving transboundary extension of Eurasian elk and Eurasian bison ranges, is also a transnational collaboration between Germany and Poland[36]
Wildlife damage	Predation of livestock by large carnivores is associated with depleted natural prey populations Damage to agricultural crops (grazing, browsing, trampling) by wild ungulates and/or waterfowl exceeds damage from livestock predation Wildlife damage can be costly and raises conflict with people Exclusion or deterrence at local scale, compensation schemes and participatory stewardship schemes are ways of mitigating or preventing negative impacts	In Poland, Grey wolf attacks on sheep farms were found to be negatively correlated with Red deer populations[37]; in Germany where wild prey is plentiful livestock makes up less than 1% of the biomass consumed by Grey wolves[38] In 2021, nearly €19 million was paid out in compensation for damage done by geese in the Netherlands, compared to €46,000 for damage done by Grey wolves[39]
Attitudes to wildlife	Knowledge on social and economic issues as well as cultural and historical background is key to understanding people's attitudes to wildlife Level of exposure and distance to returning wildlife affects attitudes, with more positive attitudes in urban areas and more negative attitudes in rural areas Top-down approaches to decision making can lead to resentment among local communities, so participatory approaches are considered a better way of developing management plans Disconnection of people from nature can make understanding people's attitudes to wildlife comeback difficult; communication and environmental education strategies can help bridge the gap	In both Norway and Sweden, attitudes to Grey wolves are more positive in urban areas than in rural areas[40] Participatory approaches have been used as part of the European Commission Regional Platforms on People and Large Carnivores to improve engagement with local stakeholders and ensure they are involved in management decisions[41] Local educational programmes have been key to improving awareness and local attitudes to turtle conservation in the Mediterranean, and for reducing the impact of fisheries bycatch by sharing best practices with local fishermen[42]

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SPOTLIGHT 4

A LEGAL TOOLKIT FOR WILDLIFE COMEBACK

Legislation and protective measures play a key role when encouraging the recovery of a species or habitat that has been subject to direct (e.g. hunting or logging) or indirect (e.g. pollution from agricultural runoff) human-induced threats.

Legislation that protects species from excessive offtake (e.g. unregulated hunting or persecution) and licensing regimes that regulate hunting at a sustainable level can underpin the successful recovery of species previously subject to overexploitation (e.g. Grey seal, Alpine ibex and Barnacle goose) or persecution (e.g. Grey wolf and Dalmatian pelican *Pelecanus crispus*). Implementing and adhering to international governance systems to regulate the trade in protected species (e.g. CITES and EU Wildlife Trade Regulations), as well as regional legal tools for protecting wildlife and the environment (e.g. the EU Nature Directives and the Bern Convention) and translating them into national legislations have been important for enabling nature recovery [1–3]. Within this report, half of all listed mammal species had legal protection specified as a reason for their recovery (Figure 12) and this applied to all listed species of mammalian carnivores (e.g. Golden jackal, Eurasian and Iberian lynx, and Wolverine). All 25 bird species included in this report had legal protection cited as a driver of recovery (Figure 13). Legislation banning the usage of Persistent Organic Pollutants (POPs) in the EU during the 1990s, including organochlorine pesticides like DDT, was especially influential in the recovery of waterbirds and raptors (e.g. White-tailed eagle), freshwater mammal species (e.g. Eurasian otter) [4] and marine mammals (e.g. Ringed and Harbour seals). Unfortunately, as the name implies, these chemicals remain in the environment for a long time; in 2015, traces of DDT and other banned pesticides were linked to the deaths of Geoffroy's bats (*Myotis emarginatus*) in the Netherlands, likely from exposure to treated wood [5].

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Moreover, legislation and licensing are only as effective as enforcement capacity will allow. In the initial years of post-Soviet Union collapse, increased poaching and weakened wildlife law enforcement saw Wild boar (*Sus scrofa*) populations decline across Russia by half between 1991 and 1995 [6]. Low capacity for Protected Area management, weak enforcement, corruption and low penalisation of wildlife and environmental crimes can undermine the efficacy of legislation [7] and reduce species recovery potential. Despite Europe's strong legislative and protective measures, including Natura 2000 sites – described as "the largest coordinated network of protected areas" Directorate-General for Environment (European Commission) [8] – and the Emerald Network of Areas of Special Conservation Interest for Non-EU countries, the region is still blighted by wildlife and environmental crimes. Europe-wide illegal offtake of wild birds (e.g shooting and trapping) is estimated at over 20 million birds per year [9] with hotspots across south-eastern Europe and the Mediterranean (coinciding with the Mediterranean/Black Sea Flyway) [9,10]. For mammals, the Carpathians are both an important area for populations of large mammals and a hotspot for large carnivore poaching [10,11]. Evidence for the continued local persecution, through mainly poisoning or shooting, of birds of prey such as Osprey and White-tailed eagle in southern Europe and the Red kite in the United Kingdom, or the recent increase in persecution of the Spanish imperial eagle in Spain, demonstrates the need for more stringent enforcement of legal protection. Moreover, the illegal use of poison baits for mammalian species is a very important threat to birds of prey in Europe.

A further challenge for the region is that the EU's open borders provide opportunities for transboundary wildlife crimes, making the region a source, transit hub and destination for illegal wildlife trade [12]. Seizures of bodies, body parts and derivatives of comeback species such as the Brown bear [13] and Grey wolf [12], and the occurrence of illegal trade of the Eastern imperial eagle[14] within Europe, all point to the importance of strengthening legislative and enforcement capacity and transboundary collaboration when managing comeback species.

Transboundary agreements to protect and enable wildlife movements, migratory behaviour, gene flow and access to seasonal resources are in place across the EU Protected Areas network, including the Convention on Migratory Species (CMS) and other regional conventions (see Appendix 2 Table 1)[15]. However, these commitments and their impacts on wildlife have not always been taken into consideration when implementing fencing and other human-built physical barriers (e.g. roads or dams). This disconnect has become more pronounced since the mid-2000s, when human migration into and across Europe spiked, and European efforts to control illicit crossings with border security fencing increased[15]. The impact that border security fences have on wildlife in south-east Europe and the Mediterranean has been documented to increase large mammal mortality (e.g. Red deer on the Croatian-Hungary border[16]). Similarly, in Eastern Europe, a wall under construction through the Białowieża Forest to restrict refugee movements between Belarus and Poland is predicted to disrupt opportunities for gene flow between European bison subpopulations[17], a species that already has fragmented subpopulations with relatively low genetic variability[18].

BOX 2

Closing gaps for environmental crime inside and outside of the EU

To improve national implementation of EU environmental law, the EU LIFE Programme funded the creation of the Successful Wildlife Crime Prosecution in Europe (SWiPE) project in 2020, which now operates in 11 European countries, and a review of the 2016 EU Action Plan to tackle wildlife trafficking is in preparation[19].

Outside the EU, access to support, legislative tools and frameworks to analyse and strengthen national efforts are available through membership of the CITES network and other international initiatives, such as the International Consortium on Combating Wildlife Crime (ICCWC). The latter has devised an international standard to assess and monitor the strength of legislations and criminal justice responses for environmental crimes. So far, only the United Kingdom[20] and Bosnia and Herzegovina[21] have undertaken the ICCWC Toolkit and Indicator Framework assessments within Europe.

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SPOTLIGHT 5

LARGE CARNIVORE COMEBACK AND THEIR ROLE IN REWILDING

Large carnivores are perhaps the most contentious group for rewilding, and their comeback has been the subject of much scientific and public debate[1–7].

