

N° 11

Science Review



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GBIF SECRETARIAT

Foreword



JOE MILLER
GBIF Executive Secretary

Welcome to GBIF Science Review No.11!

This compendium again offers a glimpse of the depth and extent of scientific research that the GBIF network supports every day. In 2023, the authors who rely on GBIF published an average of 34 peer-reviewed, GBIF-enabled papers each week. That rate makes it impossible for a curated selection of 50 summaries to be more than a fraction of the work, but we hope that together they highlight some of the most important, innovative and insightful articles from recent months.

So if the exercise of reading Science Review No.11 is taking parts to stand in for the whole, the same applies to the feature section that concludes the issue. GBIF-enabled research on the topic of climate change is never simply about biodiversity; instead, these papers reveal the range of researchers' efforts to understand and reveal the complex and dynamic interplay between climate change and biodiversity.

About the Science Review



DANIEL NOESGAARD
Science Communications
Coordinator

GBIF-mediated data is now used in nearly six papers every single day of the year. While this presents a bit of a logistical challenge for those of us attempting to track and categorize these papers, we are spoiled for choice when picking interesting papers to feature. There are just so many!

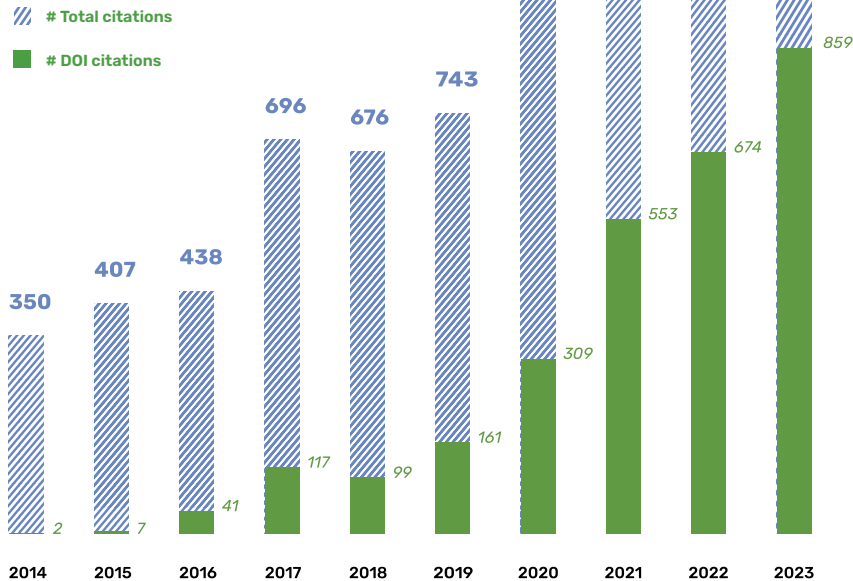
On the flip side, this also means that we can't feature all the papers we would like to. But our approach remains to offer a selection of the best and most interesting papers from all over the world to showcase the breadth of scientific topics and disciplines benefiting from free and open data from GBIF.

If you have thoughts or feedback on the Review—or if you feel we've missed something—please do get in touch.

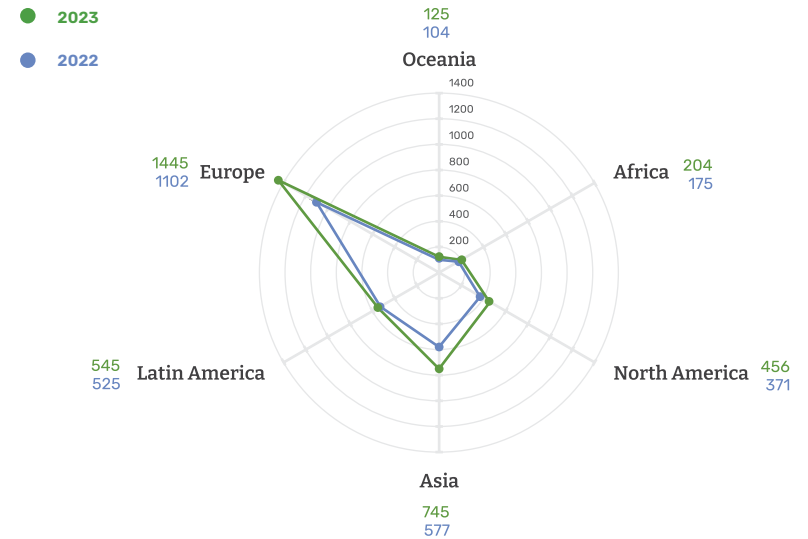
Uses and trends

These visualizations of the use of GBIF-mediated data reveal more than the growing number of peer-reviewed publications supported each year. The overlay on the graph below emphasizes authors' increasing use of DOI-based citations, a crucial practice for maintaining data provenance and scientific transparency. At right, the charts reveal the expanded geographic distribution of institutions whose researchers apply the data in their research. Each trend highlights GBIF's widening sphere of influence and impact on scientific research.

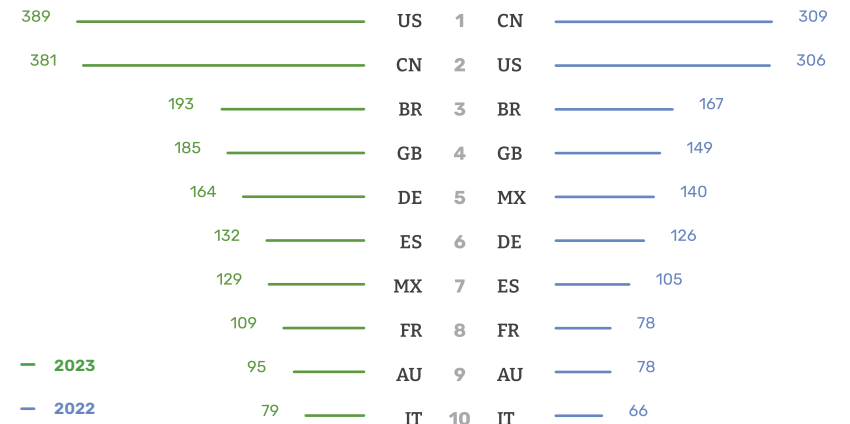
Annual number of peer-reviewed articles using GBIF-mediated data



Peer-reviewed articles by region



Peer-reviewed uses by country

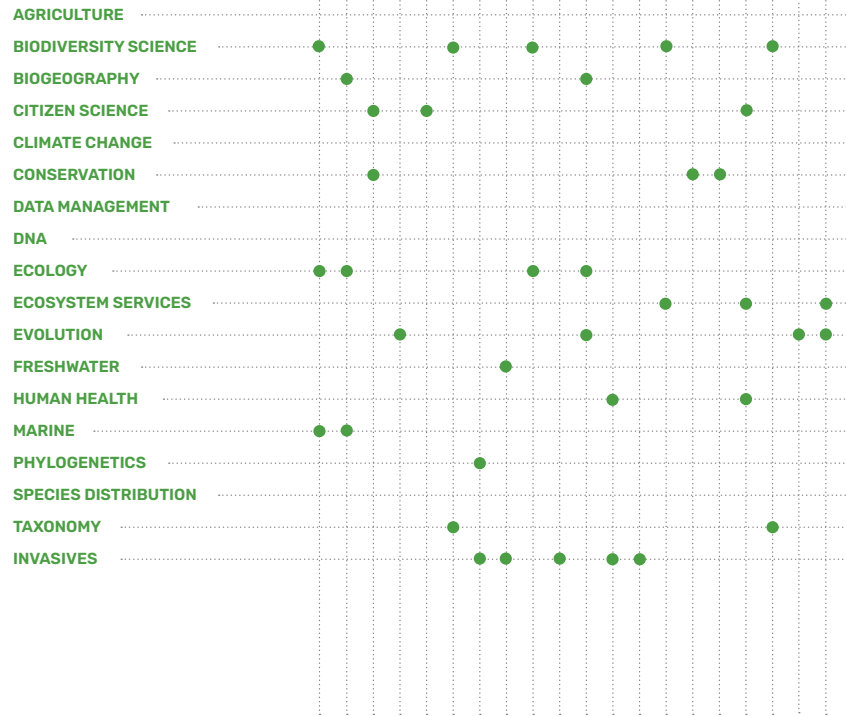


Navigation

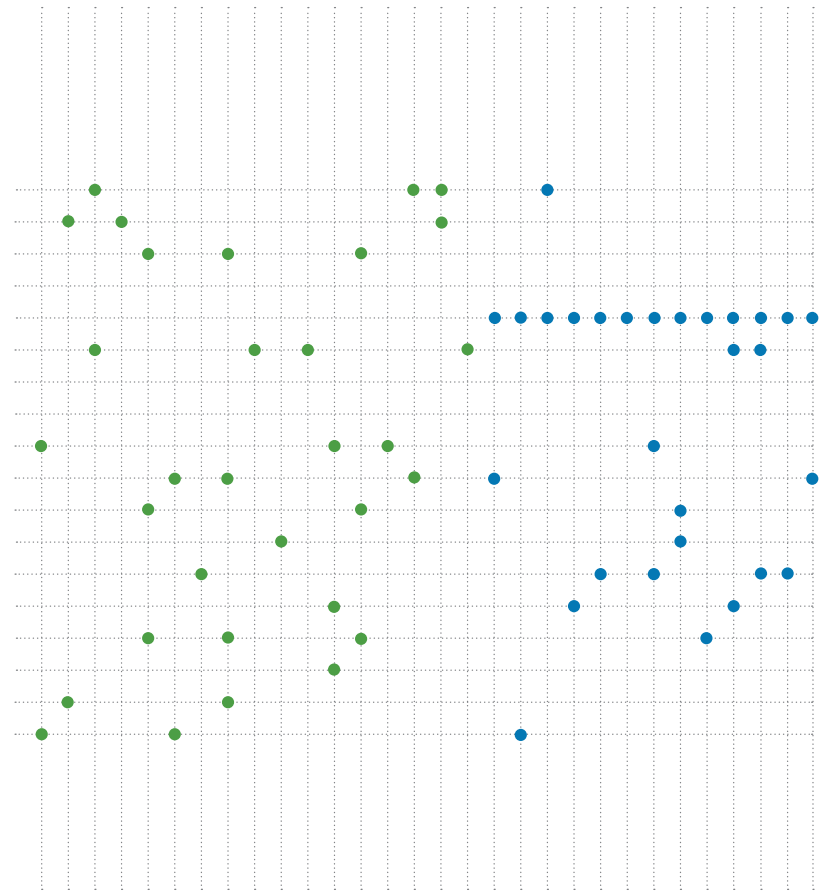
Summary number



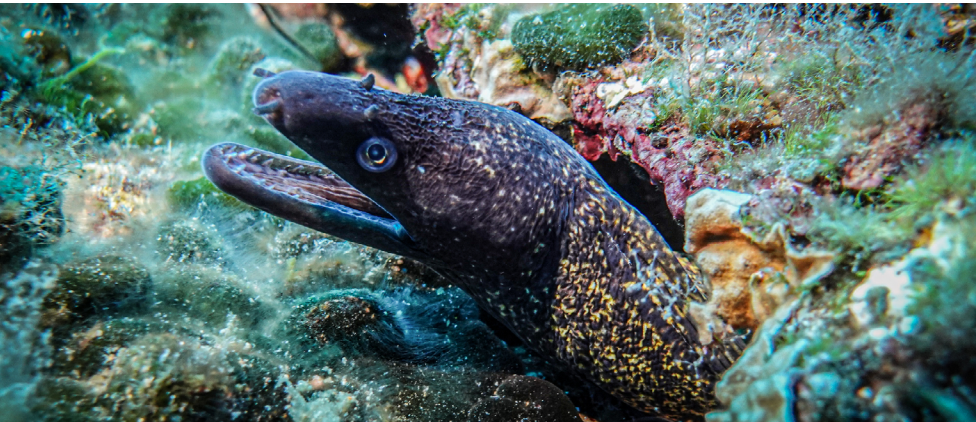
Topics



Page number



Enhancing marine biodiversity data collection using commercial ferry network



Black moray - *Muraena helena* Linnaeus, 1758 - observed in near Komiza, Croatia by marieaurelia CC BY-NC 4.0

MARINE

ECOLOGY

BIODIVERSITY SCIENCE

Simulation study shows that sampling from commercial vessel routes can capture biodiversity effectively, with potential global coverage using automated eDNA sampling

• **4,140**
SPECIES OCCURRENCES

The monetary and logistical challenges of collecting biodiversity data in ocean environments has led to the underrepresentation of marine species in publicly available data. And with up to 50 per cent being collected only from coastal areas, novel sampling approaches are essential for scaling up surveys to represent marine communities more accurately.


Using the Mediterranean and its community of marine predators as a study case, this paper explored whether


sampling biodiversity along commercial ferry routes can yield less biased biodiversity survey outcomes. As a baseline representation of “perfect knowledge”, the authors built stacked species distribution models of 43 species based on six environmental variables and all available occurrence records from GBIF and OBIS.


Selecting 15 Mediterranean ferry routes of varying length, the authors simulated sampling of different sizes and strategies, using the baseline occurrence dataset as the source. They then created new distribution models based on the ferry route network, assessing correlation between these and the “perfect knowledge” model.


The ferry route model was more closely related to the “perfect knowledge” model than when randomly sampling across the entire Mediterranean, showing that a geographically biased sampling strategy can work, provided that it covers wide areas and diversified habitats.


While the study does not address specific sampling methods, the findings are clearly relevant for upscaling sampling for emerging biodiversity monitoring techniques such as automated eDNA sampling. The approach could also be expanded to other commercial vessel types, potentially covering the entire global shipping network.

Boyse E, Beger M, Valsecchi E, Goodman SJ. 

United Kingdom, Italy 

Sampling from commercial vessel routes can capture marine biodiversity distributions effectively 

Ecology and Evolution 

doi.org/10.1002/ece3.9810 



Tropical seagrass dispersal: active or passive?



Halodule wrightii Asch. observed near Luanda, Angola by Ester Serrao (CC BY-NC 4.0)

ECOLOGY

MARINE

BIOGEOGRAPHY

16,000
SPECIES OCCURRENCES

Genetic analysis and biophysical modelling of tropical pan-Atlantic species reveal distinct genetic clusters and evidence suggesting passive oceanic dispersal improbable

Marine plants can passively disperse with the help of abiotic factors such as waves, tides and currents or by passing through the digestive systems of fish, seabirds or turtles. The processes mediating such transport and the effects on connectivity between populations are, however, poorly understood.

