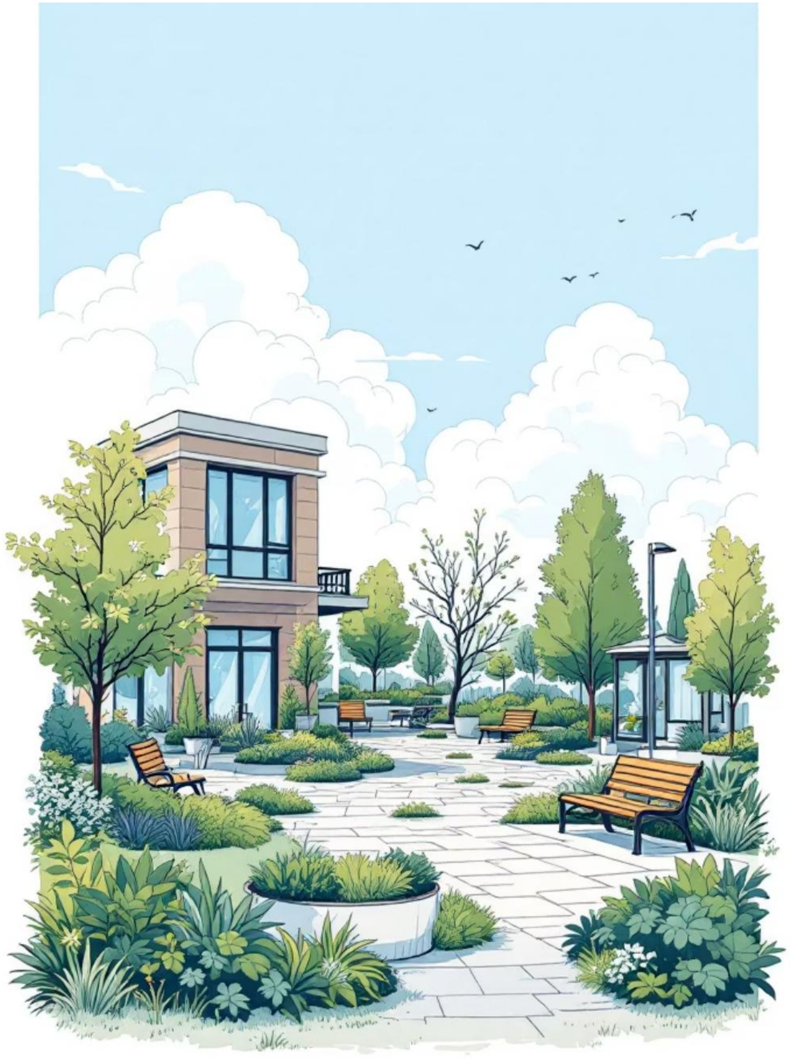
Urban Ecosystems as Novel Ecosystems

Exploring how cities create unprecedented ecological conditions and what this means for conservation and restoration

What Are Novel Ecosystems?

Novel ecosystems are biological communities that have no historical precedent. They emerge when human activities fundamentally transform environmental conditions, creating combinations of species, abiotic factors, and ecosystem processes that never existed before.

Unlike degraded ecosystems that can recover to a previous state, novel ecosystems represent new ecological baselines. In urban areas, these systems are becoming the norm rather than the exception.



Drivers of Novelty in Urban Environments

Physical Modification

Impervious surfaces, altered hydrology, and substrate changes create unprecedented abiotic conditions

Species Introductions

Global trade and travel facilitate the movement of species across biogeographic barriers

Urban Heat Island

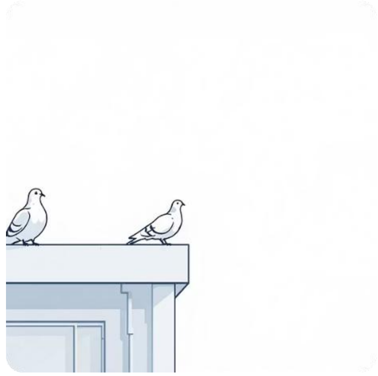
Elevated temperatures shift species distributions and phenological patterns

Chemical Alterations

Air, water, and soil pollution create selective pressures unlike natural environments

Species Assemblages Without Historical Analogues

Urban environments assemble species combinations that never coexisted in evolutionary history, creating unprecedented ecological interactions.