Living alongside these species can bring tensions and conflict, particularly among those who perceive or experience an elevated risk to their personal safety – and who may be asked to alter behaviours and practices to accommodate the return of large carnivores – and perhaps most often among those who risk financial losses following the return of large carnivores, e.g. livestock farmers and pastoral communities[2,8] (See Table 3 and as reviewed in 'dealing with wildlife damage' with Deinet, *et al.*[9]). Nevertheless, carnivores (e.g. apex predators such as the Grey wolf and mesocarnivores such as the European badger) play an important role within ecosystems. Often keystone species, they may encourage the restoration of trophic cascades and enhance ecosystem functionality[10,11] and their (re-)introduction underpins several rewilding approaches (see Spotlight 1).

Some regions have chosen approaches that aim to keep humans and carnivores separate. In the United States, larger National Parks and protected areas are capable of sustaining large species and accommodating their range size requirements[12,13]. For European large carnivore species (and large mammals in general), the efficacy of European protected areas is debated (apart from for the Wolverine, whose distribution is largely within protected areas) due to ongoing human disturbance and the spatial limitations of most protected areas compared to large mammals' range size requirements[14,15]. Some have argued that the range expansion of some species owes less to protected areas and more to their ability to coexist with people and adapt to human-dominated landscapes[15], highlighting the importance of working toward enabling coexistence between people and carnivores within Europe.

Enabling European coexistence with carnivores requires a suite of policies across the board, from land-use planning on predator-prey-livestock zones and fencing[10,16] to enabling wildlife corridors (nationally and internationally) to allow for adequate gene flow and natural roaming behaviours[17,18]. Other measures include updating recommended livestock husbandry practices, livestock compensation schemes and conservation payments, public safety protocols, hunting quotas and permits[19]. The future for European carnivores will be secured through the implementation of a coexistence approach[12,20] facilitated by multilateral policies and frameworks, e.g. EU Member States have access to the EU Platform on Coexistence between People and Large Carnivores.

An important European example of carnivore coexistence following wildlife comeback is the Iberian lynx's remarkable recovery in Spain and Portugal (see species account). Successful implementation of legislation, education programmes, reintroductions and the collaborative efforts of landowners, 20 organisations and state authorities[21] (supported by substantial funding from the EU LIFE programme) took the wild population from 94 individuals in 2002, to 1,111 in 2020[22].

European carnivores such as the Grey wolf, Brown bear, Eurasian lynx, Iberian lynx and Wolverine are part of EU LIFE species recovery projects, a programme that commenced in 1992 across EU European range states[18] and coincided with species protections under the EU Habitats Directive (with some national exceptions (see Appendix 2 Table 2 and species accounts for details)[23]. Since their near-extirpation in the early to mid-20th century, all focal species within the EU LIFE projects have seen recoveries in their population sizes and ranges[18,24]. Trends in recovery for these species have varied across Europe (regionally and nationally) and the reasons underlying these patterns can be complex and difficult to unpick (e.g. cultural acceptance of carnivores versus habitat suitability within a range state[6,24]). Permissive hunting of the Iberian wolf population in Spain is thought to have limited its recovery compared to the rest of the European Grey wolf population[25].

In general, legal protection, prey species recovery and reforestation have been the most significant drivers for recovery of European large carnivores[18]. Some tolerance of, and adaptation to, human proximity, density and modified landscapes has been observed in the group overall[14,15]. However, this is species and context specific – a recent modelling study found that for Brown bear, Grey wolf and Eurasian lynx, habitat suitability is significantly influenced by human population density and recent land cover changes, and yet no significant influence on habitat suitability was found for species protection levels[6].

BRUNO D'AMICIS / REWILDING EUROPE

BOX 3

Reviving traditional husbandry methods and informing carnivore coexistence policy

A review of the dietary choices of Grey wolves across 27 range states found wild prey were preferentially selected over livestock[27]. However, a recent study of Grey wolf attacks on livestock in the central Iberian Peninsula found that attacks were more likely to occur at higher altitudes with low human population densities, irrespective of wild prey availability. Notably, this same study indicated that reducing these attacks was possible with increased husbandry measures: the use of fencing, cattle guard dogs and enclosures (e.g. cattle sheds)[4].

Many of these methods were historically used as traditional large carnivore deterrents, but within landscapes where these species became extirpated these practices subsequently declined[7,19]. The use of fencing as a deterrent from attacks is also supported from analysis of ten years of Grey wolf interaction data within the northern Italian Apennines[7]. (Re)introducing these husbandry techniques into local agricultural policy frameworks and financially supporting their implementation will be important for coexistence as populations of Grey wolves and other large carnivores increase in number and expand their ranges.

Further north, in the Netherlands, the introduction of these methods (fencing, guard dogs, etc.) has seen successful uptake with positive results thanks to government support, NGO involvement and landowner and livestock-owner participation[28].

Habitat suitability models have also demonstrated that there is space for further recovery of some large carnivores in Europe. For example, one such model, which considered climatic, environmental, topographic and human impact variables, calculated that Brown bears in the Cantabrian Mountains currently occupy just under 50% of suitable habitat in the area, suggesting there is much potential for future range expansion[26].

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GRZEGORZ LESNIEWSKI

Policy, legislation, and opportunities for rewilding within Europe

Rewilding can be applied as a conservation approach for restoring ecological processes that can contribute towards national and multilateral policy targets and agreements aiming to reduce biodiversity loss[1,2]. More recently, rewilding has also been proposed as a complementary tool to support the mitigation of, and adaptation to, climate change impacts[3,4].

The utility and importance of rewilding towards the overarching goals of ecosystem restoration and addressing the impacts of climate change has been recognised both regionally, within the EU Nature Restoration Plan (part of the EU Biodiversity Strategy for 2030 in the European Green Deal for Nature[5]) and globally, within the 'United Nations Decade on Ecosystem Restoration' (www.decadeonrestoration.org)[6]. Among conservation practitioners, uptake of rewilding initiatives for biodiversity conservation, both at small and at landscape scales, has increased rapidly across Europe within the last decade. The European Rewilding Network (see https://rewildingeurope.com/european-rewilding-network/), launched in 2013 by Rewilding Europe, now includes 80 members in 27 countries. Since 2003, Europe has seen over 15 national rewilding-focused organisations established, working at either a landscape or national level.

Europe, with its high proportion of human-dominated and degraded landscapes, coupled with trends in rural depopulation, land abandonment and urbanisation, offers significant potential for the recovery of nature and could improve its biodiversity status through adopting appropriate rewilding approaches. Rewilding has many forms (see Spotlight 1) and does not have to exclude people from nature to make a significant difference to ecosystem health and function[7], an essential consideration within this highly populated region. On the contrary, rewilding can bring a holistic approach to the revival of landscapes, embracing nature and wildness in the middle of our society[8]. The resource-rich European region has the political will, access to policy and legislative tools, and the motivation provided by increasing public awareness; the question, in the next decade, is whether policy makers and practitioners can galvanise all this into delivering the action necessary for European nature recovery?


GUIDO BISSATTINI / SKUA NATURE

Deploying rewilding at the regional scale would support the EU's 'Green Deal for Nature' Biodiversity Strategy 2030, whilst nurturing economic and societal benefits[9,10]. At a national level, translating the proposed EU Nature Restoration Law into legally binding targets could serve to strengthen policy makers' interest in ecosystem restoration and rewilding, and open a channel for investment (offering multi-disciplinary expertise, frameworks and finance). This would represent a challenge, but is not without precedent internationally, e.g. the codification of CITES into national legislations, or within the European region, the national reporting requirements and Action Plans of the EU Nature Directives. A further benefit would be the 'mainstreaming' of regenerating ecosystem processes and shifting institutional focus away from single species conservation or the preservation of selected groups of species.