Halodule wrightii is the only seagrass species distributed along both east and west tropical Atlantic shores, and the authors of this study, used it as a model organism for

assessing connectivity across an entire ocean through genetic analysis and biophysical modelling.

To quantify genetic diversity among and between populations, the authors sampled shoots from 32 Atlantic localities, extracting DNA for genotyping. They used GBIF-mediated occurrences of *H. wrightii* combined with data of ocean currents to build a biophysical model they then used to simulate 10 years of potential propagule dispersion.

The analysis revealed three distinct genetic clusters in the Gulf of Mexico, West Atlantic and West Africa, respectively, suggesting limited gene flow and connectivity between these populations. The ocean current dispersal model, which simulated the delivery of more than 600,000 particles, showed sharp long-distance declines and no probability of connectivity between the geographically distant clusters.

Overall, these findings suggest that long range dispersal of *H. wrightii* is not mediated by ocean currents, lending support an an alternative hypothesis involving active vectors like grazers.

2

Tavares AI, Assis J, Larkin PD, Creed JC, Magalhães K, Horta P, et al.

United States, São Tomé and Príncipe, Portugal, Norway, Guinea-Bissau, Mauritania, Netherlands, Brazil, Angola

Long range gene flow beyond predictions from oceanographic transport in a tropical marine foundation species

Scientific Reports

doi.org/10.1038/s41598-023-36367-y



Risks and rewards: using citizen science for threatened species monitoring



Critically endangered gharial (aka fish-eating crocodile) - *Gavialis gangeticus* (Gmelin, 1789) observed near Narayani, Nepal by shanes (CC BY-NC 4.0)

CONSERVATION

CITIZEN SCIENCE

✦ **20,220,581**
SPECIES OCCURRENCES

Researchers use case study of iNaturalist data to assess potential of citizen science in aiding conservation of threatened species

Monitoring threatened species is crucial to effective conservation, but requires rigorous collection of long-term data at large spatial scales, which is both time-consuming and expensive. The global increase of data collected and shared through citizen/community science (CS) programmes-like such as *iNaturalist*- may help this process.

In this study, researchers assessed the risks and rewards of using CS data for threatened species monitoring. They downloaded all verified, research-grade *iNaturalist*

observations shared through GBIF, then extracted threatened species records using the *IUCN Red List*.

In terms of risks, the resulting dataset revealed evidence of taxonomic bias towards birds, plants and mammals. However, compared to professionally collected datasets, the CS data had a high percentage of “less charismatic” species. Along with dramatic seasonal peaks in observations, the authors noted that CS observations tended to cluster in easily accessible locations in urban and cropland environments, and nearly 60 per cent of all records came from just five countries (USA, Canada, Mexico, Russia and New Zealand). The authors also noted dramatic seasonal peaks in observations.

On the positive side, CS data matched or even exceeded threatened species richness in some regions, recording up to four times more vertebrate species than previously known. Thirty per cent of observations took place in areas presumed as largely private, not immediately accessible to public monitoring. Overall, more than 20 per cent of all *iNaturalist* users contributed data about at least one threatened species.

In conclusion, the authors suggested that capitalizing on CS data might substantially shift the global conservation landscape provided that risks are sufficiently mitigated. They recommended that practitioners incorporate rigorous data quality controls while improving CS data through training, engagement and empowerment of volunteers and their local communities.

Soroye P, Edwards BPM, Buxton RT, Ethier JP, Frempong-Manso A, Keefe HE, et al.

Canada

The risks and rewards of community science for threatened species monitoring

Conservation Science and Practice

doi.org/10.1111/csp2.12788



Tinamou birds: using egg coloration as mating signals



Eggs of Tinamou species: *Eudromia elegans*, *Tinamus solitarius*, *Rhynchotus rufescens* and *Crypturellus tataupa*.
Photos via iNaturalist by [nicochimento](#), [rawelly](#), [DANIEL OSCAR MOLINA](#) and [Nicolas Olejnik](#) (CC BY-NC 4.0)

EVOLUTION

364,462
SPECIES OCCURRENCES

Study reveals evolutionary links between tinamou egg colours, song patterns and habitat, providing support for mating signal hypothesis

Birds' coloured plumage and song often serve to signal, attract and recognize mates. Tinamous (order [Tinamiformes](#)), which are adapted for camouflage, are not particularly colourful birds. However, the 48 extant species of tinamous produce eggs in an exceptional array of colours.

Researchers in this study proposed that tinamou egg coloration serves as a mating signal for attraction and recognition. To support this hypothesis, they predicted that egg colours coevolved with songs, that the trait was divergently adapted to local habitats, and that species

sharing habitats and similar song patterns thus should have different egg colours.

They used nest photos from citizen scientists and museum specimen records to quantify egg colouration in RGB color space and acquired song data from a previous study, enabling them to quantify frequency and bandwidth in four variables. In order to determine the likelihood of ancestral sympatry (i.e., species sharing ancestors from the same geographic area), they used GBIF-mediated occurrences sorted to ecoregions.

Through statistical testing the authors found significant associations supporting that egg colouration evolved with song as a sensory-driven trait. They also showed that species with likely ancestral sympatry and similar song patterns tended to have different egg colours. Overall, these findings provided strong support for the hypothesis that egg colours act as mating signals for tinamous.

4

Li Q, Chen D, Wang S.

United States, China

Character displacement of egg colors during tinamou speciation

Evolution

doi.org/10.1093/evolut/qpad085



Value of social media and citizen science data in species distribution modelling



Banded demoiselle - *Calopteryx splendens* (Harris, 1780) - observed in Rickmansworth, UK by Neil Shepherd (CC BY-NC 4.0)

CITIZEN SCIENCE

16,395
SPECIES OCCURRENCES

United Kingdom

Comparing biodiversity data from various sources, study shows that social media and citizen science both contribute unique information; if ignored, results may underestimate habitat suitability

With the increase in species occurrences reported through citizen science and other non-traditional monitoring sources, it is important to examine the quality and usefulness of such data and how it compares to traditional sources of biodiversity information.

Using the example of banded demoiselle (*Calopteryx splendens*) in the United Kingdom, researchers investigated how species occurrences vary between sources, and the extent they might be complimentary.

5

They extracted data from GBIF and the [National Biodiversity Network \(NBN\) Atlas](#) as well as several social media platforms, categorizing a total of 17,831 occurrence records based on their type of source.

Overall, roughly half of the data collected on *C. splendens* was unique to its data type. The performance of species distribution models implemented with data from each different source was good and broadly similar across all data types, all having mean temperature and freshwater cover as important predictors.

The model based on traditional sources suggested 50,800 km² of suitable UK habitat, whereas data from citizen science and social media predict ranges of 54,600 km² and 41,500 km², respectively. The combined data produced an estimate of 57,600 km² suitable habitat.

The study showed that while relying on biodiversity data derived from citizen science or social media alone might not be ideal, excluding these sources from analyses of species distributions may significantly underestimate the potential availability of suitable habitat.

O'Neill D, Häkkinen H, Neumann J, Shaffrey L, Cheffings C, Norris K, et al.

United Kingdom

Investigating the potential of social media and citizen science data to track changes in species' distributions

Ecology and Evolution

doi.org/10.1002/ece3.10063



Soil metabarcoding: using eDNA to describe plant communities at a global scale



Oakleaf fleabane - *Erigeron quercifolius* Lam. observed in Gainesville, FL, USA by elchu (CC BY-NC 4.0)

TAXONOMY

BIODIVERSITY SCIENCE

🌱 **156,200,298**
SPECIES OCCURRENCES

Researchers show that estimates of large-scale plant diversity and community composition patterns derived from soil eDNA barcoding agree with those from traditional sources

Metabarcoding—the process of sequencing specific elements of environmental DNA (eDNA) from multiple species in parallel—can provide information about organisms present in an ecosystem. When applied to soil, metabarcoding can also be used to characterize both local- and regional-scale plant communities.

In this study, researchers assessed the value of soil eDNA in describing global-scale variation in plant community composition using samples from an existing

network with 325 locations worldwide. From just two grams of soil pooled from 40 points within 50x50 meter sampling areas at each location, the authors extracted DNA and amplified and sequenced a short fragment (the P6 loop of the chloroplast trnL intron) for analysis.

They clustered more than 2 million sequence reads into about 29,000 operational taxonomic units (OTUs) identifiable as plants. These formed the basis of a statistical analysis in which the authors compared the eDNA data with a GBIF dataset of more than 150 million occurrences of 266,000 vascular plant species.

In their results, they demonstrated good agreement between large-scale patterns described by the eDNA dataset and those described by GBIF-mediated occurrences, showing that barcoding based on the short P6 loop sequence is viable and can be rewarding at a global scale. For macroecological patterns, eDNA sequencing may provide results just as informative as traditional plant surveys.



Vasar M, Davison J, Moora M, Sepp SK, Anslan S, Al-Quraishy S, et al.

Canada, South Africa, Sweden, Czechia, Colombia, Namibia, Mexico, France, Argentina, Estonia, Australia, Saudi Arabia, Thailand

Metabarcoding of soil environmental DNA to estimate plant diversity globally

Frontiers in Plant Science

doi.org/10.3389/fpls.2023.1106617



Complex dynamics of plant invasions across spatial and invasion stages



Common reed - *Phragmites australis* (Cav.) Trin. ex Steud. - observed in Wuxi, Jiangsu, China
by wangwang2018 (CC BY-NC 4.0)

PHYLOGENETICS

INVASIVES

🌱 **54,380**
SPECIES OCCURRENCES

📍 China

Study of invasive plants in China suggests that having close relatives present makes introduction and naturalization easier—but difference drives invasion

During plant invasions, phylogenetic relatedness of alien species to existing community members may either facilitate or hinder successful establishment, depending on the scale. Biotic interactions with other existing alien species at different stages of invasion, however, may also play a role.

In this study, researchers sought to determine the variation of phylogenetic relatedness of alien species across spatial scales, and whether the different stages—introduction, naturalization and invasion—showed similar patterns.

Working from a comprehensive list of all alien plant species in China, the authors extracted species occurrences from GBIF and the National Specimen Information Infrastructure (NSII), resulting in more than 87,000 records across 706 angiosperm plant species.

Based on molecular sequence data from GenBank, they constructed a phylogenetic tree and assessed phylogenetic relatedness of the species at different invasion stages, as well as spatial and taxonomic scales, using two measures: net relatedness index (NRI) and nearest taxon index (NTI).

Overall, analyses of the phylogenetic relatedness scores suggested that the presence of a close relative in a community may facilitate successful naturalization of an alien species. At the same time, the phylogenetic spaces of invasive species differed significantly from that of naturalized and introduced species, suggesting a need to be phylogenetically different in order to become invasive.

Banerjee AK, Tan F, Feng H,
Liang X, Wang J, Yin M, et al.

China

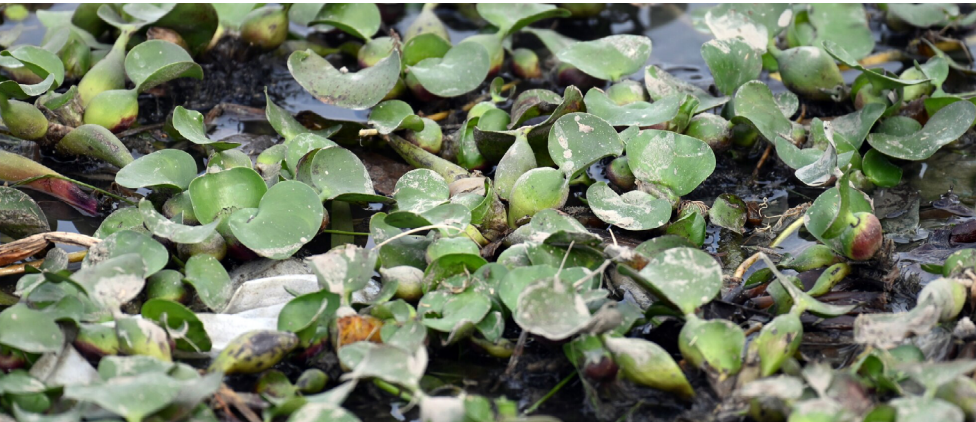
Invasive alien plants are
phylogenetically distinct from
other alien species across
spatial and taxonomic scales
in China

Frontiers in Plant Science

[doi.org/10.3389/
fpls.2023.1075344](https://doi.org/10.3389/fpls.2023.1075344)



BioLake: bioclimatic predictors for aquatic invasive species



Water-hyacinth - *Pontederia crassipes* Mart. - observed in San Benito, TX, USA by Michael Orgill (CC BY-NC 4.0)

INVASIVES

FRESHWATER

73
AQUATIC SPECIES

United States

Study presents new set of bioclimatic layers specific to lake temperatures, assessing their performance in predicting aquatic invasions in the US

Researchers and policymakers seeking to assess species' invasion risk often rely on modelling fundamental ecological niches based on climatic variables in the species native range. For freshwater species, however, this has been less successful, potentially due to the lack of climatic layers specific to lake temperatures.

In this publication, researchers developed a new set of lake-specific bioclimatic layers—BioLake—using global estimates from a recent physics-based climate

model estimating hourly values of temperature in several strata from 1950 to the present.

Using GBIF-mediated records of 73 current US plant and animal invaders that occur outside North America, the authors tested modelling predictions, calculating scores separately for lake (BioLake) and air (BioClim) temperature-based layers, respectively. They included consistent precipitation layers in both assessments.

Both sets of layers produced models scoring higher than a null model, indicating the predictive power of the methods. The models based on BioClim-layers, however, did yield higher climatic suitability scores than BioLake-layers in known sites of invasion.

Providing a starting point for aquatic invasive species distribution modelling and risk assessment, the study suggests that finer scale lake and river temperature data may improve predictions, and also highlights the need to consider other biotic and human factors as well.

Burner RC, Daniel WM, Engelstad PS, Churchill CJ, Erickson RA.

United States

BioLake: A first assessment of lake temperature-derived bioclimatic predictors for aquatic invasive species

Ecosphere

doi.org/10.1002/ecs2.4616



Camera trapping using machine learning: cheap wildlife monitoring for all



Badger - *Meles meles* (Linnaeus, 1758) - automatically recorded near Heffingen, Luxembourg. Photo via National Museum of Natural History, Luxembourg.