Urban Generalists

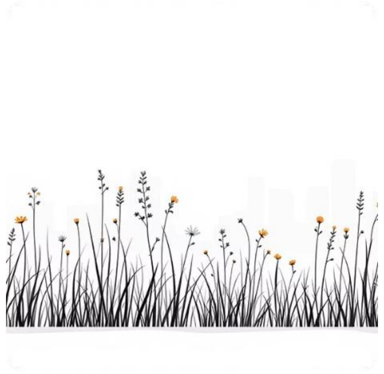
Species like pigeons thrive in human-modified landscapes

Cultivated Diversity

Ornamental plants from different continents grow side by side

Adaptive Opportunists

Animals adapt behaviors to exploit urban resources



Spontaneous Colonisers

Weeds and (non-)native species fill disturbed spaces unpredictably

Global Ecology and Biogeography
A Journal of Macroecology

RESEARCH ARTICLE | Open Access

Here, There and Everywhere: Widespread Non-Native Plants in the World's Urban Ecosystems

David M. Richardson, Lauren B. Trotta, Myla F. J. Aronson, Benjamin Baiser, Marc W. Cadotte, Marta Carboni, Laura Celesti-Grapow, Sonja Knapp ... See all authors

From cliffs to concrete

BIOLOGICAL REVIEWS
Cambridge Philosophical Society

Original Article | Open Access

The impact of urbanisation on social behaviour: a comprehensive review

Avery L. Maune, Barbara A. Caspers, Isabel Damas-Moreira

First published: 29 December 2025 | https://doi.org/10.1002/brv.70113 | VIEW METRICS

Urban Generalists

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Weeds and (non-)native species fill disturbed spaces unpredictably

(fast-growing, stress-tolerant “ruderal” species)

The Role of Non-Native and Opportunistic Species

Non-Native Species

Urban environments are dominated by species introduced from other continents and biomes. Rather than simply replacing native species, these newcomers create entirely new community structures.

- Fill ecological niches left vacant by disturbance
- Provide ecosystem services in novel combinations
- Establish self-sustaining populations without human support

Opportunistic Species

Generalist species exploit the variable and disturbed conditions of cities; often outperforming specialists adapted to stable environments.

- Rapid reproduction and dispersal capabilities
- Broad environmental tolerances
- Flexible resource use strategies

```
(1) ORIGINAL NETWORK

        A ----- B ----- C
         \     / \     /
          \   /   \   /
            D ----- E
               \   /
                 F


(2) NODE & EDGE LOSS

        A           C
         \         /
          \       /
            D     E
                   \
                    F


(3) REWIRING

        A ----- E ----- C
                |
                |
                F
                |
                D


(4) NOVEL NETWORK

        A ----- E ----- C
                |       |
                |       X
                |      /
                F     /
                |    /
                D   H
```

Departure from Reference Conditions

Historical Baseline

Pre-development ecosystem structure and composition

Urban Transformation

Irreversible changes to abiotic conditions and species pools

Novel State

Self-sustaining ecosystems with no path back to historical conditions

Urban ecosystems cannot return to historical reference conditions because the underlying drivers—climate, soil, hydrology, and species pools—have been permanently altered. The question shifts from "**restoration to historical baseline**" to "**what functioning ecosystems can exist under current conditions?**"

Implications for Restoration Ecology

Redefining Success

Restoration goals must shift from historical fidelity to functional performance. How well does the ecosystem provide services rather than how closely it resembles the past?

Accepting Hybrid Systems

Urban restoration increasingly creates hybrid ecosystems combining native and non-native species, designed for specific functions rather than historical accuracy.