In 2020, 21 European conservation NGOs published a position statement to underline the importance of how the EU Nature Restoration Law should be implemented – stressing the urgent need for targeted, large-scale restoration across the EU, and that it should complement and seek to fill gaps within existing EU environmental legislation[11], creating links between the biodiversity and climate change agendas. Rewilding approaches could support the implementation of these recommendations to create more high-quality, self-sufficient ecosystems, reversing degradation and loss. These approaches could be applied inside and outside of protected areas with climate adaptations in mind.


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Another route would be to explore the possibility of a legal obligation for European Member States under Article 8(f) of the Convention on Biological Diversity (CBD) regarding in-situ conservation, specifically to undertake efforts to restore megafauna species (where appropriate to the ecosystem). This obligation provides an opportunity to promote the continued recovery of populations of large mammals in Europe, with an emphasis on megafauna due to their influential roles within ecosystems, wide-ranging trophic interactions and often disproportionate influence on environmental processes (see Spotlight 1)[12,13].

POLICY IMPLICATIONS OF REWILDING

Whilst legislation and policy frameworks can enable rewilding implementation and support national progress towards biodiversity policy targets[1], rewilding can also have implications which require the development of specific policies (e.g. human-wildlife conflict prevention and mitigation, fencing and strategic zoning) to support project sustainability and promote acceptance by local communities[7,14]. In theory, these restoration and rewilding targets should also require a framework for monitoring and evaluation to be developed that is appropriate for tracking ecosystem processes and ecosystem health[15]. However, in practice, for a multitude of reasons (e.g. funding and time constraints), this is rarely implemented.

An array of materials for best practice to support the policy maker and rewilding practitioner have been (or are in the process of being) developed. Global experts and conservation organisations developed guidance for a "Global Charter for Rewilding the Earth" in 2020[16]. The International Union for the Conservation of Nature (IUCN) has also published guidelines for reintroductions (IUCN/SSC[17]), alongside principles for implementing and upscaling Nature-based Solutions (Cohen-Shacham, *et al.*[18]), and in 2021, at the IUCN World Conservation Congress, adopted a resolution to instigate a Rewilding Working Group (RWG) to consolidate knowledge from across the disciplines in this rapidly evolving field.

Within Europe, some rewilding researchers have sought to identify opportunities in EU legislation to recognise the importance of ecosystem processes and their regeneration[8,10,19,20,21]. Including

BOX 4

Abandonment, rewilding and reversing farmland bird declines

Farmland bird populations in Europe have declined by more than 50% since 1980[36] (Figure 15), mainly due to agricultural intensification. Repeated efforts to halt and reverse this decline by reforming the EU Common Agricultural Policy have yet to succeed, despite evidence from demonstration projects like the RSPB's Hope Farm that it is possible to run a commercially viable farm and restore and maintain farmland biodiversity (Figure 16)[37].

'Abandoning' intensive agriculture on even small parts of more farms, by removing land from production and returning it to nature (e.g. field margins, hedges and ponds), has the potential to restore farmland bird populations and much other biodiversity, including pollinators and others capable of providing biological pest control, reducing the need for pesticides.

Achieving this at sufficient scale remains a challenge, but rewilding approaches such as (re) introducing grazing species can help to maintain habitat heterogeneity, by maintaining patches of open habitat and preventing full natural succession through scrub to woodland[20,38].

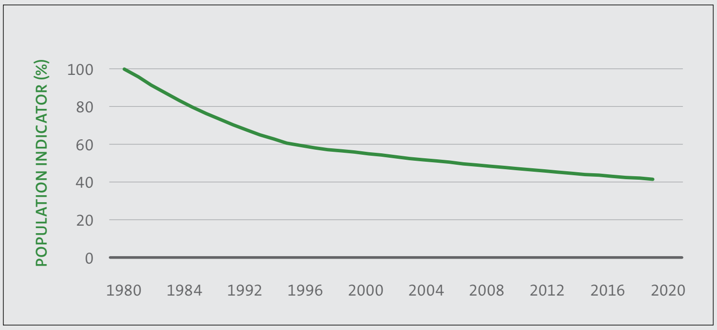

Figure 15. The Farmland Bird Index, developed by the Pan-European Common Bird Monitoring Scheme (PECBMS) (EBCC/ BirdLife/RSPB/CSO), shows a continuing decline in common farmland birds in Europe.

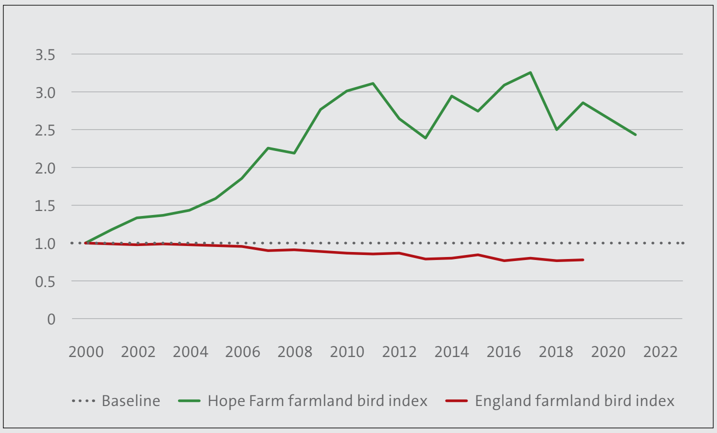

Figure 16. Farmland Bird Index at Hope Farm, England, where intensive agriculture has been converted to a more wildlife-friendly approach (trend in green), compared to overall Farmland Bird Index in England (trend in red) (RSPB)[37].

rewilding as an option for land management within agricultural policies and using rewilding approaches to implement ecosystem regeneration policy targets could also complement climate mitigation and adaption strategies [19,20,22] and support a more successful implementation of the target to expand coverage of Natura 2000 sites on land and sea, by 8% and 3% respectively by 2030 [23]. Within freshwater systems, there are opportunities to help to restore ecosystems, flood regimes and the natural functions of rivers, through rewilding floodplain and riverine habitats. An example of which is being attempted by the long-term initiative on the River Meuse on the Dutch-Belgian border [24], which could demonstrate that rewilding can support the EU Biodiversity Strategy target to restore 25,000 km of free-flowing rivers by 2030 [5].

AGRICULTURAL POLICIES AND LAND ABANDONMENT TRENDS – SPACE FOR REWILDING?

Within Europe, where over half of EU land cover is used for agricultural purposes [25], there is an increasing trend for rural depopulation [19,26], creating two areas of interest for large scale rewilding: agricultural and land abandonment policies [27]. Previously, the EU Common Agricultural Policy (CAP) used a range of CAP tools to incentivise the usage of unproductive or marginal lands for agricultural purposes, rather than to leave the land either unaltered or managed with biodiversity in mind [28,29]. This represented a missed opportunity for rewilding (e.g. trophic rewilding – using large herbivores to restore naturalistic grazing processes [20]) to create or maintain a diverse patchwork of habitats around the agricultural landscape, such as might be beneficial for ecosystem services and biodiversity [15,30]. A review of the CAP was completed to align it closer to the environmental and climate objectives of the EU's Post-2020 plan [25,29].

The ongoing trend of land abandonment within rural areas provides opportunities for rewilding that can ultimately benefit local communities (e.g. through tourism and nature-based economies), slowing or reversing rural depopulation and preserving culturally important landscapes [27,31]. Smallholdings and family farms are important for local employment and landscape management within rural Europe [32] and can be compatible with rewilding and wildlife comeback. Some criticism of rewilding (especially of passive rewilding) has pointed to land abandonment leading to increased homogeneity in the landscape and scrub-fuelled wildfires. However, depending on the landscape and ecosystem, agricultural policies could be developed to incentivise ecosystem service-minded practices [20] (e.g. subsidising schemes which encourage large herbivore grazing to reduce the dominance of homogenous scrub and afforestation linked to wildfires [33]) and maintain livelihood opportunities in rural areas (e.g. adding value to products with 'wildlife-friendly' certification [34] and creating jobs linked to wildlife tourism [35]).