ECOLOGY

BIODIVERSITY SCIENCE

330
SPECIES OCCURRENCES

Researchers introduce robust and effective camera trap system based on free and open software and cheap and accessible hardware, allowing for easy deployment by professional and citizen scientists alike

Camera traps are ideal for automated capturing and monitoring wildlife, but traditional equipment often relies on infrared sensors to activate recording. Even a short delay is enough for small and fast-moving animals to leave the frame before recording starts, often leading to producing empty recordings.

In this paper, researchers proposed a novel camera trap triggering system based solely on a camera sensor. Intended for affordable use by citizen scientists, the system

can be deployed using a cheap, low-power Raspberry Pi mini-computer with a camera and minimal storage requirements for less than €100.

Relying on innovative detector algorithms based on machine learning, the [DynAikonTrap](#) system incorporates a sequence of filters that ultimately leads to the storage of animal images, while automatically discarding video with no animals. While motion detection is faster than animal detection, a buffer between the two filters allows for near real-time analysis.

Using a set of 330 animal video recordings derived from GBIF-mediated occurrences, annotated by frame to indicate animal presence, the authors trained and benchmarked various configurations of detection filters. The ideal filter configuration of DynAikonTrap was able to continuously analyse and record more than 6 hours of animal presence per day at very low power usage.

Sharing their source code freely and openly, the authors provided complete instructions on how to deploy DynAikonTrap on inexpensive hardware, making camera trapping easy and affordable for both researchers and citizen scientists alike.



Riechmann M, Gardiner R, Waddington K, Rueger R, Leymarie FF, Rueger S.

United Kingdom, Switzerland

Motion vectors and deep neural networks for video camera traps

Ecological Informatics

doi.org/10.1016/j.ecoinf.2022.101657



Invasive insects on the rise: plant introductions predict insect invasions

10



Box tree moth - *Cydalima perspectalis* (Walker, 1859) - observed in Penne-d'Agenais, France by Sylvain G (CC BY-NC 4.0)

INVASIVES

465,102,690
SPECIES OCCURRENCES

Study finds strong link between previous plant introductions and current insect invasions, suggesting a global insect invasion debt of nearly 3,500 introductions to occur in a near future

Outnumbering all other non-native animals, insects are extremely successful invaders, with more than 7,000 species established outside their native range. Insects are often introduced accidentally alongside ornamental plants, prompting the hypothesis that plant introductions may predict insect invasions.

Analysing records of 16,000 insect establishments and 54,000 plant naturalizations derived from GBIF-mediated occurrences and other sources, researchers tested

this hypothesis using generalized linear mixed models. In their analysis, they investigated the predictive power of several candidates for the ability to explain current insect flows between biogeographical regions.

Comparing early and late introductions, they found that the current distribution of non-native insects was more correlated to the distribution of nonnative plants from 1900 than 2010, suggesting that plant introductions preceed insect invasion by an extensive time lag. They also found that plant naturalizations were a better predictor of insect invasions than the flows of both plant trade and general trade.

Based on the observed time lag between plant and insect flows, the authors estimated a global debt of 3,442 insect introductions—an increase in potential invasions of 35 per cent in a near future. The significance of this debt was largest in the Afrotropics, the Neotropics and Indomalaya, where their analysis predicted an expected 10 to 20-fold increase in nonnative insect discoveries.

With evidence of a strong link between plant and insect invasions, the study highlights the importance of limiting the spread of nonnative plants in order to prevent future insect introductions and their potentially devastating impacts on both ecosystems and human societies.

Bonnamour A, Blake RE, Liebhold AM, Nahrung HF, Roques A, Turner RM, et al.

France, New Zealand, Switzerland, Australia, Czechia, Japan

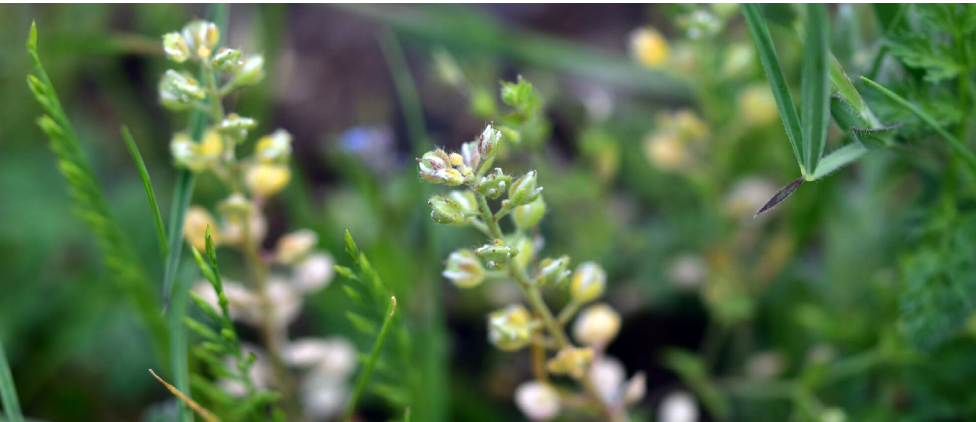
Historical plant introductions predict current insect invasions

Proceedings of the National Academy of Sciences

doi.org/10.1073/pnas.2221826120



Annual vs. perennial: global assessment of plant life cycles



Desert madwort - *Alyssum desertorum* Stapf - observed in Gornji Karin, Croatia by Sebastian Čato (CC BY-NC 4.0)

BIOGEOGRAPHY

EVOLUTION

ECOLOGY

• **355,828,125**
SPECIES OCCURRENCES

Extensive study of hundreds of thousands of plant species shows that annuals—favoured in hot and dry regions—are only half as common as previously thought

Most plants either reproduce and complete their entire life cycle within one season (annuals)—or live for many years, reproducing multiple times (perennials). Despite plants' central place in ecology and evolution, the global prevalence and distribution of their life cycles are poorly documented.

Relying on 11 disparate plant trait databases, researchers gathered, cleaned and curated consensus data on more than 235,000 plant species, representing roughly two-thirds of all accepted plants, making it the largest plant life-cycle database to date.

They matched the life-cycle data with GBIF-mediated species occurrences, downloading and cleaning ~355 million records related to more than 180,000 species, which they assigned to ecoregions. To assess drivers of life-cycle strategies, they complemented species occurrences with data on climate and human footprint.

Annuals comprised just six per cent of all species, less than half of previous estimates. Focusing on herbaceous species (i.e., disregarding woody species which are all perennial), they showed that annuals were more prominent in hot and dry regions—especially those with high human footprint.

A more focused analysis on the warmest quarter of the year provided an even better model, able to accurately describe patterns observed in ecoregions with similar yearly climate means, but different proportions of annuals. This would explain why some Mediterranean-like climates have more annuals than desert systems.

Looking into the future, under the assumption that the prevalence of annuals will align with climate and human footprint trends, the authors finally predicted that by 2060, more than two-thirds of all ecoregions will experience an increase in the proportion of annual plant species.

11

Poppenwimer T, Mayrose I, DeMalach N.

Israel

Revising the global biogeography of annual and perennial plants

Nature

doi.org/10.1038/s41586-023-06644-x



Giant land snails: invasive disease carriers and tropical pets



Giant land snail - *Lissachatina fulica* (Bowdich, 1822) observed in Singapore by hiro_shoji (CC BY-NC 4.0)

HUMAN HEALTH

INVASIVES

🌐 **11,000**
SPECIES OCCURRENCES

Assessment of tropical snail reveals 15 human pathogens and high potential transmission risk through tropical invasion and pet ownership

Originating in East Africa and now invasive in many tropical regions worldwide, the giant land snail (*Lissachatina fulica*) is a popular exotic pet, a culinary ingredient, and also a vector of several human pathogens, including rat lungworm, known to cause meningitis.

In this study, researchers assessed and mapped the risk of disease transmission associated with invasion and pet trade of *L. fulica*. They conducted a literature review to identify relevant parasites and pathogens, finding 36 documented species including helminths,

bacteria and protozoans, of which 15 species were known to infect humans.

Using GBIF-mediated occurrences of the snail, the authors created an ensemble model of its distribution potential based on bioclimatic variables of temperature and rainfall. The models suggested climatic suitability for *L. fulica* throughout all tropical regions. Mapping against human densities suggested that the snail thrived in densely populated areas.

By crawling geolocated social media posts on Instagram tagged with the species' name, the authors extracted and verified 750 images of *L. fulica*, most from temperate European regions, depicting the snail as a pet. Many users would hold the snail in their hands or even on their face, seemingly unaware of the health risks associated with these animals.

With potential for increased transmission of pathogens through both tropical spread and pet ownership in less climatically suitable regions, *L. fulica* represents a serious health risk. To prevent infections, the study called for raising public awareness and regulating pet trade and ownership worldwide.

12

Gippet JMW, Bates OK, Moulin J, Bertelsmeier C.

Switzerland

The global risk of infectious disease emergence from giant land snail invasion and pet trade

Parasites & Vectors

doi.org/10.1186/s13071-023-06000-y



Global cost of invasive ants



Red fire ants - *Solenopsis invicta* Buren, 1972 - observed in Tuscola, TX, USA by Luke Padon (CC BY 4.0)

INVASIVES

19
SPECIES

Assessment of economic consequences of ant invasions worldwide reveal staggering yet likely under-reported costs

Among the most widespread and destructive invaders worldwide, invasive ants have substantial and numerous impacts on their invaded habitats including displacing native species, altering ecosystem functions, decreasing agricultural yields and damaging infrastructure.

With costs of invasions largely undocumented, this study aimed to produce the first global assessment of the economic consequences of invasive ants. The authors examined the most costly invaders, the type of costs incurred, their distributions, and gaps in cost reporting.

Based on the [InvaCost database](#), the authors updated searches for cost documents across several online databases, adding scientific names of 19 focus species and economic terms translated into 11 languages. This process yielded 700 raw cost entries for further inspection.

Processing and analysis of the resulting documents found economic costs reported since 1930 for 12 ant species in 27 countries totalling more than USD 50 billion. Two species (*Solenopsis invicta* and *Wasmannia auropunctata*) and two countries (USA and Australia) accounted for 80 per cent of all global costs in the results. The vast majority of reported costs were from damage impacting agricultural and public sectors.

When cross-referencing locations of identified costs with GBIF-mediated occurrences of responsible species, the authors found significant gaps. More than 40 per cent of invaded regions had no reports of economic costs. At the country level, costs were only reported in 20 per cent of countries with species present.

So while the study revealed massive costs of invasive ants worldwide, the scale of underreporting suggested the numbers may be grossly underestimated. Improved cost reporting would be required to prioritize and improve management coordination and performance, urgently needed to curtail global impacts of invasive ants.

13

Angulo E, Hoffmann BD, Ballesteros-Mejia L, Taheri A, Balzani P, Bang A, et al.

France, Spain, India, Kuwait, Australia, Morocco, Czechia, Italy

Economic costs of invasive alien ants worldwide

Biological Invasions

doi.org/10.1007/s10530-022-02791-w



The role of biodiversity and infrastructure in tourism in Costa Rica



Coppery-headed emerald - *Microchera cupreiceps* (Lawrence, 1866) - observed in Monte Verde, Costa Rica by Adam Jackson.

BIODIVERSITY SCIENCE

ECOSYSTEM SERVICES

11,170,690 SPECIES OCCURRENCES

Costa Rica

Accessibility drives most tourism in Costa Rica, but biodiversity also plays a key role in attracting tourists

Nature-based tourism can contribute to local and sustainable development by creating attractive livelihoods supporting biodiversity conservation. The degree to which biodiversity drives tourism, relative to infrastructure, however, is poorly understood.

This study analyzed patterns of tourism in Costa Rican protected areas and the country as a whole by examining the role of species richness derived from GBIF-mediated occurrences, as well as infrastructure such as hotel density and distance to roads and water.

To quantify tourism in time and space, the authors used numbers of eBird checklists and Flickr photos posted online as proxies of bird watching and general tourism, respectively. Creating spatially explicit models with these as response variables, they compared the ability of biodiversity and infrastructure in predicting levels of tourism.

At all scales, accessibility was the main driver of tourism in general with distance to roads and hotel density being the most important predictors. Although modest compared to infrastructure, bird richness, particularly that of threatened and endemic species, had a positive effect on both birdwatching and general tourism.

Overall, the results suggested that while access to roads and hotels are the most important driver, tourism is higher in places with both good access and high biodiversity. Future investments aimed at increasing economic benefits from tourism should prioritize safeguarding biodiversity in addition to improving infrastructure.

Echeverri A, Smith JR, MacArthur-Waltz D, Lauck KS, Anderson CB, Monge Vargas R, et al. United States, Costa Rica Biodiversity and infrastructure interact to drive tourism to and within Costa Rica Proceedings of the National Academy of Sciences <https://doi.org/10.1073/pnas.2107662119>



Exponential increase in records of invasive alien species worldwide

15



Chinese mitten crab - *Eriocheir sinensis* H.Milne Edwards, 1853 - observed in Weurt, Netherlands
by Lars Willighagen (CC BY 4.0)

CONSERVATION

54,162,808
SPECIES OCCURRENCES

Study suggests invasive alien species are expanding rapidly across the globe despite control efforts

The impacts of human-facilitated introduction and range expansion of invasive alien species (IAS) on ecological and socioeconomic systems worldwide are undeniable. Managing and mitigating their damaging effects requires better understanding of the global spread of IAS.

In this study, researchers compiled a global list of known IAS plants and animals threatening ecosystems and verified the validity of species names against relevant taxonomic checklists. They then extracted more than 50 million occurrence records of these species from GBIF and other sources.

After excluding duplicates, records from native range, and species with less than 200 occurrences, they analysed the growth of 178 IAS using linear regression models individually, across higher taxonomic groups, and all species pooled together.

While some individual species showed signs of saturation, the overall results of the pooled species and taxonomic groups displayed patterns of exponential growth in records outside native ranges. The increase in number of records was higher in non-native ranges than native ranges when controlled for sampling effort.

For all species combined, the number of non-native occurrences was estimated to double in 14 years. Molluscs and crustaceans had the highest rates of increase in records with an estimated doubling time of just six years. The average rates for flowering plants were much lower, requiring 17 years to double.

At the continental level, North America had the most taxonomic groups (10 out of 11) exhibiting exponential growth rates, followed by Europe (five groups), Asia and South America (three groups), Oceania (two groups) and Africa (one group). These results show that despite efforts to curtail spread, IAS are continuing to expand their ranges at alarming rates worldwide.