Ecosystem Services Focus

Urban areas prioritises services like air purification, temperature regulation, and stormwater management over taxonomic composition.

Adaptive Management

Restoration designs must accommodate ongoing change rather than attempting to freeze ecosystems in a particular state.

Rethinking "Baseline" and "Naturalness" in Urban Systems

New Frameworks Needed

Traditional conservation frameworks struggle with urban reality. We need new paradigms that:

- Define baselines based on current and future conditions, not past states
- Recognise that "natural" includes human-influenced systems
- Value ecosystem function alongside taxonomic composition
- Embrace dynamic change rather than equilibrium assumptions

"The question is not whether urban ecosystems are 'natural'—they clearly aren't in the traditional sense. The question is whether they can be ecologically functional and valuable."

Basic and Applied Ecology
Volume 52, May 2021, Pages 82-94

A conceptual framework for urban ecological restoration and rehabilitation

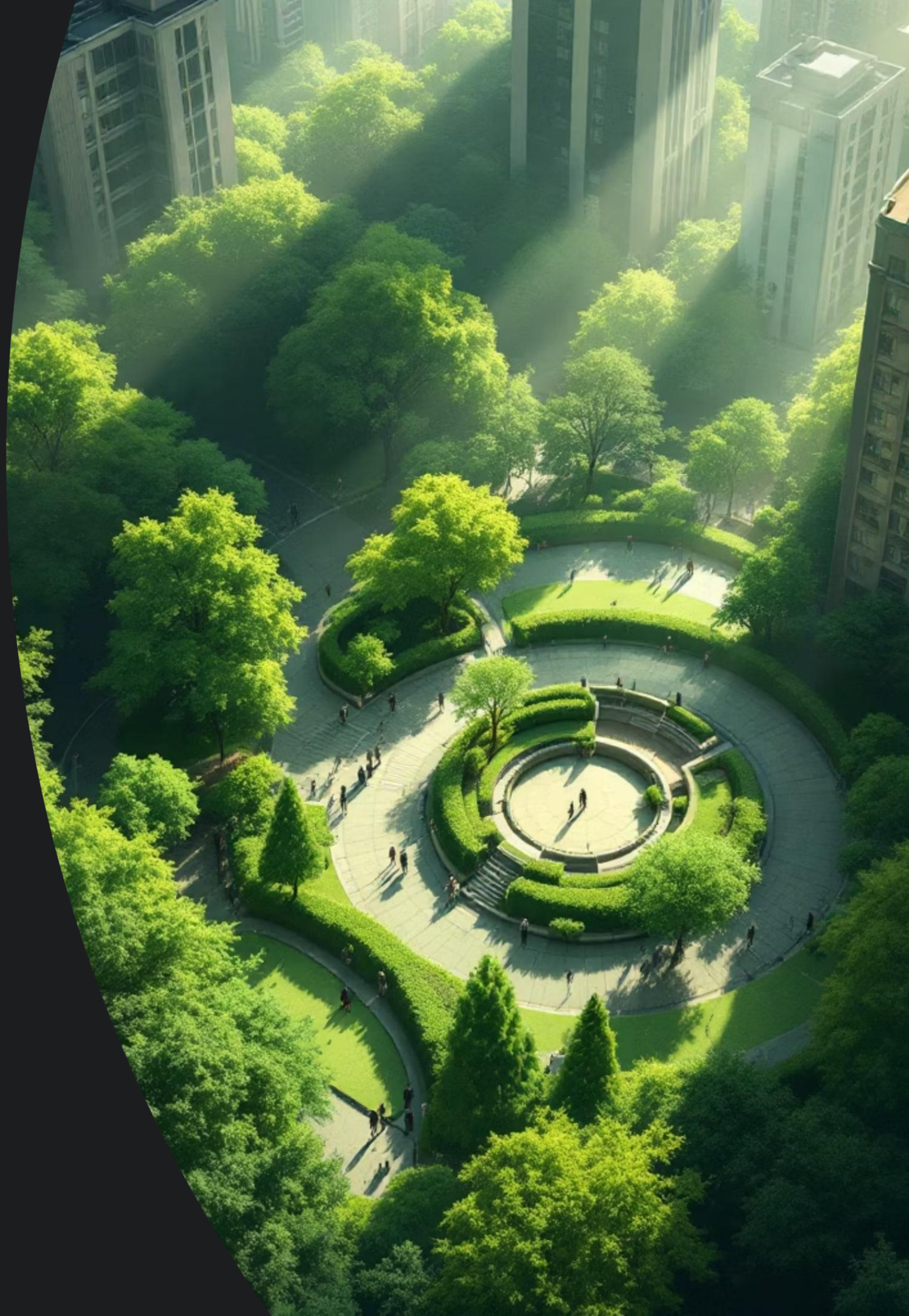
Valentin H. Klaus [a], Kathrin Kiehl [b]