BOX 5

Rewilding of abandoned land and wildlife comeback

Since the Chornobyl nuclear accident in Ukraine in 1986, an exclusion zone has been observed as a public safety measure [39]. This area of approximately 4,200 km^2 of abandoned farmland and forest across Belarus and Ukraine has become an unintentional site for rewilding.

An evaluation of the Belarussian long-term monitoring data in 2015, reported increasing relative abundances of comeback species such as Wild boar, Roe deer, Red deer, Eurasian elk and Grey wolf, irrespective of radiation, increased scrub coverage and annual wildfires [40]. The Grey wolf has fared especially well with relative abundance seven times higher than within other Belarussian reserves. With the absence of human activity, remote sensing data documented land cover types changing in composition from open, agricultural land to scrub, forested and re-wetted areas [41]. In doing so, wetland specialist bird species such as the Greater spotted eagle (*Clanga clanga*) and White-tailed eagle (previously extinct in the area), increased in abundance [41]. The lack of forest management and increased scrub, together with climate change, has been linked to an increased likelihood of wildfires within the area, and in 2020, a large-scale wildfire covering approximately 870 km^2 was recorded [39].

However, such events may be considered to constitute natural disturbance, contributing to the maintenance of overall habitat heterogeneity and species diversity. Increasing relative abundance of mammal and bird species aside, an in-depth study initiated in 2015 [42] to evaluate the regeneration of ecosystem services within the Ukrainian proportion of the exclusion zone was in progress prior to the recent Russian military invasion. The future of this study and the ongoing recovery of species in this unique area is now much less certain.

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Conclusion

Nearly 10 years after the first Wildlife Comeback in Europe report was published in 2013, we have expanded our analysis of recovering species in Europe with an additional 13 European vertebrates (including one from a new taxonomic class), to present an analysis of 50 species. Our main findings are summarised below.

WILDLIFE CONTINUES TO COMEBACK

- Positive trends in both range size and abundance have continued for most of the species first analysed in 2013.
- Among those mammal species analysed for this report, the largest increases in range size and relative abundance were seen in the Eurasian beaver (*Castor fiber*). Overall, herbivore species showed more positive trends than carnivores.
- Among the birds, the Barnacle goose (*Branta leucopsis*) showed the greatest increase in range size and abundance.

EVIDENCE FOR STABILISATION AND SOME DECLINES

- Some species are no longer increasing. One mammal (Eurasian otter *Lutra lutra*) and six bird species (Roseate tern *Sterna dougallii*, Cinereous vulture *Aegypius monachus*, Lesser kestrel *Falco naumanni*, White-headed duck *Oxyura leucocephala*, Saker falcon *Falco cherrug* and Eastern imperial eagle *Aquila heliaca*) show recent declines in range size.
- Some species' populations may currently be declining despite their previous recovery from historical lows (e.g. Audouin's gull *Larus audouinii*, White-headed duck *Oxyura leucocephala*, and some Eurasian lynx *Lynx lynx* populations).

THE RATE AND PROBABILITY OF RECOVERY

Even for recovering species, long-term increases in population size and range sizes in birds were less likely where there was a greater variety of pressures acting upon populations and when more conservation measures were present. For mammals, increases in abundance were weaker where populations faced pressures or were utilised and stronger where there were conservation measures in place.

- The most important reported reasons for wildlife comeback in Europe include both active species management and passive, natural recovery, indicating that in some cases wildlife can recuperate on its own. Key reasons identified for the recovery of mammal species were *Harvest management* (such as limiting the amount of legal hunting permitted), *Reintroductions and translocations*, *Natural expansion and recolonisation* and *Species ecology*. For birds, *Legal protection* (e.g. from shooting, egg collecting etc. & disturbance), followed by *Site/habitat protection* and *Habitat management and restoration* were the most important factors.
- The most frequently reported limitations to recovery for mammal species were found to *Exploitation* and *Habitat degradation or change*. For bird species, key limits to recovery arose from *Agriculture and aquaculture*, followed by *Transportation or service corridors* and *Human intrusions or disturbance*, as well as the *Unintentional effects of hunting, fishing & persecution*.

OUTLOOK FOR WILDLIFE RECOVERY IN EUROPE

Despite a picture of increasing abundance and expanding distributions for many European bird and mammal species, nearly one in eight birds and about one in five mammals are still at risk of extinction, as well as many other species. This report harnesses data from long-term data sources available for mammals, birds and a single reptile species which aren't widely accessible or in existence for other species groups. More long-term monitoring of underrepresented species groups (fishes, amphibians, invertebrates, plants etc.) are needed to fill gaps in our understanding and to provide a fuller picture of trends in European biodiversity and key factors for recovery.

Furthermore, the results of this report should be viewed in the context of large historical range contractions. In some instances, such as with European carnivores and many bird species, ranges and abundances had already declined dramatically from historical distributions by the mid-20th century. Therefore, wildlife resurgence should be assessed cautiously, as although many species have come back, much of their former range remains unoccupied and many are still below historical abundance levels, having not yet reached the levels necessary to secure viable long-term populations within Europe.

Wildlife comeback from very low numbers is possible in Europe but it brings both challenges and opportunities. Within ecosystems, wildlife comeback can play a role in restoring species assemblages and guilds, regenerating ecosystem functions (e.g. through carnivory or scavenging) and amplifying carbon cycling and storage processes, creating potential for a nature-based solution for climate change to be applied at scale. Across Europe we see old and new approaches for co-existence, from the revival of traditional husbandry methods (e.g. livestock guard dogs) and the growing wildlife watching market (see Figure 16), to the inclusion of wildlife-friendly certification schemes (e.g. "Rewilding" edition of red wine in Portugal).

As the region fights to meet its biodiversity and climate targets over the coming decades, there are exciting opportunities to adopt rewilding approaches, not only to support the regeneration of ecosystem health and in some cases facilitate wildlife comeback, but also to provide economic, social, cultural and health benefits for people.


JAMES RODDIE / SCOTLANDBIGPICTURE.COM

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STAFFAN WIDSTRAND / REWILDING EUROPE

APPENDIX 1

Methods

TAXONOMIC AND GEOGRAPHIC SCOPE

MAMMALS AND REPTILES

Following the methods set out in Deinet *et al* (2013)[1] we collected data on the distribution and population abundance of comeback species over time, drawing this data from published literature. The species list comprised selected species of terrestrial and marine mammals, all of which are believed to have experienced significant comebacks in Europe over the last few decades (18 of the 24 mammal species were previously selected for the 2013 report). Six new species of mammal and one reptile species were additionally selected for inclusion in this report, based upon sufficient availability of data within the Living Planet Index (LPI) Database and trends that suggested populations were increasing on average for that species.

The terrestrial study area was based on the definition presented in the IUCN European Mammal Assessment[2] while for marine populations our study area included the Exclusive Economic Zones (EEZ)[3] of all European nations, Macaronesian islands belonging to Portugal and Spain (Azores, Madeira and Canary Islands), Channel Islands, Mediterranean Sea, Black Sea, Baltic Sea, North Sea and North-East Atlantic. (Figure 1).

BIRDS

Following the same protocol as the Wildlife Comeback in Europe 2013 report, we selected species on the basis that they had "all undergone a recovery after a period of serious decline"[1]. This led us to include the 19 bird species from the 2013 report and an additional six new species.