Mormul RP, Vieira DS, Bailly D, Fidanza K, da Silva VFB, da Graça WJ, et al

Brazil

Invasive alien species records are exponentially rising across the Earth

Biological Invasions

doi.org/10.1007/s10530-022-02843-1



Big and blue: online butterfly trade driven by aesthetic appeal



Morpho menelaus (Linnaeus, 1758) specimens collected in Cacao, French Guiana.
Photo via Auckland Museum (CC BY 4.0)

CONSERVATION

1,890
OCCURRENCE IMAGES

Study of thousands of eBay transactions find that perceived rarity best predicts selling price while volume depends of aesthetic appreciation value

Butterflies have long been admired and collected by humankind, and modern enthusiasm for the colourful lepidopterans hasn't waned. Gliding under the radar of CITES regulation, butterflies are easily traded online and shipped internationally as dried samples, difficult to detect by customs as they do not show up on x-rays.

To quantify the extent of online butterfly trade, this study monitored eBay transactions for a year, logging more than 50,000 sales of 3,767 different species, representing nearly 20 per cent of all butterflies on Earth.

The authors collated a database of all traded species with potential sales predictors, including distribution, abundance, conservation status, traits and phylogenetic distinctiveness.

As aesthetic appreciation by consumers is difficult to quantify, the authors implemented a rating system based on GBIF-mediated occurrence images of pinned, male specimens. They asked crowd-sourced judges to iteratively pick their favourite between two specimens, continuing for 100 randomized pairs per judge, until reaching a stabilized ranking after 200 judges.

Often shipped from the Global South to the US or Europe, specimens' median price was \$6.75. Sale prices amounted to about a third of the average daily wage in the countries of origin. At the extreme end, a single pair of Ludlow's Bhutan swallowtails (*Bhutanitis ludlowi*) (EN) sold in Russia for just under \$9,000.

Further analysis revealed that while species perceived as "rare" (e.g. threatened according to IUCN or regulated by CITES) had higher prices, the crowd-sourced aesthetic ranking best predicted a species' trade volume. Features such as wingspan, shape and colour explained about half of the variance in aesthetic ranking. The highest ranked species were most often large with brilliant colours, such as *Morpho menelaus* and *Papilio ulysses*.

16

Wang Z, Chan WP, Pham NT,
Zeng J, Pierce NE, Lohman DJ,
et al

United States, Philippines,
Viet Nam

One in five butterfly species sold
online across borders

Biological Conservation

[doi.org/10.1016/j.
biocon.2023.110092](https://doi.org/10.1016/j.biocon.2023.110092)



Urban green spaces boost physical activity and public health



Daurian Redstart - *Phoenicurus aureus* (Pallas, 1776) - observed in Guangzhou, China by Ievne (CC BY-NC 4.0)

HUMAN HEALTH

CITIZEN SCIENCE

ECOSYSTEM SERVICES

27,552
SPECIES OCCURRENCES

China

Study shows that green areas in the city make people more likely to take walks, especially if they can spot animals on their way

Humans need physical activity in order to stay healthy, but less than a third of the world's population are getting enough exercise. Physical inactivity is now one of the leading risk factors for mortality worldwide. For most people, walking is a cheap and easy way of exercising. It has benefits not only for one's health, but also for the environment, as it doesn't require electrical equipment or indoor air conditioning.

Knowing that access to urban green areas makes people more likely to spend time outdoors, researchers of

this study explored if and how green spaces may have a positive impact on recreational walking. The authors surveyed 1,000 families in Guangzhou, China, about their walking habits and their subjective perception of the quality of nearby green spaces, which they quantified using satellite imagery.

To assess possible effects of animals in green spaces, they used a neural network approach to scan more than 220,000 neighbourhood street-view images for animal presences. They also used GBIF-mediated eBird observations to quantify the presence of birds in the areas being surveyed.

Combining statistical analysis of the survey responses with quantifications of green space and animals, they demonstrated that its quantity, quality and support of wildlife all correlated positively with walking propensity and duration. Their results also indicated that the presence of animals strengthened the positive effects of green space quantity and quality on walking behaviour.

By highlighting the importance of biodiversity in urban spaces, this study provides important insights for policy-makers to consider the synergistic effect of green spaces and animals on public health in green city planning.

17

Wang R, Zhang L, Zhou S, Yang L, Lu Y

United Kingdom, China, Hong Kong

The availability and visibility of animals moderate the association between green space and recreational walking: Using street view data

Journal of Transport & Health

doi.org/10.1016/j.jth.2023.101744



Using neural networks to accurately identify dragonflies and damselflies



Swampwatcher - *Potamarcha congener* (Rambur, 1842) - observed in Chennai, Tamil Nadu, India by sujikahalwa (CC BY-NC 4.0)

TAXONOMY

BIODIVERSITY SCIENCE

🔍 **285,985,184**
SPECIES OCCURRENCES

Study trains neural networks on GBIF-mediated occurrence images of odonates, improving identification accuracy in lightweight models to almost 95 per cent

Odonates (order *Odonata*: dragonflies and damselflies) are important ecosystem service providers, preying on and controlling populations of mosquitos and other vectors of human disease, while also acting as indicators sensitive to changes in habitats, environment and climate.

Recognizing the complexities in accurately identifying odonate species, this study proposed a Convolutional Neural Network approach to fast and effective identification of dragonflies and damselflies.

Focussing on India, the authors sourced a collection of ~55,000 images of 256 native species from iNaturalist (via GBIF), Flickr and other sources. They then trained nine customized CNN architectures at four different image resolutions, dividing the dataset into 80 per cent for training and 20 per cent for validation.

The best performing model correctly identified the species in question in 94 per cent of cases. When prompted to select the top three candidates, the model included the correct species 98 per cent of the time. Model performance increased relatively with image resolution, although only to a certain degree after which additional irrelevant features led to overfitting.

While the best performing models had the most depth, size and system requirements, even the most lightweight model, SqueezeNet, which uses just five megabytes of storage, had a 94 per cent top-three accuracy rate, making it ideal for small computing platforms, like web browsers and mobile phones.

Theivaprakasham H, Darshana S, Ravi V, Sowmya V, Gopalakrishnan EA, Soman KP

India, Saudi Arabia

Odonata identification using Customized Convolutional Neural Networks

Expert Systems with Applications

<https://doi.org/10.1016/j.eswa.2022.117688>



Centipedes: high genetic diversity among arthropods



Ethmostigmus rubripes Brandt, 1840 *observed* in Kiamba, QLD, Australia by stedman (CC BY-NC 4.0)

EVOLUTION

✦ **152,654**
SPECIES OCCURRENCES

Study explores intraspecific genetic diversity of centipedes using occurrence-coupled sequence data, finding correlations between species traits and latitude

Consisting of more than 3,100 species, centipedes (class **Chilopoda**) are an ancient clade of soil ecosystem predators with a 420 million-year evolutionary history. Little is known about the intraspecific genetic diversity of centipedes, despite their striking variation in traits.

Leveraging recent growth in publicly available DNA sequence data, researchers compiled an exhaustive database of Chilopoda sequences from dozens of published studies. They also retrieved sequences from the

phylogatR database, matching GenBank accessions and **BOLD** entries with georeferenced specimens in GBIF.

Initial analysis of their dataset, consisting of 1,245 mitochondrial DNA sequences representing 128 species, revealed a broad geographical distribution that spans more than 100 degrees latitude. Members of the **Scolopendromorpha** order hailed from mainly tropical origins, while **Lithobiomorpha** predominated in temperate regions of the Northern hemisphere.

Among centipedes, several traits correlated positively with high diversity. As such, smaller-bodied, non-blind species from lower latitudes had the greatest values of genetic diversity.

Overall, Chilopoda genetic diversity fell at the higher end of the spectrum compared not only to other arthropods but also to vertebrates. The authors suggested this finding might be related to the long evolutionary history and low dispersal ability of the class.

19

Bharti DK, Pawar PY, Edgecombe GD, Joshi J

United Kingdom, India

Genetic diversity varies with species traits and latitude in predatory soil arthropods (Myriapoda: Chilopoda)

Global Ecology and Biogeography

doi.org/10.1111/geb.13709



Insects: the original pollinators of flowering plants

20



Sonoran blue - *Philotes sonorensis* (C.Felder & R.Felder, 1865) - visiting a desert lavender - *Condea emoryi* (Torr.) Harley & J.F.B.Pastore - *observed* in Plum Canyon, CA, USA by John and Nancy Crosby (CC BY-NC 4.0)

EVOLUTION

ECOSYSTEM SERVICES

✦ **285,985,184**
SPECIES OCCURRENCES

Reconstructing the ancestral pollination mode of flowering plants, study reveals insects as the first pollinators, visiting plants throughout 85 per cent of their shared evolutionary history

Angiosperms (flowering plants) depend on pollination to reproduce sexually, with pollen transfer facilitated by insects, vertebrates, wind or even water. A key question in angiosperm evolution remains how the ancestors of flowering plants were pollinated and how this may have shifted over time.

Using a robust, dated phylogeny of angiosperms coded with pollination modes at the species level, researchers behind this study set out to reconstruct the evolution

of angiosperm pollination and quantify the timing and drivers of shifts in modes.

Using so-called correlated Hidden Markov Models based on the phylogeny and pollination modes, they demonstrated that insects were the most likely ancestral pollinators of angiosperms. This finding also held for ancestors of 57 of 64 angiosperm orders.

Their analysis further revealed far more transitions from animal to wind pollination than the reverse. Using GBIF-mediated angiosperm occurrences, the authors found that species with high habitat openness were 20 per cent more likely to be pollinated by animals, whereas wind pollination increased with distance from the equator.

Overall, the analysis estimated that insects have pollinated flowering plants for more than 85 per cent of their evolutionary past, highlighting the long history of interactions between insects and angiosperms still vital to biodiversity today.

Stephens RE, Gallagher RV, Dun L, Cornwell W, Sauquet H

Australia

Insect pollination for most of angiosperm evolutionary history

New Phytologist

doi.org/10.1111/nph.18993



Invasion niche dynamics: invaders displacing invaders



Red swamp crayfish - *Procambarus clarkii* (Girard, 1852) - observed in A Coruña, Spain
by Antón Vázquez (CC BY-NC 4.0)

ECOLOGY

INVASIVES

4,450
SPECIES OCCURRENCES

Study analyses 200 years of crayfish history in the Iberian peninsula to document ecological niche dynamics and the effect of biological invasions

Many factors affect the extent to which a species fully occupy—or realize—their ecological niches. With highly dynamic and comparable distributions, invasive species can offer unique opportunities for studying the dynamics of species distributions and realized niches.

Combining systematic historical and recent surveys of the presences of crayfish species in the Iberian Peninsula, this study assessed how two recent invaders from North America affected the niche and distribution of

the Italian crayfish (*Austropotamobius fulcisanus*), introduced to Spain in the late 16th century.

The authors thoroughly collated occurrence data for the three species, relying on geographical diaries and books for historical records of *A. fulcisanus* and biodiversity databases including GBIF for the newcomers, the red swamp crayfish (*Procambarus clarkii*) and the signal crayfish (*Pacifastacus leniusculus*).

The historical mapping showed that the Italian crayfish's distribution expanded until the late 1960s, then shrank drastically after the introduction of the two other species. The two North American species eventually occupied the entirety of the Italian crayfish's niche with little to no co-occurrence, shifting the distribution of *A. fulcisanus* to limited areas in rough, high-elevation territories.

Using ecological niche modelling, the authors demonstrated how the changes in distribution were reflected in the realized niche, expanding from the 1850s until its collapse unfilled significant portions of its fundamental niche after 1960. These results demonstrate the dynamics of a species' realized niche and how it may shift in response to global change processes, such as biological invasions.

21

Viana DS, Oficialdegui FJ, Soriano M del C, Hermoso V, Clavero M

Spain, Czechia

Niche dynamics along two centuries of multiple crayfish invasions

Journal of Animal Ecology

doi.org/10.1111/1365-2656.14007



Machine learning unveils mammalian species hiding in plain sight



Myotis formosus subsp. flavus Shamel, 1944 *observed* at undisclosed location by BGG (CC BY-NC 4.0)

TAXONOMY

BIODIVERSITY SCIENCE

✦ 3.3 MILLION SPECIES OCCURRENCES

Study suggest hidden biodiversity among small-bodied mammals and calls for increased funding for taxonomy to address knowledge gaps

Taxonomists have formally described and named more than a million species on the planet. The actual number of existing species, however, is likely much higher, a phenomenon referred to as the the Linnean shortfall.

To explore whether this gap in knowledge is caused by poor taxonomic practice or too little effort, this study used machine learning techniques to build a model for mammals to predict cryptic species likely to contain such hidden biodiversity.

Using a combination of 90,000 DNA sequences and 3.3 million species occurrences from GBIF, the authors curated a database with 117 environmental, climatic and morphological trait variables for more than 4,000 mammalian species to train their predictive model.

Their results suggested that the majority of hidden species are likely to be found among small-bodied clades, such as bats, rodents, and eulipotyphans (hedgehogs, moles and shrews), with larger geographic ranges in regions with more rainfall in the warmest quarter of the year.

Intriguingly, the model also flagged the importance of variables quantifying sampling effort, suggesting that previously studied taxa are more likely to contain hidden species. In other words, traditional taxonomic research appears to be effective, though it lacks sufficient investments to overcome the Linnean shortfall.

22

Parsons DJ, Pelletier TA, Wieringa JG, Duckett DJ, Carstens BC

United States

Analysis of biodiversity data suggests that mammal species are hidden in predictable places

Proceedings of the National Academy of Sciences

<https://doi.org/10.1073/pnas.2103400119>



Mapping the global impact of agriculture on biodiversity



Cattle in Colombia's eastern plains. Photo by CIAT/NeilPalmer (CC BY-SA 2.0)

CONSERVATION

AGRICULTURE

566,184,545
SPECIES OCCURRENCES

Comprehensive study quantifies conflicts between conservation priorities and agricultural land-use worldwide

The conversion of terrestrial habitats required to sustain the global agricultural production of food, fiber and fuel is the primary driver of human-induced species loss. Mapping conflicts between agriculture and conservation priorities is needed in order to safeguard biodiversity.

In this study, researchers used GBIF-mediated occurrence data to model the ecological niches of more than 7,000 terrestrial species known to be threatened by agriculture. Employing a “zonation” approach with input from the generated models, the authors calculated a

23

Conservation Priority (CP) index that scored the entire world at a 0.5-degree resolution.

Using global supply chain databases, the authors then added spatial information about crops and livestock in 197 countries to estimate the land used by of 42 different agricultural commodities and six livestock systems.

Initial exploration of overlaps showed that more than three quarters of agricultural land-use occurred in sites with medium-high CP scores, a third of them with very high CP. The land-use occurring in low-CP areas represented only a few commodities (barley, sugar beet, sunflower and wheat).

While coffee, cocoa, plantain and oil palm production occurred almost exclusively in very high CP areas, cattle, maize, rice and soybean occupied the most abundant land-use areas and thus posed the greatest threat to biodiversity. In contrast, commodities such as pearl millet, sunflower, cotton, lentils, chickpeas and cowpeas represented the lowest conservation risk.

Providing a quantitative basis for conflicts between humanity and nature as well as a valuable input for informing sustainable agriculture, the findings of the study were also visualized in a [web-based GIS tool](#).

Hoang NT, Taherzadeh O, Ohashi H, Yonekura Y, Nishijima S, Yamabe M, et al

Norway, Netherlands, Japan

Mapping potential conflicts between global agriculture and terrestrial conservation

Proceedings of the National Academy of Sciences

doi.org/10.1073/pnas.2208376120



Global, continental and biome-scale tree species census



By the Napo River near Tena, Ecuador. Photo by F Delventhal via Flickr (CC BY 2.0)

BIODIVERSITY SCIENCE

28,192
SPECIES

Study estimates more than 9,000 undiscovered tree species worldwide, with nearly half of these in South America

Trees are among the largest and most widespread group of organisms, essential to ecosystem stability and services, and supporting a wealth of terrestrial biodiversity. Knowledge of the number of tree species in the world, however, is limited, relying on expert opinions and checklists with uneven geographic coverage.

In an attempt to provide an estimate of the actual number of tree species on Earth, a large multinational team of researchers collaborated on compiling and curating a new comprehensive dataset that combines plot

data from the Global Forest Biodiversity Initiative with species occurrences from GBIF and several other aggregators.

Based on the new dataset, which contained more than 64,000 named species, the authors calculated the potential global and continental tree species richness, arriving at an adjusted estimate of ~73,000 species. This result implied that more than 9,000 tree species remain to be discovered and described.

At the continental level, the authors estimated that about 43 per cent of all Earth's tree species occur in South America, suggesting a gap of almost 4,000 species currently unknown to science. Globally, as many as 40 per cent of species were likely rare, comprised of few populations and small distributions.

Between two thirds of all known species occurred in tropical and subtropical moist forest biomes across all continents. The study estimated that hotspots of undiscovered species may exist in such undersampled regions.

With anthropogenic land use and climate change disproportionately threatening rare species, the study provides valuable insights into the vulnerability of global forest biodiversity, essential to informing and prioritizing forest conservation efforts worldwide.

24

Cazzolla Gatti R, Reich PB, Gamarra JGP, Crowther T, Hui C, Morera A, et al

Denmark, Russian Federation, Canada, French Guiana, China, Viet Nam, Sweden, Uganda, Romania, Italy, Peru, France, Spain, Switzerland, Chile, Estonia, Germany, Denmark, Belgium, Bolivia, Republic of Korea, United States, India, Portugal, South Africa, Poland, Kenya, Netherlands, Czechia, Gabon, Colombia, Austria, Venezuela, Brunei Darussalam, United Kingdom, New Zealand, Indonesia, Argentina, Costa Rica, New Caledonia, Slovakia, Australia, Serbia, Saudi Arabia, Brazil

The number of tree species on Earth

Proceedings of the National Academy of Sciences

doi.org/10.1073/pnas.2115329119



Evidence of replicated radiation in angiosperm lineage

25



Viburnum jucundum C.V.Morton observed in San Cristóbal de las Casas, Chis., Mexico
by Neptalí Ramírez Marcial (CC BY 4.0)

EVOLUTION

PHYLOGENETICS

BIOGEOGRAPHY

881
SPECIES OCCURRENCES

Study maps 10 million years of Viburnum biogeography and morphology, suggesting parallel but independent evolution of up to four distinct leaf forms in nine areas of endemism

Replicated radiation is a type of parallel evolution in which sets of similar forms evolved repeatedly in different regions. The phenomenon is well-documented among animals, but, compelling examples are missing for plants.

Combining DNA sequencing, phylogenetic and biogeographical mapping informed by GBIF-mediated specimen data with morphological analyses, this study explored the possibility of replicated radiation within the Oreinotinus lineage of the angiosperm clade Viburnum.

The authors showed how Oreinotinus moved progressively from eastern Mexico to Central America and from there into the Caribbean and South America over a period of 10–15 million years. They identified areas of endemism in which species formed clades, being more closely related to one another than to those in other regions.

By analysing herbarium sheets and field images, they demonstrated how four distinct leaf forms evolved independently within the lineages in different areas of endemism. These forms did not originate early in Oreinotinus and then spread across the continent, but evolved repeatedly in nine out of 11 areas as lineages diversified.

The authors suggest ecological adaptation as the driver of the observed parallelism as the leaf forms emerged in similar climatic niches within their region. Altogether, they argue that the findings represent perhaps the first well-documented example of replicated radiation among plants.

Donoghue MJ, Eaton DAR, Maya-Lastra CA, Landis MJ, Sweeney PW, Olson ME, et al

Mexico

Replicated radiation of a plant clade along a cloud forest archipelago

Nature Ecology & Evolution

doi.org/10.1038/s41559-022-01823-x



Invasive alien species threaten European ecosystem services



Tree of heaven - *Ailanthus altissima* (Mill.) Swingle - observed in Cinco Vilas, Portugal by pedro_fonseca_alverca (CC BY-NC 4.0)

INVASIVES

ECOSYSTEM SERVICES

✳️ **150,307**
SPECIES OCCURRENCES

Study of four invasive plants predicts expansion and increased negative impact on the provision of three key ecosystem services

As one of the leading causes of biological loss, invasive alien species (IAS) represent a threat to global biodiversity. IAS, however, may also impact the provision of other ecosystem services such as crops, water supplies and erosion control.

In order to explore the potential impact of invasive plants on natural provisioning services in Europe, researchers in this study selected four different types of invaders of EU concern: a tree (*Ailanthus altissima*), a shrub (*Baccharis halimifolia*), a vine (*Impatiens glandulifera*), and an herb (*Pueraria montana*).


Using the Invasive Species Effects Assessment tool (INSEAT) protocol, the authors began by assessing the impact of the four IAS on 16 different ecosystem services, identifying most negative impacts on wild species diversity, crops and erosion regulation.


Combining GBIF-mediated occurrences with data on climate, soil and accessibility, they modelled the current and future distributions of the four IAS and evaluated the change in potential range sizes.


By mapping probability of invasion combined with provision of ecosystem services for all four species, the authors created 60 bivariate choropleth maps, indicating specific risk across the continent at a 5-arc min resolution.


The results showed that all species except *I. glandulifera* appear likely to expand their suitable ranges. Overall, the models predicted an increase in critical and high impact areas in Western Europe and the British Isles, while the Mediterranean region projected as less impacted. With risks to all three ecosystem services explored, the results of the study highlight a need for actions to mitigate spread and impact of IAS in Europe.

26

Pérez G, Vilà M, Gallardo B 

Spain, United Kingdom 

Potential impact of four invasive alien plants on the provision of ecosystem services in Europe under present and future climatic scenarios 

Ecosystem Services 

doi.org/10.1016/j.ecoser.2022.101459 



Informing wildlife surveillance to prevent virus outbreaks in India



Western reef heron - *Egretta gularis* (Bosc, 1792) - observed in Kattampally, India by Afsar Nayakkan (CC BY 4.0)

HUMAN HEALTH

1,889,268
SPECIES OCCURRENCES

India

Study identifies key waterbird species associated with Japanese encephalitis virus outbreaks in India, informing surveillance strategies and highlighting habitat conservation in disease prevention

Japanese encephalitis virus (JEV) is a zoonotic pathogen transmitted by *Culex* mosquitoes that often causes fatal inflammation of the brain in humans, particularly among children. It is endemic in numerous Asian countries, but India experiences the highest incidence and fatalities from the virus.

In this study, researchers sought to identify wildlife targets to develop JEV surveillance among waterbirds, particularly in the *Ardeidae* family (herons and egrets), known as potential JEV reservoirs.

27

Using GBIF-mediated occurrences of 48 Indian waterbirds, the authors derived species landscape suitability from an ensemble of three distribution modelling algorithms. They then estimated total waterbird richness and analysed its association with confirmed cases of JEV outbreaks.

Twenty-one species showed positive correlations with the distribution of JEV outbreaks. The authors discovered associations among species in each of the investigated families, but *Ardeidae* family richness alone was associated with outbreaks, reaffirming the importance of *Ardeidae* in JEV maintenance.

Notably, however, the relationship between ardeid richness and JEV outbreaks was non-linear, with risk increasing at zero to four species, peaking around five, and then decreasing sharply. As such, areas with the highest ardeid richness generally had a reduced risk of outbreak, suggesting another potential benefit of habitat conservation for public health.

Walsh MG, Pattanaik A, Vyas N, Saxena D, Webb C, Sawleshwarkar S, et al

India, Australia

A biogeographical description of the wild waterbird species associated with high-risk landscapes of Japanese encephalitis virus in India

Transboundary and Emerging Diseases

doi.org/10.1111/tbed.14656



Insights and gaps: mapping the diversity of Europe's wild bees

28



Mason bee - *Osmia cornuta* (Latreille, 1805) - observed in Barcelona, Spain by Cristobal Jimenez (CC BY-NC-ND 4.0)

BIOGEOGRAPHY

TAXONOMY

PHYLOGENETICS

ECOSYSTEM SERVICES

1,520,434
SPECIES OCCURRENCES

Study reveals latitudinal patterns in European wild bee diversity, but highlights data deficiencies and quality issues across publicly available datasets

As pollinators of both wild plants and crops, wild bees are important providers of ecosystem services. Despite being one of the most intensively surveyed regions in the world, Europe remains data deficient for more than half of its known bee species.

In an attempt to fill knowledge gaps and identify priority targets of survey efforts and conservation, this study investigated patterns of taxonomic and phylogenetic diversities of 1,500 wild bee species in Europe.

The authors first combined open data from GBIF with restricted datasets from the Status and Trends of European Pollinators (STEP) project and others sources, compiling, curating and verifying almost three million species occurrences across continental Europe.

Their subsequent analysis of taxonomic diversity revealed a latitudinal gradient with higher bee species richness in southern Europe, with North Macedonia showing the highest predicted diversity, and Norway the lowest. In the model, the best environmental predictors of high diversity were high solar radiation and arid climates.

The model of phylogenetic diversity presented moderate and homogenous values across the continent with fewer clear patterns than taxonomic diversity. Overall, however, southern Europe had the highest phylogenetic diversity, best predicted by high temperatures in the warmest month.

The authors identified some degree of undersampling across more than 70 per cent of Europe, most markedly in the Balkans. Highlighting stark differences in the quality and coverage between open and restricted access datasets, the authors call for tools to structure and standardize data sharing.

Leclercq N, Marshall L, Caruso G,
Schiel K, Weekers T, Carvalho
LG, et al

United Kingdom, Portugal,
Luxembourg, Brazil, Germany,
Belgium

European bee diversity:
Taxonomic and phylogenetic
patterns

Journal of Biogeography

doi.org/10.1111/jbi.14614



Threats to Madagascar's extraordinary biodiversity



Senna meridionalis (R.Vig.) Du Puy observed in Atsimo-Andrefana, Madagascar
by CORDENOS Thierry (CC BY-NC 4.0)

CONSERVATION

254,843
SPECIES OCCURRENCES

Madagascar

Large neural network analysis finds threatened ferns and lycophytes grossly underestimated, and reveals threats to both animals and plants from overexploitation and unsustainable agriculture

Humans have affected the environment on Madagascar since their earliest arrival, directly or indirectly leading to the extinction of dozens of species. Today, while species may face different threats, many remain unassessed, and species may be disappearing before they are even described.

Using GBIF-mediated occurrence records for all vascular plants in Madagascar from iNaturalist and the Missouri Botanical Garden, the authors of this substantial review

compiled a dataset of nearly 10,000 species, representing 83.5 per cent of the known Malagasy flora, adding data on 57 features, including biome, climate, elevation, forest cover, geography, human footprint and use.

Based on this dataset, they trained a Bayesian Neural Network (BNN) using ~4,000 species for which Red List assessments already existed, then leveraged the model to predict the conservation status and threats for the remaining 5,887 unassessed species.

Across most taxonomic groups, the model predicted a similar distribution of threat categories as in the already assessed species, indicating that current percentages of threatened plants are likely representative of the entire group. Ferns and lycophytes were the notable exception, as the model predicted large deviations, suggesting an underestimate of threatened species within these groups.

To further consolidate existing knowledge on threats to Malagasy flora and fauna, the authors revealed a disproportionately high number of genetically distinct at-risk species. They showed that overexploitation and unsustainable agricultural practices threaten two thirds of all vertebrates and 90 per cent of all plants.

On a positive note, the 10 per cent of Madagascar's land area currently protected covers at least part of the range of 97 per cent of vertebrates and two thirds of all plants.

29

Ralimanana H, Perrigo AL,
Smith RJ, Borrell JS, Faurby S,
Rajaonah MT, et al

Chile, Sweden, France,
Mozambique, Switzerland,
Lithuania, Madagascar, South
Africa, Germany, Denmark,
Portugal, Czechia, Brazil

Madagascar's extraordinary
biodiversity: Threats and
opportunities

Science

doi.org/10.1126/science.adf1466



Dam infrastructure threatens freshwater dolphin habitats



Amazon dolphin, *Inia geoffrensis* (Blainville, 1817), observed in Loreto, Peru by chickadeebanditry (CC BY-NC 4.0)

FRESHWATER

2,293
SPECIES OCCURRENCES

Shown to prefer winding rivers with confluences, three dolphin species are negative impacted by large-scale hydrolic modifications altering riverine ecosystems

The Amazon dolphin (*Inia geoffrensis*), Ganges dolphin (*Platanista gangetica*), and Indus dolphin (*Platanista minor*) are freshwater cetaceans who depend on habitats threatened by dam infrastructure that alter hydrological regimes and impairs riverine ecosystems.