For the abundance data collection, the geographic scope encompassed the entire European range of the species, as defined above for mammals, but with the addition of Greenland, Turkey, and the Caucasus, where relevant, due to the extended scope of the European Red List of Birds from which much of the population size and trend data is derived. The distribution data comes from the second European Breeding Bird Atlas[4] (EBBA2; www.ebba2.info). The EBBA2 study area covers all of Europe, including the European parts of Russia and Kazakhstan, Transcaucasia, and the whole of Turkey and Cyprus, as well as nearby archipelagos in the Atlantic and Arctic Oceans and in the Mediterranean Sea. The EBBA2 focuses particularly on eastern Europe, where most data in the first European Breeding Bird Atlas[5] (EBBA1) were only based on expert knowledge, rather than targeted field expeditions, and where only rough information on species' ranges was available.

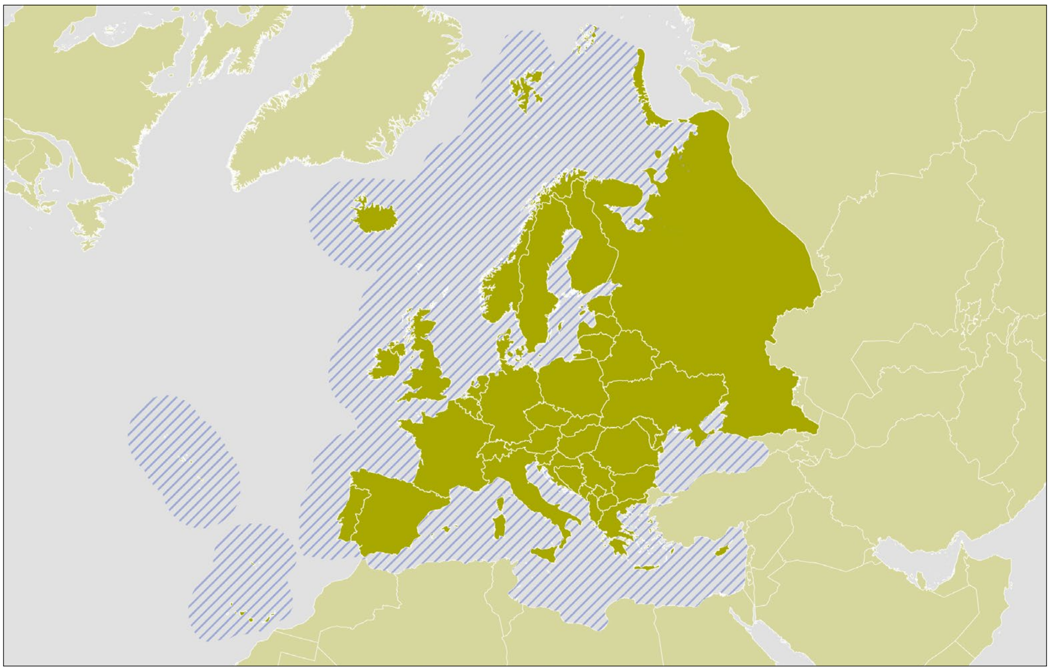

Figure 1. Map illustrating the terrestrial and marine geographic scope of this Wildlife Comeback report. Terrestrial scope (shaded dark green) follows Temple and Terry[2]. Marine geographic scope (hatched area) includes Exclusive Economic Zones (EEZ)[3] of all European nations, Macaronesian islands belonging to Portugal and Spain (Azores, Madeira and Canary Islands), Channel Islands, Mediterranean Sea, Black Sea, Baltic Sea, North Sea and North-East Atlantic.

DATA COLLECTION – ABUNDANCE

MAMMALS AND REPTILES

The following data were used to evaluate trends in relative abundance for each species. Population abundance data for each species were predominantly drawn from the Living Planet Index Database[6,7]. These data have been compiled from published scientific literature, online databases, researchers and institutions, and from grey literature (for full details see Collen, *et al* (2009)[6]). These data were augmented through additional data collection targeted at specific species, countries and locations to ensure good coverage of focal species and locations, and to ensure national and European-wide population estimates were up to date. The following requirements had to be met in order for abundance trend data to be included[6]:

1. a measure or proxy measure of population size was available for at least 2 years, e.g. full population count, catch per unit effort, density
2. information was available on how the data were collected and what the units of measurement were
3. the geographic location of the population was provided and lay within the defined European boundaries
4. the data were collected using the same method on the same population throughout the time series and
5. the data source was referenced and traceable.

Our use of the term 'population' for mammals refers to a species monitored at a particular location and does not always equate to the ecological definition of a population (as per the Living Planet Index Database standards and definitions)

For the species dashboard, national level estimates of current total abundance and population trends were collated for each species from their most recent IUCN Red List assessment[8].

BIRDS

Population estimates for birds were collated from a variety of different sources. Generally, estimates were based on collations of systematic surveys and monitoring schemes undertaken at national level. The main source for population sizes, both overall and at national level, was the European Red List of Birds[9]. However, one of the main sources for waterbird species was also the Waterbirds Populations Portal[10]. In addition, international species Action Plans were also often used. All sources used for population estimates can be found in the individual species accounts.

Population size estimates were collected between 1960 and 2021, depending on the data available, at a Europe-wide level, and for some species, also at the level of geographically distinct populations within Europe. Population estimates were either for the breeding population, measured in breeding pairs, or the wintering population, measured in individuals. Population sizes gathered through the IUCN Red List and presented in the population size dashboard are measured in mature individuals. Where the source for these estimates differed from the IUCN Red List, the population size used was converted to mature individuals, using a 2:1 ratio for converting pairs and 3:2 ratio for converting individuals.

In addition, the Pan-European Common Bird Monitoring Scheme[11] (PECBMS) index was used in the species account graphics, where it was available (two species). This consists of a multiplicative trend over a time period considered, and reflects the average percentage change, from year to year. If the slope value is 1, there is no trend. If the slope value is >1, the trend is positive, and if the slope value <1, the trend is negative.

DATA COLLECTION – DISTRIBUTION

MAMMALS AND REPTILES

We followed the same process as was established within the 2013 report 1 and collated species distribution information for periods defined as "historical" or "Pleistocene" (1500–1900), past (1950–60s) and present (2010–21) for all species in our data set. Herein, these are referred to as "historical", "past" and "present" distributions. Our literature search encompassed scientific papers, textbooks, atlases, species status reports and conservation Action Plans. For the 18 species from the previous report, we re-used the same maps for their historical and past distributions. Present distributions were downloaded from the most recent IUCN Red List species assessment[8]. All species maps were reviewed by species experts and amended, replaced or omitted as was deemed appropriate (see species accounts for details). Species' distributions and spatial analyses were undertaken in ArcGIS Pro 2.9.1 (Esri).

BIRDS

All the information on the distribution changes shown for breeding birds in this report is based on data from the European Breeding Bird Atlas (EBBA2)[4], one of the three main projects of the European Bird Census Council. The EBBA2 describes the distribution of breeding birds in the whole of Europe in the 2010s and documents the changes since the first European atlas (EBBA1), for which data were mainly collected in the 1980s.

The time frame for EBBA2 fieldwork focused on the period from 2013 to 2017. Some exceptions were granted in order to substantially increase the amount of data in areas where fieldwork could not be fully carried out during this period. In these cases, older data were partially used, or the fieldwork period was extended into 2018. The EBBA2 project was based on fieldwork initiatives implemented in each country during the breeding seasons of the study period. EBBA2 methodology essentially consisted of a number of different protocols aimed at properly integrating the information required to generate maps of 50-km squares. Validation of the data was primarily done at the national level and once national datasets had been merged at the European level, data were further examined and improved where possible.

The EBBA2 project collected information on the occurrence of breeding species, which was aggregated by national coordinators at the level of 50-km squares. The grid system implemented in EBBA2 was the 50-km Universal Transversal Mercator (UTM) grid used in EBBA1. The study area was divided into 5,303 50-km squares. Birds are mobile species and can be observed far from the areas where they reproduce, e.g. as visitors during migration or post-breeding dispersal. Standardised categories to determine whether a species was a possible, probable or confirmed breeder in the survey area were used for EBBA2 fieldwork. Thus, EBBA2 50-km square range maps showing species occurrence in this report only include squares in which the species was observed, and breeding was reported in at least one of these three categories.