In this study, researchers combined occurrence records of the three dolphins from literature and databases, including GBIF. Employing a density plot analysis based on environmental and alteration

variables along the occurrence records they studied the effects of physiographic and hydrologic factors on dolphin distributions.

Their analysis showed that all three species preferred confluences—areas where two or more streams join together to form a single channel—and winding rivers segments. Amazon and Ganges dolphins mainly occupied smaller third-order tributaries while Indus dolphins tend to stay in the mainstem of the rivers.

Examining 147 specific cases of hydrological alterations, the authors found most caused by barrages, or diversion dams, in the ranges of Ganges and Indus dolphins, and embankment dams in the range of Amazon dolphins.

While the authors did identify one example of an impoundment upstream of a barrage improving conditions for Ganges dolphins, most other reported structures had negative impacts on dolphins due to either habitat fragmentation or reduction.

30

Rai A, Bashir T, Lagunes-Díaz EG, Shrestha B

Nepal, India, Mexico, United States

The effect of physiographic and hydrologic complexities and their alterations on the distribution of obligate freshwater dolphins

Ecology and Evolution

doi.org/10.1002/ece3.10106



The global performance of protected areas in insect conservation



Paralichas pectinatus observed in Machida, Japan by 登坂久雄 (CC BY-NC 4.0)

CONSERVATION

📌 **106,911,975**
SPECIES OCCURRENCES

Study shows that 75 per cent of all insect species are poorly covered by protected areas

Insects, essential to many vital ecosystem processes, are declining worldwide due to threats from climate change and habitat loss. While species-specific conservation action can help, the massive diversity of insects renders such efforts too slow and expensive.

This study explores how protected areas (PAs) may instead help safeguard habitats and protect insects at a general level. By coupling insect distributions derived from GBIF-mediated occurrence records of nearly 90,000 species with global PA coverage maps, researchers quantified overlapping areas to measure insect representation.

Using a target threshold set according to calculated range sizes for each species, the authors predicted that PA coverage falls short for more than 75 per cent of insects. The entire global distribution of about 1,800 species fell outside any PAs. Mean coverage by PAs across all species was about 19 per cent.

Geographically speaking, the highest proportions of species reaching target PA coverage was in northern South America, most of Africa, western Europe and western Australia while many species in North America and most of Asia fell short of targets.

The authors acknowledged that the results are influenced by narrowly distributed species that are poorly surveyed. As the [Kunming-Montreal Global Biodiversity Framework](#) (GBF) of the [Convention on Biological Diversity](#) (CBD) drives new ambition for PA growth, the study calls for designating areas that specifically consider insect conservation.

31

Chowdhury S, Zalucki MP, Hanson JO, Tiatragul S, Green D, Watson JEM, et al

Canada, Germany, Australia

Three-quarters of insect species are insufficiently represented by protected areas

One Earth

doi.org/10.1016/j.oneear.2022.12.003



Global synthesis of knowledge on pyrosomes



Atlantic pyrosomes (*Pyrosoma atlanticum* Péron, 1804) observed near Wellington, New Zealand by Luca Davenport-Thomas (CC BY-SA 4.0)

SPECIES DISTRIBUTION

ECOLOGY

MARINE

📍 **12,437**
SPECIES OCCURRENCES

Study reviews existing understanding of biology of the ocean's elusive fire bodies, while presenting a hypothesis on the ecology and bloom formation in the dominant species

Pyrosomes, or “fire bodies”, are free-floating colonies of marine invertebrates that form gelatinous tubes, and earn their name from the faint blue bioluminescence they display as light passes through the colony. Massive, sudden increases in populations, known as blooms, are frequent occurrences and have been known to completely clog up fishing nets and block the water intakes of coastal power plants.

This review presents a global synthesis of available knowledge on pyrosomes, including current understanding of

reproduction, habitat, predation and carbon cycling. Pyrosome colonies can grow at rates of up to 75 per cent per day, reaching up to 20 meters in size. In bloom, pyrosomes are able to clear up 95 per cent of total phytoplankton stock. They are themselves consumed by fish, turtles, birds and sea lions.

By collecting pyrosome occurrence records from literature and databases including GBIF and OBIS, the authors developed habitat envelopes that pair observations with habitat measurements and satellite records of sea surface temperature and chlorophyll-*a* production.

The envelopes encompassing data for eight pyrosome species showed distributions that span wide ranges of both temperature and chlorophyll-*a* levels. While the dominant species, *Pyrosoma atlanticum*, occurred in temperatures from 5°C to 25°C, less common species of the *Pyrostremma* and *Pyrosomella* genera had narrower preferences for temperatures above 20°C.

The authors conclude by posing the hypothesis that *P. atlanticum*, forms blooms in high-productivity waters below 18°C and is able to maintain its optimal temperature by daily vertical migration in the water column traveling up to 500 m every night and day.

32

Lilly LE, Suthers IM, Everett JD,
Richardson AJ

Australia

A global review of pyrosomes:
Shedding light on the ocean's
elusive gelatinous “fire-bodies”

Limnology and Oceanography
Letters

doi.org/10.1002/lol2.10350



Diversification of neotropical freshwater fishes



Pseudoplatystoma punctifer (Castelnau, 1855) *observed* near Elena, Bolivia by D. Porcelli.
Photo via iNaturalist.org (CC BY-NC 4.0)

EVOLUTION

PHYLOGENETICS

BIOGEOGRAPHY

• **252,436**
SPECIES OCCURRENCES

Study of nearly 5,000 species show that mountain uplifts and river reconfiguration events strongly affected diversification of South American freshwater fish fauna

With more than 5,000 species, South America harbours the most taxonomically diverse fauna of continental freshwater fishes in the world. However, understanding of how major geological events over millions of years have contributed to diversity patterns in the region is poorly understood.

In this study, researchers used GBIF and other sources to compile an occurrence dataset covering 95 per cent of all the freshwater fish species described for South America,

after carefully filtering, validating and revising the results. In addition, they employed a new, comprehensive molecular phylogeny based on DNA sequences from three decades of ichthyological studies, which represents 99 per cent of described genera.

By integrating occurrence and phylogenetic data, the researchers were able to estimate ancestral ranges, dispersal events and phylogenetic endemism at the subbasin level, tracking the influence of hydrogeographic events on evolutionary processes over 100 million years. The study identified five significant shifts in diversification rates, each associated with major landscape evolution events occurring during the Paleogene and Miocene (between 30 and seven million years ago).

In Western Amazonia, the high rates of diversification and extensive biotic exchanges linked to hydrogeographic events and formation of biogeographic corridors in the past 20 million years have helped shape the region's extraordinary species richness and high phylogenetic endemism.

33

Cassemiro FAS, Albert JS,
Antonelli A, Menegotto A, Wüest
RD, Cerezer F, et al

Switzerland, Sweden, United
States, Brazil, United Kingdom

Landscape dynamics
and diversification of the
megadiverse South American
freshwater fish fauna

Proceedings of the National
Academy of Sciences

[doi.org/10.1073/
pnas.2211974120](https://doi.org/10.1073/pnas.2211974120)



Are rare species more common than common species?

34



Orange river falcon [*Scleroptila gutturalis* subsp. *levalliantoides* (A. Smith, 1836)]
observed near Deneyville, South Africa by Niall Perrins (CC BY-NC 4.0)

ECOLOGY

• **1,455,868,110**
SPECIES OCCURRENCES

Use of GBIF-mediated occurrences as a proxy for species abundances uncovers sampling-dependent, universal unimodality in the distributions of global abundance

“Who can explain why one species ranges widely and is very numerous, and why another allied species has a narrow range and is rare?”

—Charles Darwin, *On the Origin of Species* (1859)

As Darwin and others have observed, some species are very rare while others are very common. What, then, is the most common phenomenon: being rare, being common—or something in between? And is there a universal shape to the distribution of species abundance?

To explore answers to these questions, researchers downloaded all GBIF-mediated species occurrences between 1880 and end of 2020, aggregating records by year and species. They then analysed global species abundance distributions for 39 classes of eukaryotes, preparing visualizations of 20-year rolling windows that show the number of species within abundance categories, ranging from a single individual to millions of individuals.

The analyses showed that improved sampling and greater availability of data over time unveiled the true shape of the distributions, as is most clearly evident in well-sampled taxa such as birds. By 2000, the distribution of bird species abundances was nearly perfectly bell-shaped and symmetrical, with most species having intermediate abundances.

Among other taxa, such as amphibians and ray-finned fishes, broad distribution patterns were not fully revealed, though they exhibited similar patterns of unveiling over time, moving towards a bell-shaped, unimodal distribution with only a single highest value as sampling increases.

Testing the statistic fit of the distributions, the authors found the Poisson log-normal distribution to best describe the observations for 38 out of the eukaryote 39 classes, suggesting a universality in the shape of abundance distributions across taxonomic groups.

Callaghan CT, Borda-de-Água L,
van Klink R, Rozzi R, Pereira HM

Germany, United States,
Portugal

Unveiling global species
abundance distributions

Nature Ecology & Evolution

doi.org/10.1038/s41559-023-02173-y



Natural pest control as an ecosystem service

35



Oat-birdcherry aphid [*Rhopalosiphum padi* (Linnaeus, 1758)] observed in Baumschulenweg, Germany by Sascha N. (CC BY 4.0)

AGRICULTURE

ECOSYSTEM SERVICES

785
DATASETS

Germany

Modelling framework to assess the ecosystem service potential of natural pest control uses northern German cereal fields as a study area

Despite widespread pesticide use, agricultural pests can cause substantial crop losses for farmers. The use of chemical pesticides is increasingly discouraged due to negative effects on human health and toxicity for non-target organisms.

In this study, researchers explored the ecosystem service potential of natural pest control by arthropods in agricultural landscapes as an alternative to pesticides in a study area in northern Germany.

By coupling GBIF-mediated occurrences of two known pests—Oat-birdcherry aphid (*Rhopalosiphum padi*) and English grain aphid (*Sitobion avena*)—and their natural arthropod enemies with data on climate and land use, the authors built species distribution models fitted at the regional scale.

To account for landscape complexity and biotic interactions, they also created a separate set of models assessing species co-occurrences in order to refine the potential distributions and predict pest control potential at the local scale.

While the aphid pests had a overall low suitability in the whole study area, pest control potential depended on the landscape complexity of the agricultural areas. As such, large crop fields presented low natural pest control potential, while smaller fields featuring a higher level of semi-natural habitats had higher potential for natural pest control.

The framework presented in the study can easily be adapted to study other pests, agroecosystems and their potential for natural pest control.

Perennes M, Diekötter T,
Hoffmann H, Martin EA, Schröder
B, Burkhard B

Germany

Modelling potential natural pest
control ecosystem services
provided by arthropods in
agricultural landscapes

Agriculture, Ecosystems &
Environment

[doi.org/10.1016/j.
agee.2022.108250](https://doi.org/10.1016/j.agee.2022.108250)



Diversity and distribution of edible plants in Colombia

36



Quercus humboldtii Bonpl. observed in Boyacá, Colombia by Apipa (CC BY-NC 4.0)

AGRICULTURE

BIODIVERSITY SCIENCE

🌱 **603,186**
SPECIES OCCURRENCES

🌍 **Colombia**

Study expands current knowledge on Colombian edible flora, cataloguing more than 3,800 species and identifying diversity hotspots and data gaps

More than 7,000 plant species are known to be edible and safe for human consumption. Modern commercialization of agriculture favouring yield, however, has reduced almost the entire global human diet to just 10 species.

Despite being the second most biodiverse country in the world with thousands of useful plants, Colombia's human communities suffer widespread poverty, with more than half the population experiencing from food insecurity.

To gain a full picture of the potential for revitalizing edible plants and conservation-through-use, this study combined spatial and taxonomic analyses to map the diversity and distribution of edible plants in Colombia.

Compiling taxonomic data from various international and Colombian checklists, the authors catalogued a total of 3,805 edible plant species in the country, most of them native. While local farmers cultivate 662 species, only about 24 per cent of these are native to Colombia.

The authors downloaded GBIF-mediated occurrence records of all catalogued species, covering 82 per cent of the edible Colombian flora. Initial analysis revealed, however, that just 10 species made up 25 per cent of the occurrences and the top three species were not native to Colombia.

The area with most species (and occurrence data) was Antioquia, the sixth-largest department of Colombia, with 1,823 edible species. Distribution was very specific with most species only occurring in five or fewer departments. Only a single species, *Eleusine indica*—an introduced grass—occurred in all 33 departments.

The study highlighted the cultivation of breadnut (*Brosimum alicastrum*) as an example of best practice for revitalization through sustainable production and consumption to increase food security. The authors, however, also stressed a need to fill data gaps through focussed research in poorly explored areas, especially in the Amazonian and Caribbean regions.

Gori B, Ulian T, Bernal HY, Diazgranados M

Colombia, United Kingdom

Understanding the diversity and biogeography of Colombian edible plants

Scientific Reports

doi.org/10.1038/s41598-022-11600-2



Global extinction risks for all palm species

37



Carpoxylon macrospermum H.Wendl. & Drude observed in Tafea, Vanuatu by Neal Kelso (CC BY 4.0)

CONSERVATION

63,233
SPECIES OCCURRENCES

Madagascar, Papua New
Guinea, Philippines, Viet Nam
Vanuatu

Machine-learning approach suggests that more than 1,000 species are threatened with extinction, including nearly one third of all palms used for food, medicine and construction

One of the most socioeconomically important plant groups in the world, palms are a keystone family providing essential contributions to millions of people. Global anthropogenic changes pose known threats to the many benefits that Arecaceae provide, but only 23 per cent of the family's species were recently assessed for extinction risk.

Recognizing the time-consuming and resource-intensive process required for gold-standard Red List assessment, this study employed a machine-learning approach to

predict extinction risk based on existing assessments, coupled with variables on climate, human impact and forest loss GBIF-mediated occurrences of all palm species.

After training and testing the approach, the authors' most accurate model classified 703 palm species as threatened. When benchmarked against existing assessments, this finding suggests that 56 per cent of the 1,889 palm species were threatened.

To help set conservation priorities, the authors also explored the extinction risk among species of interest—those that are functionally distinct, genetically distinct or used in some fashion. This analysis assessed around 48 per cent of the functionally and evolutionarily distinct species as threatened, compared with 29 per cent of the species in use.