DATA ANALYSIS – ABUNDANCE

MAMMALS AND REPTILES

For the mammal and reptile species included in this report, we calculated changes in relative abundance, which captures the rate at which wildlife populations are changing over time on average. Some of these populations may contain many individuals, some very few, but it is the average relative change that we are trying to measure here, rather than the total change in absolute numbers of individual animals. To calculate rates of abundance change in mammal species, we used a method of aggregating population abundance trends developed for the Living Planet Index[1,2]. Since its inception in 1998, this technique has undergone a number of developments (see Ledger, *et al* (2022)[12] for full details and see Collen, *et al* (2009)[6] for the method used here).

A Generalised Additive Modelling framework was used to obtain a modelled trend for each population. Multiple population time-series for a species were aggregated to produce a single species trend using a geometric mean. This trend was converted to an index using the difference between the average change in abundance for one year compared with the preceding year. This produced an index with an initial value set to 1 in 1960 (or the first year of available data). The confidence intervals were calculated using bootstrap resampling of 10,000 iterations to indicate variability in the underlying population trends.

Decadal change was calculated for the 1960s, 1970s, 1980s, 1990s, 2000s and 2010–16 as the difference between the index value of the last and the index value of the first year of the decade. The same process was used to provide confidence intervals for the decadal and overall change. The overall change was drawn as the difference between the index value of the first year of the time series (usually 1960) and the index value in 2016. For the species account overview, this overall change was displayed as the percentage increase since the baseline year (usually 1960 but this varied between species). The average annual growth rates for each species were also calculated and expressed as a percentage change per year. The change per decade and overall change for each species were presented in the same bar charts. For some decades, notably 2010–16, we did not have data for the full 10 years, so these trends should be interpreted with caution.

Assessing data representation

Efforts were also made to collate population data from specific locations or a smaller scale over those at a national or larger scale. This is because the effect of perceived threats and management interventions can be more easily identified at a smaller spatial scale. It is therefore important to understand the extent to which the population and national monitoring data available are representative of each species. To give an indication of the representativeness of each abundance dataset, we calculated two different measures of coverage:

1. Minimum percentage coverage of the total European population: for each species, we averaged the number of individuals in each time series collected over the study period and summed those averages. We then divided this by the latest European population estimate and multiplied it by 100. We excluded from this analysis any time series which did not directly represent individuals, such as density estimates, as we could not assume the number of individuals present. For this reason, we describe this representation as the minimum percentage coverage of our data set. For some of the species, we were not able to calculate this metric as an accurate estimate for the total European population was not available.

2. Country coverage: calculated as the percentage of countries for which data were available compared to the number of European countries in which the species occurred (as listed in the IUCN Red List [8]).

Limitations of relative abundance trends

It is important within a study such as this one, to recognise the limitations of the data set collected as well as what can and cannot be inferred from the results:

1. Geographic representation: here we use the data that are available for mammals in Europe to give an indication of general trends for each species, within the countries we have data for. We make it clear which countries are represented and how much of the European population we have trend data for.
2. Temporal representation: the data used for mammals are not from national level systematic monitoring programmes, and so the timeframe and length of time series varies between populations. This means that data are available for a different number of populations each decade (Table 1). To minimise this issue, we exclude any populations which have a significant effect on the trend as a result of a data effect rather than a genuine trend.
3. While both relative and absolute trends in abundance tell us the trajectory that a population might be moving in, they do not give any information about where that population is in relation to some pre-defined target population size, or how a population is functioning in its environment. Historic reference points are important, which is why we also use range maps and a description of historical abundance.

BIRDS

The percentage change of the population size shown in the species account dashboard was calculated from the difference between the minimum population estimate recorded during the time period for which data were available for each species (i.e. the beginning of population recovery, occurring anywhere between 1960 and 2002) and the most recent population estimate available (ranging from 2016 to 2021). The annual growth

Table 1. Number of populations included within the LPI trend analysis per species, overall and by decade (From the Living Planet Index Database [13]).

Order	Species	Species common name	Total number of populations	Number of populations per decade					
				1960s	1970s	1980s	1990s	2000s	2010–16
Artiodactyla	*Alces alces*	Eurasian elk	55		11	11	54	51	46
Artiodactyla	*Bison bonasus*	European bison	20	1	8	8	17	19	10
Artiodactyla	*Capra ibex*	Alpine ibex	6		3	3	3	6	6
Artiodactyla	*Capra pyrenaica*	Iberian wild goat	9	2	3	4	3	8	1
Artiodactyla	*Capreolus capreolus*	Western roe deer	59	3	13	18	52	52	43
Artiodactyla	*Cervus elaphus*	Red deer	63	5	17	20	58	60	44
Artiodactyla	*Rupicapra pyrenaica*	Southern chamois	31		2	17	28	31	13
Artiodactyla	*Rupicapra rupicapra*	Northern chamois	31	5	8	22	23	30	23
Artiodactyla	*Sus scrofa*	Wild boar	73	2	9	11	68	70	63
Carnivora	*Canis aureus*	Golden jackal	4					3	3
Carnivora	*Canis lupus*	Grey wolf	86	2	17	21	25	27	12
Carnivora	*Gulo gulo*	Wolverine	19			3	17	17	13
Carnivora	*Halichoerus grypus*	Grey seal	18		4	11	14	16	5
Carnivora	*Lutra lutra*	Eurasian otter	31		3	17	24	25	6
Carnivora	*Lynx lynx*	Eurasian lynx	75	6	19	21	62	67	53
Carnivora	*Lynx pardinus*	Iberian lynx	7			1	1	3	5
Carnivora	*Martes martes*	Pine marten	25			7	16	21	16
Carnivora	*Meles meles*	European badger	69	2	5	10	10	61	58
Carnivora	*Phoca vitulina*	Harbour seal	32	4	10	20	25	27	9
Carnivora	*Pusa hispida*	Ringed seal	12		5	6	7	7	3
Carnivora	*Ursus arctos*	Brown bear	67	7	11	15	48	60	48
Cetacea	*Megaptera novaeangliae*	Humpback whale	2				2	1	
Chiroptera	*Myotis emarginatus*	Geoffroy's bat	12		1	4	10	12	8
Rodentia	*Castor fiber*	Eurasian beaver	98	5	10	11	51	51	86
Testudines	*Caretta caretta*	Loggerhead turtle	14			7	12	14	2

rate (% increase per year) for each species was obtained by taking the overall percentage change and calculating the average change across each year within the time period. Although this method calculates its rate of recovery over the long-term, its trend direction may differ to that presented in the European Red List trend or the current trend indicated in the text. These differences are due to differing time periods on which the trends are calculated: Red List trends are calculated over three species' generation lengths, and current trends vary in length, but usually illustrate a much shorter-term period.

DATA ANALYSIS – DISTRIBUTION

MAMMALS AND REPTILES

Recent range changes: past (1950–1960s) to present (2010–2021)

For each species, the geodesic range area (km^2) was calculated at two time points (past and present). These areas were then used to examine changes in range area. The percentage range change was calculated from the difference between the past and the present geodesic area.

Range change maps were produced for all species, depicting range persistence, expansion and contraction over the mid-last century period (except for the Northern chamois which is 1930 and the European bison which is 1971) until the present.

Species richness maps

We constructed species richness maps for mammal species using hexagonal grids of 50 km (distance between centre of hexagons) covering the study area. For overall species richness, the number of species overlapping grid cells from present or past distributions were counted, giving a number of species present per cell. For change maps ('gains' and 'losses') only those areas where species had expanded or contacted (from past to present) were counted. These analyses were only conducted for species where experts judged the past and present maps were of sufficient accuracy to assess changes in range (12 species). These analyses were then repeated to separately assess ungulate and carnivore species.