Based on the total evidence, the researchers identified 25 regions in which more than 40 per cent of palm species of interest were threatened, including Madagascar (82 per cent), New Guinea (58 per cent) and Philippines (57 per cent). Some regions, such as Viet Nam and Vanuatu, presented as novel priority regions for palm conservation.

While the study identified potential use substitutes for 91 per cent of the threatened species, sixteen species lacked substitutes, affecting at least one species in 30 regions. The potential loss of important irreplaceable palm species highlights the urgent need for conservation action.

Bellot S, Lu Y, Antonelli A, Baker WJ, Dransfield J, Forest F, et al

Sweden, Switzerland, United Kingdom

The likely extinction of hundreds of palm species threatens their contributions to people and ecosystems

Nature Ecology & Evolution

doi.org/10.1038/s41559-022-01858-0



About this special section

What do an Ancient Egyptian papyrus and the Global Urban Tree Inventory have in common?

When studied in combination with data from the GBIF network, the information contained in both can reveal fresh insights about the impact of climate change on species and the natural world.

The climate-related research summarized in this section of the Science Review reflects and embodies how GBIF enables global research at multiple scales and spanning disciplinary boundaries—or, in this case, even interdisciplinary ones. The small sample is diverse, not simply limited to expanding, contracting or shifting species ranges (e.g. #41, #47), but also the hidden value of trees' ecosystem services (#38.), the increased incidence of malaria (#42) and SARS-like viruses (#48), wildlife interactions (#49), and reconstructions of paleogeographic (#45) and phylogenetic evolution (#46).

And if these aren't to your taste, not to worry—find something you like among the nearly 450 more GBIF-enabled papers on climate change from 2023 alone (<https://gbif.link/lit23-climate>).



KYLE COPAS
Communications Manager

CLIMATE CHANGE

The hidden value of trees: quantifying ecosystem services and their major threats

38



Loblolly pine - *Pinus taeda* L. - observed in Cambridge, MD, USA by John Landers (CC BY-NC 4.0)

ECOSYSTEM SERVICES

CLIMATE CHANGE

👤 **317**
SPECIES

📍 **United States**

Trees across the contiguous United States provide \$114 billion in ecosystem services annually, but face significant threats from climate change and other risks

In addition to providing wood, food and other marketable products, trees are responsible for sequestering and storing carbon from greenhouse gasses and filtering air pollutants. These ecosystem services are critical to human well-being, but their value is underappreciated.

In this study, researchers assessed the monetary value of both tree products and air and climate regulation ecosystem services in the contiguous United States while also quantifying and mapping risks from pests, pathogens, climate change and major fires.

The authors synthesized data from publicly available datasets with well-vetted valuation approaches covering the entire country, including the U.S. Forest Service, the National Emissions Inventory, the U.S. Environmental Protection Agency and the U.S. Department of Agriculture. They used GBIF-mediated tree occurrences for the whole North American continent to compute climatic envelopes to assess threats from changing climates.

Trees in U.S. forests, orchards and plantations provided ecosystem services worth nearly US\$114 billion per year. Climate and air regulation accounted for 88 per cent of this figure, while only 12 per cent came from provisioning services. Pines (*Pinus*) and oaks (*Quercus*) were the top contributing genera, representing nearly US\$48 billion per year. The most valuable species was the loblolly pine (*Pinus taeda*).

These ecosystem services were under threat, particularly from climate change, as 88 per cent of species were projected to have at least 10 per cent of their biomass exposed to unsuitable climates by 2050, impacting nearly 40 per cent of total tree biomass. Pests and pathogens threatened 16 per cent of species, while 40 per cent of U.S. trees were under threat of increased wildfires.

Cavender-Bares JM, Nelson E, Meireles JE, Lasky JR, Miteva DA, Nowak DJ, et al.

United Kingdom, United States

The hidden value of trees: Quantifying the ecosystem services of tree lineages and their major threats across the contiguous US

PLOS Sustainability and Transformation

doi.org/10.1371/journal.pstr.0000010



Invasives and climate change: Global synthesis of responses to extreme weather



European starling - *Sturnus vulgaris* Linnaeus, 1758 *observed* in Port Arthur, Tasmania
by toohey-forest-wildlife (CC BY-NC 4.0)

INVASIVES

CLIMATE CHANGE

✦ **39,639,986**
SPECIES OCCURRENCES

Study analysing results of more than 400 papers find non-native species less sensitive to extreme weather than native species worldwide

Invasive species and climate change are two major threats to global biodiversity. With the ability to influence the impact of invasive species, climate change, however, manifests itself not just as increasing mean temperatures, but also as more extreme weather events (EWEs), such as heatwaves, storms, floods and droughts.

In this meta-analysis of 443 studies, researchers systematically reviewed eight categories of responses of native and non-native species to five types of EWEs. In total, they synthesized more than 5,000 comparable

measures of effects on 6, 7, and 10 classes of terrestrial, freshwater and marine organisms, respectively.

Overall, the authors found that non-native species experienced more positive effects from EWEs compared to native species. In terrestrial ecosystems, only heatwaves negatively affected non-native species, while cold spells and drought also had adverse impacts on natives. In freshwater ecosystems, native species responded negatively to nearly all types of EWEs, whereas while only storms showed negative effects on non-native species. Marine species, on the whole, were not significantly impacted by EWEs.

To explore areas of high overlap between EWEs and potential EWE-tolerant invaders, the authors used GBIF-mediated occurrences to model the distributions of non-native species from their meta-analysis, overlaying maps of EWE hotspots derived from various meteorological databases.

The combined risks of EWEs and invasions were widespread but varied significantly depending on the type of EWE. Heatwaves posed the greatest risks in Australia and the Americas, while storms were most threatening in the Caribbean and India. Flood risks were highest in South America and East Asia, whereas droughts posed the greatest combined risks in Europe and South America. Cold spell risks were most pronounced in high-latitude regions.

39

Gu S, Qi T, Rohr JR, Liu X

United States, China

Meta-analysis reveals less sensitivity of non-native animals than natives to extreme weather worldwide

Nature Ecology & Evolution

doi.org/10.1038/s41559-023-02235-1



Sustainable cashew cropping in West Africa



Cashew - *Anacardium occidentale* L. *observed* in Djougou, Benin by iles-ecologiques (CC BY-NC 4.0)

CLIMATE CHANGE

AGRICULTURE

🌱 **1.705**
SPECIES OCCURRENCES

📍 Togo

Study explores climate resiliency of cashews, mapping highly suitable areas for cultivation across half of Togo, expected to increase to 75 per cent by 2055

Identifying crops resilient to climate change and areas suitable for future cultivation is key to sustainable agriculture. In West African countries like Togo, cashew (*Anacardium occidentale*) cropping has gained importance with recent trade in kernels and balms increasing.

Aimed at mapping favourable habitats for cashew cultivation in Togo, this study used field-studied and GBIF-mediated occurrences combined with soil and climate data to model the potential distribution of the crop now and in the future. The authors relied on the

MaxEnt algorithm, which they calibrated and tested to ensure a well-performing model.

Soil was by far the most important variable in the model followed by isothermality, temperature seasonality and precipitation. More than half the area of Togo was classified as highly favourable to cashew cultivation with unfavourable habitats restricted to areas in the northern and southern coastal regions.

When projected into climate scenarios for the year 2055, the model predicted significant increases of suitable habitat of 8–10 per cent, leaving more than 75 per cent of Togolese territory either moderately or highly suitable for future cashew cultivation.

By suggesting that cashew cropping represents a highly resilient strategy in light of climate change, the study's findings may help secure locations for suitable cultivation and help pave the way for a sustainable future for Togolese farmers.

40

ASSANG M.D., ATAKPAMA W., AHOUANDJINOUE O.B.E., DIMOBEK., GOUWAKINNOU G.N., AKPAGANA K

Togo, Benin, Nigeria, Burkina Faso

Priority area of sustainable cropping of the Cashew (*Anacardium occidentale* L.) in Togo: Economic implications and biodiversity conservation

Revue Nature et Technologie

<https://www.asjp.cerist.dz/en/article/213517>



Increasing vagrancy of Atlantic walrus in temperate Europe



Atlantic walrus - *Odobenus rosmarus rosmarus* - *observed* near Alnwick, UK by Iain Robson.

MARINE

CLIMATE CHANGE


818
SPECIES OCCURRENCES


Study of walrus sightings in the past century shows increasing numbers, possibly linked to climate change and population growth


While rarely venturing outside sub-Arctic waters, the Atlantic walrus (*Odobenus rosmarus rosmarus*) has been known to make appearances as far south as Spain. Vagrant animals moving outside their recognized range may be a sign of shifting distributions as a consequence of climate change leading to unsuitable conditions.


In this brief report published in Polar Biology, researchers gathered historic and contemporary records of walrus sightings in temperate Europe to describe vagrancy patterns and investigate trends and drivers over time.

41

Chiacchio M, Aae R 

Norway, Germany 

3000 leagues under the sea:
the voyages of vagrant walrus
(*Odobenus rosmarus*) in
temperate Europe 

Polar Biology 

doi.org/10.1007/s00300-023-03218-5 

Relying mainly on GBIF-mediated occurrences supplemented with data from social media and local newspapers, the authors collected a total of 254 deduplicated sightings. By analysing dates and locations of older sightings, the authors inferred that the sightings between 1923 and 2012 represented no more than 30 individual walrus.

The more recent observations with accompanying photos allowed for identification based on diagnostic characteristics, with which the authors narrowed down the observations between 2012 and 2022 to six individuals, bringing the total number of vagrant walrus to just 36.

The authors were able to calculate daily movement rates, suggesting individuals in fairly healthy condition. Additionally, they observed that males covered significantly larger distances than females.

A generalized linear model showed a significant increase in walrus observations over time, suggesting that more vagrants are reaching temperate Europe due to a combination of increasingly unsuitable conditions and growing population sizes in their natural range.



Climate change increasing malaria vulnerability in Kenya

42



Croton dichogamus Pax observed in Laikipia, Kenya by Kian Hayles-Cotton (CC BY-NC 4.0)

HUMAN HEALTH

CLIMATE CHANGE

5,663
SPECIES OCCURRENCES

Kenya

Study predicts decreased richness of medicinal plant species combined with increased suitability for mosquito vectors, leading to higher risk of disease

Due to lack of access to modern healthcare and high costs of anti-malaria drugs, the use of traditional plant medicines is common, especially in rural communities. In Kenya, 80 per cent of the population rely on local plants for fighting malaria, but unprecedented rates of climate change may soon threaten access to relevant medicinal species.

In this study, researchers used GBIF-mediated occurrence data for 21 known anti-malarial plants and three mosquito vectors and modelled their distributions,

overlap and the impact of future climates. The authors focussed on Samburu County in the Rift Valley, a stronghold for anti-malarial plants also burdened with high incidence of malaria.

Their models showed a significant overlap between habitat currently suitable for vectors and anti-malarial plants. When forecasting using climate data for 2050 and 2070, most regions, however, stood to lose anti-malarial plant species, with overall richness predicted to decrease in all climate scenarios.

For the vectors, the pattern was the opposite, and the authors predicted that suitable mosquito habitat would increase from 37 per cent to 65 per cent of Samburu County. This marked a significant increase in the overlap between areas of low anti-malarial plant richness and suitable habitat for vectors, thus increasing the overall vulnerability to disease.

With these results, the authors call for increased focus on in situ conservation of anti-malarial plants and vector monitoring and control, especially in areas likely to be most impacted by future climate patterns.

Gafna DJ, Obando JA, Kalwij JM, Dolos K, Schmidlein S

South Africa, Germany, Netherlands, Kenya

Climate Change Impacts on the Availability of Anti-malarial Plants in Kenya

Climate Change Ecology

doi.org/10.1016/j.ecochg.2023.100070



Global warming leads to extreme escalation of heat failure in cold-blooded animals



Opaleye - *Girella nigricans* (Ayres, 1860) - observed near Rancho Palos Verdes, CA, USA by Steve Addison (CC BY 4.0)

CLIMATE CHANGE

2,710
SPECIES OCCURRENCES

By 2100, projected warming could cause heat failure rates in some ectotherms to soar, reducing survival time during heatwaves from hours to mere minutes

The effects of global warming are often assessed as long-term impacts on species or population distributions. For individuals, especially among ectotherm (“cold-blooded”) organisms, however, fatal heat failure may occur during heatwaves or even diurnal temperature extremes.

This study explores the thermal sensitivities of ectotherms at the level of biological processes of growth, homeostasis and ageing. While these remain modest in the “permissive” temperature range associated

with life, they become extraordinarily sensitive in the stressful temperature range with fatal consequences.

By analysing the effects of temperature on the rates of biological processes in data compiled for 314 ectotherm species, they showed that thermal sensitivities mirror those of enzyme catalytic rates, feeding and metabolism, increasing fitness with temperature by seven per cent per degree. At the breaking point between permissive and stressful ranges, however, the rate of heat failure more than doubles with each degree of warming.

To assess the potential impacts of future warming, the authors analysed temperature changes experienced by two species, *Girella nigricans* and *Pheidole megacephala*, using GBIF-mediated occurrences. These analyses showed that projected warming in the year 2100 will increase heat failure rate by up to 2,100% and 690% for the two species, respectively.

For context, an increase of 1,000% (tenfold) means that an ectotherm will experience 150 per cent of its lethal dose on a hot day, as opposed to 15 per cent in today's climate. An organism currently able to survive for 5 hours during a heatwave, would succumb to heat failure and death within 30 minutes.

43

Jørgensen LB, Ørsted M, Malte H, Wang T, Overgaard J

Denmark

Extreme escalation of heat failure rates in ectotherms with global warming

Nature

doi.org/10.1038/s41586-022-05334-4



What bit the ancient Egyptians?



Boomslang - *Dispholidus typus* (Smith, 1828) - *observed* by julian_descoubes (CC BY-NC 4.0)

CLIMATE CHANGE

HUMAN HEALTH

ECOLOGY

📍 **11,628**
SPECIES OCCURRENCES

📍 Egypt

Combining ancient scrolls with species distribution modelling, study suggests Ancient Egypt had far more venomous snakes than the country has today

The Brooklyn Papyrus, a medical treatise from Ancient Egypt (~600–330 BCE), describes 37 venomous snakes in the empire including details on the effects of bites, recommended treatments and chances of survival. While the identities of some snakes are uncertain, several species included do not occur in modern Egypt.