BIRDS

Addressing change in the breeding distribution of species over the approximately 30 years since the EBBA1 was an important objective of the EBBA2 project and the results of this were used to show distributional change in this report. The two atlases differ greatly, particularly in terms of geographical coverage. For this reason, as in EBBA2, the range change maps used in this report were restricted to a well-defined, continuous geographical area based on areas properly covered in EBBA1 [4].

The range change maps give an impression of the spatial pattern of gains and losses in the distribution of a species, but do not quantify the magnitude of change. For the particular purpose of this publication, the data from EBBA1 and EBBA2 were re-analysed to determine the percentage of change between these two atlases with respect to the situation in the 1980s. The formula used was:

$$\textit{Change since EBBA1} = \frac{\textit{no. sq EBBA2 - no. sq EBBA1}}{\textit{no. sq EBBA1}}$$

It is important to note that Change since EBBA1 was not calculated using all the squares in which the species has been reported to be present in either EBBA1 or EBBA2, but only using a subset of squares that were considered sufficiently covered in terms of intensity of fieldwork (see Keller, *et al* (2020) [4] for details).

Range change maps and percentages should be interpreted with caution. The intensity of coverage per 50-km square was not the same in the two atlases. For simplification, range change maps do not incorporate information on this parameter as it was done in EBBA2 to identify squares insufficiently covered [4]. Moreover, gains in distribution are more easily documented than losses, as one breeding record is sufficient to mark a new square. Losses, on the other hand, only become visible when a species has disappeared completely and are often preceded by a population decline. Therefore, we recommend consulting the species accounts in the EBBA2 book [4] and the EBBA2 website (https://ebba2.info/) for more detailed information on changes for the 25 bird species included in this report. Despite these general warnings, we believe that the methods applied here adequately document overall trends in the distribution of these breeding bird species between EBBA1 and EBBA2, and while a few of these calculated changes could still be due to differences in survey effort, the direction of the calculated changes are clear and unambiguous.

Finally, in addition to breeding range change maps for each of the 25 bird species included in this report, a map that shows the overall breeding range change in the number of these species occurring in the analysed 30-year period was produced. This map simply shows the difference between the number of these species reported to breed in each 50-km square in EBBA2 and EBBA1. Warnings for the proper interpretation of maps defined at the species level should also be applied to the overall change map.

DATA ANALYSIS – DRIVERS OF RECOVERY AND LIMITS TO GROWTH

The analysis presented in this section is taken from the manuscript "Recovering birds and mammals across Europe continue to be negatively impacted by threats but benefit from conservation measures." Full details of the data and methods used, as well as the full results are available in Gray, *et al* (2022)[14].

MAMMALS

We excluded the Loggerhead turtle for this analysis as it is the only reptile species. For the 24 mammal species selected, we had a data set containing 940 populations across 38 countries. For each population, we calculated a response variable measuring the relative change in population size since 1960. Annual rates of population change were calculated following the Generalised Additive Modelling framework in Collen, *et al* (2009)[6], using the rlpi package (https://github.com/Zoological-Society-of-London/rlpi). These annual rates were summed to give a logged value of total change in abundance for each population.

We used ancillary information collated at the population level on management interventions, documented reasons for why a population had increased, current pressures to the population and whether or not the population was being utilised. This information was recorded directly from the population data source only. Where there was no information in the data source for these categories we coded 'unknown'.

We ran a linear mixed effects model to test for a relationship between total abundance change and six explanatory variables: (a) whether the population receives targeted management, b) whether individuals or parts of individuals are regularly intentionally removed from the population in a way that may or may not be sustainable and/or legal, indicating that it is "utilised", c) whether one or more threats are known to impact the population, d) whether the population is found within a protected area, e) time series length and f) Log transformed body mass, with both species and country included as random effects. Model selection was performed based on AIC values. We present the results of the best model in an infographic which shows that the relative (positive) change in population size of recovering mammals is greater where those populations are managed, and lower where the population is utilised or known to be impacted by threats.

Data concerning pressures and reasons for recovery were derived from the Living Planet Index database, where pressures are recorded at the population level from the original sources of the time-series[14]. To illustrate the main ongoing pressures recorded for mammal populations, we summarised the pressure types into seven categories (overexploitation, habitat loss, habitat degradation, disease, invasive species, climate change and pollution) and presented the frequency with which each threat type was recorded (some populations had multiple threat types recorded). To document the reason recorded for mammal population recoveries, we coded the data according to 18 categories, in order to distinguish between site-based measures, species-specific measures, law and policy, and more passive drivers such as natural range expansion. We presented the frequency with which each reason for recovery was recorded (some populations had multiple reasons recorded).

BIRDS

We excluded two of the 25 bird species featured in our report for this analysis. We excluded the Pink-footed goose (*Anser brachyrhynchus*) as it does not breed in the EU and the Audouin's gull (*Larus audouinii*) which has experienced a rapid decline in recent years, despite a longer-term increase. Article 12 data for birds reported by EU Member States in 2019 as part of the Birds Directive were downloaded on 01/04/2021[15]. The data set includes information on trends in population size and range (both long and short term), pressures (factors currently affecting the species), and conservation measures per country. We extracted breeding season data on population and range change, pressures and conservation measures reported for the 23 focal species. For each species within each country, we calculated the diversity of pressures and conservation measures listed, by summing the number of level 1 categories listed.

We calculated four response variables. The first was a binary variable capturing whether the population size was reported as increasing or decreasing. The second response variable was the magnitude of change in population size. The third was a binary variable capturing whether the species range was reported as expanding or shrinking. The fourth was the magnitude of change in the range of the species. We used linear mixed effects models to test for a relationship between each of the response variables and the number of level 1 pressures and conservation measures categories, as well as the interaction between them.

We present the results of the best model in an infographic which shows that for available long-term trends in population and range size, there was strong evidence that as a greater diversity of pressures are reported, there is a decline in the probability that bird populations are increasing as opposed to decreasing. There was also some evidence that a larger range of conservation measures was associated with a higher probability of increases in abundance or range-size.

To illustrate the pressures that still constrain the recovery of bird populations, we recorded relevant data for bird species from the IUCN European Red List of Birds and Article 12 of the EU Birds Directive, as well as other sources used in the bird species accounts, such as Species Action Plans. Data on pressures in the species accounts extracted from the Article 12 reporting are named 'threats', but actually refer to ongoing pressures (as defined in the Article 12 data). Although the naming of the pressures generally follows the IUCN threats categorisation, where specific pressures (such as 'wetland drainage and degradation') were identified for several species, these were also included. It should be noted that pressures reported under Article 12 may be subject to reporting biases. For example, while some countries may have reported climate change as an ongoing pressure, others may not at all. This may not mean that climate change is not an ongoing pressure, but rather it is not seen as a priority for the reporting authority, or there may not be expertise in this pressure.

We summarised the main drivers of recovery across bird species, using the same methods as for the pressures. All sources used to illustrate pressures and conservation measures can be found in the individual species accounts.