Exploring the possibility that some of these snakes may have shifted their ranges or become locally extinct, this study used species distribution modelling to assess climatic suitability for present day and mid-Holocene Egypt.

Using GBIF-mediated occurrences and bioclimatic data on temperature and rainfall, the authors modelled the current potential distribution of ten focal species that were easily identifiable but without known occurrences within present day Egypt. With well-performing models of suitable climatic niches, they then mapped the species' distributions in Ancient Egypt according to mid-Holocene climate.


Their results predicted distributions of nine of the ten species within Ancient Egypt, including the highly venomous, four-fanged boomslang (*Dispholidus typus*), now restricted to sub-Saharan savannas. The tenth species, *Causus rhombeatus* without apparent suitable climate in the kingdom, however, did occur in neighbouring regions that were regular trading partners of the Ancient Egyptians.

Overall, these findings suggest that despite not occurring in present-day Egypt, these ten snakes may well have been present to bite Egyptians 4,000 years ago.

44

McBride E, Winder IC, Wüster W 

United Kingdom 

What Bit the Ancient Egyptians?
Niche Modelling to Identify
the Snakes Described in the
Brooklyn Medical Papyrus 

Environmental Archaeology 

doi.org/10.1080/14614103.2023.2266631 



Exploring 100 million years of turtle niches to predict range shifts under future climates

45



Asiatic softshell turtle - *Amyda cartilaginea* (Boddaert, 1770) - *observed* in Bangkok, Thailand
by Sam Hambly (CC BY-NC 4.0)

CLIMATE CHANGE

EVOLUTION

FRESHWATER

• **32,951**
SPECIES OCCURRENCES

Study of terrestrial and freshwater turtles leverages insights on past range shifts from paleogeographic reconstruction models to infer probable ecological responses to future climate change

Studies seeking to predict geographic range changes under climate change frequently use ecological niche modelling (ENM), relating current species distributions to climate variables and projecting the models into future climate scenarios.

Recognizing that the recent past does not offer reasonable analogs for the unprecedented CO₂ levels predicted in the next century, this study of turtles used a deep-time record and explored 100 million years of paleoniche dynamics.

Using species occurrences of extant terrestrial and freshwater turtles from GBIF and fossil records of extinct relatives from the [Paleobiology Database](#), the authors created ENMs, leveraging three modelling algorithms combined in an ensemble approach.

They projected these models into three past hyperthermal scenarios (38–34, 72–66 and 94–84 million years ago) as well as future predictions based on several Representative Concentration Pathways (RCP) emission scenarios.

Relying in insights from the range shifts observed in the deep past scenarios, the authors showed future predictions of poleward range expansions in the Northern Hemisphere with decreased habitat suitability at lower latitudes. This pattern represent an inversion of trend otherwise present since the Eocene–34 million years ago.

The authors note that while some freshwater turtles may able to track their changing niches better than terrestrial species, habitat destruction and fragmentation may limit the ability of both groups to cope with future climate change.

Chiarenza AA, Waterson AM, Schmidt DN, Valdes PJ, Yesson C, Holroyd PA, et al

United Kingdom, Spain

100 million years of turtle paleoniche dynamics enable the prediction of latitudinal range shifts in a warming world

Current Biology

doi.org/10.1016/j.cub.2022.11.056



How plants adapt to climate change: insights from phylogenetic analysis

46



Acaulimalva nubigena (Walp.) Krapov. *observed* in Toro Toro, Bolivia by Alfredo F. Fuentes Claros (CC BY-NC 4.0)

PHYLOGENETICS

CLIMATE CHANGE

✦ **212,765,917**
SPECIES OCCURRENCES

Study of climate preferences of 200,000 plant species paired with phylogenetic supertree provides additional evidence that climatic niches are phylogenetically conserved

Scientists expect climate change to increase the frequency of extreme weather such as heat waves, droughts and hurricanes. Given that climate is an important driver of plant traits and functions, understanding how tolerances are evolutionarily conserved is key to predicting responses to climate change.

In this study, researchers used GBIF-mediated occurrences of more than 200,000 plant species to describe bioclimatic envelopes based on data for temperature, precipitation

and solar radiation in datasets from the European Centre for Medium-Range Weather Forecasts (ECMWF) and WorldClim.

To adjust for potential observation bias in the data, the authors weighted the species envelopes against a vegetation index derived from NASA satellite imaging as a proxy for true abundance. They also performed a correction of climate bias, recovering envelopes in idealized landscapes where all climates were equally available.

Using a revised supertree of more than 25,000 species, the authors found strong evidence for phylogenetic signals in the extracted bioclimatic parameters based on both climate datasets—particularly for minimum temperature and rainfall. The signals were even stronger when corrected for observation bias.

These findings provide further evidence that the climatic tolerances of plants are phylogenetically conserved, and that plants' response to climate change will depend on their branch of the evolutionary tree of life.

Harris C. Brummitt N. Cobbold
CA, Reeve R

United Kingdom

Strong phylogenetic signals
in global plant bioclimatic
envelopes

Global Ecology and
Biogeography

doi.org/10.1111/geb.13564



Assessing impact of stressors on global penguin hotspots

47



Chinstrap penguins [*Pygoscelis antarcticus* (J.R.Forster, 1781)] *observed* in the Antarctic Peninsula
by alexws23 (CC BY-NC 4.0)

CLIMATE CHANGE

CONSERVATION

MARINE

927,212
SPECIES OCCURRENCES

Peru, Australia, New Zealand

Study identifies global penguin hotspots, quantifying impact of human activities and climate-driven environmental changes at sea

Penguins are considered important sentinel species for monitoring the marine ecosystems of the Southern Hemisphere. As charismatic umbrella species that help safeguard their ecosystems and associated services when protected, penguins can function as ambassadors with a vital role in raising awareness about marine life and environmental issues.

In this study, researchers used GBIF-mediated species occurrences of 18 extant species in combination with data on climatic and human

stressors to quantitatively assess their impact on global penguin populations.

First, the authors identified 22 penguin distribution hotspots, most of which were shared among several species. Four species, Galápagos (*Spheniscus mendiculus*), African (*S. demersus*), yellow-eyed (*Megadyptes antipodes*) and little penguin (*Eudyptula minor*), did not share their hotspots with other species. However, a hotspot in the Macquarie Island region (~1,500 km southeast of Tasmania), boasted five co-occurring penguin species.

When assessing the cumulative impact of stressors, the authors found the greatest impact in areas off western Africa, Peru, the Patagonian Shelf and waters around New Zealand and south and east Australia. Within penguin hotspots, the most significant contributor were changes to sea surface temperature.

African (*S. demersus*), chinstrap (*Pygoscelis antarcticus*) and Humboldt penguins (*S. humboldti*) came out as the most potentially impacted of all species, while erect-crested (*Eudyptes sclateri*) and king penguins (*Aptenodytes patagonicus*) were the least impacted by environmental and human stressors.

Gimeno M, Giménez J, Chiaradia A, Davis LS, Seddon PJ, Ropert-Coudert Y, et al

Spain, Australia, New Zealand, France, United Kingdom

Climate and human stressors on global penguin hotspots: Current assessments for future conservation

Global Change Biology

doi.org/10.1111/gcb.17143



Climate change brings bat hosts of SARS-like viruses closer to humans

48



Intermediate horseshoe bat (*Rhinolophus affinis* Horsfield, 1823) *observed* in Thung Tam Sao, Thailand
by BioM_Akekachoke.B (CC BY-NC 4.0)

HUMAN HEALTH

CONSERVATION

CLIMATE CHANGE

📍 **13,765**
SPECIES OCCURRENCES

📍 Myanmar, China
Laos, Thailand, Viet Nam

Mapping the distributions of sarbecovirus hosts, this study identifies Southeast Asian hotspots where bats may converge near human populations centres under future climate change

Since the discovery of SARS-CoV-2, the virus responsible for the COVID-19 pandemic, researchers have described dozens of novel SARS-like viruses (subgenus Sarbecovirus) and host interactions, particularly with bats. Understanding the effects of global climate change on bat distributions is critical for both conservation and public health.

In this study, authors identified 35 bat species with sarbecovirus interactions. Using species occurrences from GBIF and other sources cropped to IUCN range limits,

they built ecological niche model ensembles based on environmental variables to map the current potential distributions of the bats.

Seasonal variation in temperature was the most important predictor in the models that strongly affected the distribution of 12 species. Karst (the availability of caves) and precipitation also affected the predicted bat distributions, although for fewer species.

The authors found the highest bat richness in Southeast Asia with 13 species in Myanmar and 12 species in China, Lao People's Democratic Republic, Thailand and Viet Nam. When projecting the models into future climatic scenarios, these patterns remained largely unchanged, but the number of contiguous areas home to 10 or more species increased from 26 to 38.

Overall, most species in the study will likely lose suitable habitat and assemble in concentrated hotspots that shift slightly east. This change might lead to fragmented bat populations and local extinctions, but also bring more bat species into closer contact with human populations.

Combined with increased human encroachment on bat habitats, changes to bat ranges may redistribute and increase risk of sarbecoviral spillover and disease emergence.

Muylaert RL, Kingston T, Luo J, Vancine MH, Galli N, Carlson CJ, et al

New Zealand, United States, China, Brazil, Italy

Present and future distribution of bat hosts of sarbecoviruses: implications for conservation and public health

Proceedings of the Royal Society B: Biological Sciences

doi.org/10.1098/rspb.2022.0397



Beyond the tipping point for cross-species viral transmission risk



Sunda flying foxes [*Acerodon macklotii* (Temminck, 1837)] observed in Manggarai Barat, Indonesia
by cccrll (CC BY-NC 4.0)

CLIMATE CHANGE

HUMAN HEALTH

🔍 **3,870**
MAMMALIAN SPECIES

Climate change has increased the risk of viral sharing, and limiting temperature increases appears unlikely to reduce future transmission risk

Zoonotic spillover events—where animal pathogens jump to humans—are expected to increase in the future due to climate and land use change, shifting the ranges of animal carriers. This will not only bring humans in closer contact with wildlife, but also lead to new opportunities for viral sharing among wild animals.

To explore the potential for increased transmission risk, researchers combined a mammal-viral network with species distribution models for more than 3,000 mammalian species based on GBIF-mediated

occurrences and climate and land-use change scenarios for the year 2070.

Assuming that species are able to shift their ranges at the rate of global change, the study predicted that 99 per cent of mammals will overlap with at least one new species, permitting over 300,000 first encounters, effectively doubling the potential species contact from baseline. These encounters are predicted to lead to more than 15,000 new viral sharing events.

When taking into account the limited dispersal ability of flightless species, the number of first encounters and sharing events were reduced to about a third. The majority of transmission events were predicted to occur in southeast Asia, with bats accounting for nearly 90 per cent of first encounter cases.

Notably, the analysis predicts that the most optimistic scenario of climate change will lead to transmission risk at least as high as the most pessimistic one, and perhaps even higher, suggesting that greenhouse gas mitigation alone will not prevent increased viral sharing.

The authors recommend increased monitoring of not only viral spillover, but also transmission among wildlife species in order to improve the ability to respond timely to future zoonotic threats.

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Carlson CJ, Albery GF, Merow C, Trisos CH, Zipfel CM, Eskew EA, et al

United States, South Africa

Climate change increases cross-species viral transmission risk

Nature

doi.org/10.1038/s41586-022-04788-w



Urban forests under threat from climate change



Mountain fig (*Ficus virens* Aiton) observed by Rippy Bedi in Delhi, India (CC BY 4.0)

CLIMATE CHANGE

ECOSYSTEM SERVICES

• **181,914,869**
SPECIES OCCURRENCES

Study of more than 3,000 trees and shrubs planted in 164 cities across the world find three in four species at risk from future changes in temperature and precipitation

Urban forests can help connect city dwellers with nature and mitigate effects of climate change. Despite providing shade, dissipating heat through evapotranspiration and storing carbon through photosynthesis, urban trees and shrubs themselves, however, may be under risk to climate change.

In this study, researchers analysed the potential impacts of future climate change on 3,000+ tree and shrub species in 164 cities across 78 countries based on the

Global Urban Tree Inventory. For these, the authors collected occurrence records from GBIF and [sPlotOpen](#) (an open-access, global dataset of vegetation plots), and characterized the climatic niches of each species based on data on temperature and precipitation.

For each city, they calculated the potential exposure to climate change as the difference between future and current climate. Then, for each species-by-city combination, they calculated a safety margin, indicating the tolerance to climate conditions exceeding upper or lower limits. Finally, based on cities' intrinsic exposure and species' safety margins, the authors derived an overall risk to climate change.

Their analysis predicted the highest exposures to climate change in Helsinki (Finland), Winnipeg (Canada) and Minneapolis (USA). Overall, up to 65 per cent of species were currently exceeding their margins. In Barcelona (Spain), Niamey (Niger) and Singapore, this applied to 100 per cent of species present.

The authors estimated that by 2050, up to 76 per cent of all urban trees and shrubs would be at risk. The proportion of species at risk for cities tended to increase towards the equator. They found the highest risks in cities projected to have warmer and drier climates, in countries with low resilience to climate change, highlighting Pretoria (South Africa) and New Delhi (India) as examples.

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Esperon-Rodriguez M, Tjoelker MG, Lenoir J, Baumgartner JB, Beaumont LJ, Nipperess DA, et al

France, Australia

Climate change increases global risk to urban forests

Nature Climate Change

doi.org/10.1038/s41558-022-01465-8





- ✓ Cover illustration: *Pygoscelis papua*, La galerie des oiseaux. Paris, 1825. Via [Biodiversity Heritage Library](#).
- ✓ Back cover illustration: Walrus (*Odobenus Brisson*, 1762) from The Proceedings of the Zoological Society of London, 1909. Via [Biodiversity Heritage library](#).
- ✓ Special section background illustration: Walrus (*Odobenus Brisson*, 1762) from Our living world: an artistic edition of the Rev. J. G. Wood's Natural history of animate creation. New York, 1885. Via [Biodiversity Heritage Library](#).
- ✓ Inner cover illustration: Polar bear (*Ursus maritimus* Phipps, 1774), The wonders of the animal kingdom : exhibiting delineations of the most distinguished wild animals in the various menageries of this country. London, 1830. Via [Biodiversity Heritage Library](#).

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