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MARVIN LAYNES / SKUA NATURE

APPENDIX 2

Table 1. Relevant international Directives and Conventions for the legal protection and conservation of wildlife (adapted from BirdLife International 2004[1])

Legal instrument	Aim	Addendums	Definitions
EU Council Directive on the Conservation of Wild Birds (79/409/EEC, 'EU Birds Directive')	To protect all wild birds and their habitats, e.g. through the designation of Special Protection Areas (SPAs)	Annex I	Species subject to special conservation measures concerning their habitat in order to ensure their survival and reproduction in their area of distribution. Member states shall classify the most suitable territories in number and size as Special Protection Areas for the conservation of these species, taking into account their protection requirements in the geographical sea and land area where this Directive applies
		Annex II	1. Species may be hunted in the geographical sea and land area where the Directive applies
			2. Species may be hunted only in member states in respect of which they are indicated
		Annex III	1. Member states shall not prohibit 'trade activities'
			2. Member states may allow 'trade activities'
			These activities are prohibited for all other species of naturally occurring wild birds in the European territory of EU member states
EU Council Directive on the conservation of natural habitats and of wild fauna and flora (92/43/ EEC, 'EU Habitats Directive')	To contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora of community interest	Annex II	Species whose conservation requires the designation of Special Areas of Conservation
		Annex IV	Species in need of strict protection
		Annex V	Species whose taking in the wild and exploitation may be subject to management measures
Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention)	To maintain populations of wild flora and fauna with particular emphasis on endangered and vulnerable species, including migratory species	Appendix II	Strictly protected fauna species
		Appendix III	Protected fauna species
Convention on the Conservation of Migratory Species of Wild Animals (CMS, or Bonn Convention)	To provide a framework for the conservation of migratory species and their habitats by means of, as appropriate, strict protection and the conclusion of international agreements	Appendix I	Species in danger of extinction throughout all or major parts of their range
		Appendix II	Species which would benefit from international cooperation in their conservation and management
		Appendix III	Species for which Agreements should be concluded covering their conservation and management, where appropriate by providing for the maintenance of a network of suitable habitats appropriately disposed in relation to migratory routes
Agreement on the Conservation of African-Eurasian Migratory Waterbirds (AEWA, under CMS)	The conservation of African- Eurasian migratory waterbirds through coordinated measures to restore species to a favourable conservation status or to maintain them in such a status	Annex 2	Waterbird species to which the Agreement applies. Species are classified into Columns (see Annex 3) according to the degree of protection that signatories are expected to implement and then further categorised according to the level of threat.
		Annex 3	Action Plan and Table 1 (the classification of species and basis for implementation of the Action Plan)
Raptors Memorandum of Understanding (Raptors MoU, under CMS)	To take co-ordinated measures to achieve and maintain the favourable conservation status of birds of prey throughout their range and to reverse their decline when and where appropriate	Annex I	African-Eurasian migratory birds of prey
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	To ensure that international trade in specimens of wild animals and plants does not threaten their survival	Appendix I	Species that are most endangered among CITES-listed animals and plants. CITES generally prohibits commercial international trade in specimens of these species
		Appendix II	Species that are not necessarily now threatened with extinction, but that may become so unless trade is closely controlled
EU regulation of trade of fauna and flora (Council Regulation (EC) No 338/97 and 865/06 as amended)[2]	To protect EU native species of wild animals and plants from being threatened by trade – internationally or internally within the EU	Annex A	All CITES Appendix I species except where member states have entered a reservation Some CITES Appendix II and III species, which EU has adopted stricter measures for domestically
		Annex B	All other CITES Appendix II species except where member states have entered a reservation
		Annex C	All other CITES Appendix III species, except where member states have entered a reservation
		Annex D	Some CITES Appendix III species for which the EU holds a reservation Some non-CITES species in order to be consistent with other EU regulations on the protection of native species

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APPENDIX 2

Table 2. Summary table of conventions, legislations and protective measures for selected European mammals and reptiles in 2022. Please see the Species accounts for more details and please check the source legislations and conventions for updates.

						EU Habitats Directive		
Class	**Order**	**Species**	**Species authority**	**Species common name**	**Level of protection varies with subspecies (*) or country (†)**	**Annex II**	**Annex IV**	**Annex V**
Mammalia	Artiodactyla	*Alces alces*	(Linnaeus, 1758)	Eurasian elk				
Mammalia	Artiodactyla	*Bison bonasus*	(Linnaeus, 1758)	European bison		●	●	
Mammalia	Artiodactyla	*Capra ibex*	Linnaeus, 1758	Alpine ibex				●
Mammalia	Artiodactyla	*Capra pyrenaica*	Schinz, 1838	Iberian wild goat				●
Mammalia	Artiodactyla	*Capreolus capreolus*	(Linnaeus, 1758)	Western roe deer				
Mammalia	Artiodactyla	*Cervus elaphus*	Linnaeus, 1758	Red deer	*	●	●	
Mammalia	Artiodactyla	*Rupicapra pyrenaica*	Bonaparte, 1845	Southern chamois	*	●	●	●
Mammalia	Artiodactyla	*Rupicapra rupicapra*	(Linnaeus, 1758)	Northern chamois	*	●	●	●
Mammalia	Artiodactyla	*Sus scrofa*	Linnaeus, 1758	Wild boar	*			
Mammalia	Carnivora	*Canis aureus*	Linnaeus, 1758	Golden jackal				●
Mammalia	Carnivora	*Canis lupus*	Linnaeus, 1758	Grey wolf	†	●	●	●
Mammalia	Carnivora	*Gulo gulo*	(Linnaeus, 1758)	Wolverine	†	●	●	
Mammalia	Carnivora	*Halichoerus grypus*	(Fabricius, 1791)	Grey seal	†	●		●
Mammalia	Carnivora	*Lutra lutra*	(Linnaeus, 1758)	Eurasian otter		●	●	
Mammalia	Carnivora	*Lynx lynx*	(Linnaeus, 1758)	Lynx	†*	●	●	●
Mammalia	Carnivora	*Lynx pardinus*	(Temminck, 1827)	Iberian lynx		●	●	
Mammalia	Carnivora	*Martes martes*	(Linnaeus, 1758)	Pine marten				●
Mammalia	Carnivora	*Meles meles*	(Linnaeus, 1758)	Eurasian badger				
Mammalia	Carnivora	*Phoca vitulina*	Linnaeus, 1758	Harbour seal	†	●		●
Mammalia	Carnivora	*Pusa hispida*	(Schreber, 1775)	Ringed seal	*	●	●	●
Mammalia	Carnivora	*Ursus arctos*	Linnaeus, 1758	Brown bear	†	●	●	
Mammalia	Cetacea	*Megaptera novaeangliae*	(Borowski, 1781)	Humpback whale			●	
Mammalia	Chiroptera	*Myotis emarginatus*	(Geoffroy, 1806)	Geoffroy's bat		●	●	
Mammalia	Rodentia	*Castor fiber*	Linnaeus, 1758	Eurasian beaver	†	●	●	●
Reptilia	Testudines	*Caretta caretta*	(Linnaeus, 1758)	Loggerhead turtle		●	●	

Bern Convention			Bonn Convention			CITES		EU regulation of trade of fauna and flora		OSPAR	SPA/BD Protocol	Helsinki Convention	ACCOBAMS	EUROBATS
Appendix I	Appendix II	Appendix III	Annex I	Annex II	Wadden Sea Seals	Appendix I	Appendix II	Annex A	Annex B	Annex V	Annex II			
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Wildlife Comeback in Europe

Opportunities and challenges for species recovery

This report provides a follow up and expansion on the 2013 landmark “Wildlife Comeback in Europe” report, which selected species showing signs of recovery and explored the reasons behind these trends.

A total of 50 European wildlife species have been examined on trends in abundance, range sizes. Based on new analyses, the main drivers for recovery and limitations to growth are described.

The results reinforce the message that wildlife have the potential to rebound and recover within Europe. Natural recolonisation and expansion is occurring for some species. For others, measures such as the legal protection of species and sites are a strong reason behind recovery, especially for birds. Conservation efforts such as species reintroductions and translocations are also important.

Against the backdrop of a climate change crisis and critical decade for ecosystem restoration – we share a synthesis and outlook of wildlife species comeback to support progress and best inform the region’s next steps for further species recovery.

This study on wildlife comeback in Europe was commissioned by Rewilding Europe

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