Fig. 2. Examples of different types of urban ecosystems corresponding to potential restoration and rehabilitation measures as described in Tables 1 and 2. (A) Deadwood in an ancient forest relict with reduced management; (B) near-natural lakeshore at Rapperswil, Switzerland; (C) old cemetery transformed into a park with remnants of species-rich ancient dry sandy grassland in Osnabrück, Germany; (D) restoration of the river Isar in Munich, Germany, with a combination of dynamic gravel banks and partly fixed banks; (E) restoration of roadside vegetation (formerly species-poor lawn) by seeding native grassland species, Zurich, Switzerland; (F) combination of passive restoration by woodland succession and managed pioneer and grassland vegetation in the Duisburg Nord landscape park, Germany; (G) extensive green roof with heterogeneous environmental conditions, native wildflowers and a sand pile as nesting site for Hymenoptera in Germany; (H) rehabilitation of an urban creek under restricted spatial conditions, Zurich, Switzerland; (J) native wildflowers for insects in a garden flower bed, compared to neighbouring gravel bed and pavement, Osnabruck, Germany; (K) native grassland species introduced by seeding at a small traffic island in Osnabrück, Germany; (L) conventional extensive green roof with *Sedum* cultivars; (M) street with alley providing shade in a hot summer for humans and fragrant flowers of the native tree species *Tilia cordata* for bees in Germany.

Measuring Urban Ecosystem Functioning

From patterns to processes —why measurement matters in cities

Biodiversity **Functioning** **Services**



A Fundamental Conceptual Distinction

Biodiversity, functioning, and services are related —but they are not equivalent. Confusing them compromises urban analysis and management.

1

Biodiversity

The **structure** of the ecosystem —which species are present and in what abundance

2

Functioning

The **ecological processes** —energy flows, nutrient cycling, productivity

3

Services

The **benefits to humans** —climate regulation, pollination, well-being

Measuring only one of these components is not enough to understand the functional state of an urban ecosystem.

Ecological Integrity in an Urban Context

Classical Approach

Ecological integrity is defined by **reference ecosystems** — undisturbed natural states used as a comparative baseline.

Urban Challenge

In cities, **there is no clear baseline**. Urban ecosystems are permanently altered by historical disturbances and ongoing pressures.

Compositional Integrity

Which species are present relative to a reference state

Functional Integrity

Essential ecological processes are occurring, regardless of composition

Key shift: From "naturalness" → to "functioning"

Indicators of Ecological Functioning

Because ecological processes are rarely directly measurable, we rely on **measurable proxies** that reflect them indirectly.

Biodiversity

Species richness and abundance as a reflection of the functional capacity of the habitat

Vegetation Structure

Vertical stratification and horizontal heterogeneity as indicators of structural complexity

Soil

Permeability, compaction, and organic matter as indicators of edaphic processes

Habitat Features

Dead wood, cavities, and microhabitats as support for complex trophic chains

Biodiversity Metrics: The Basics

Species Richness

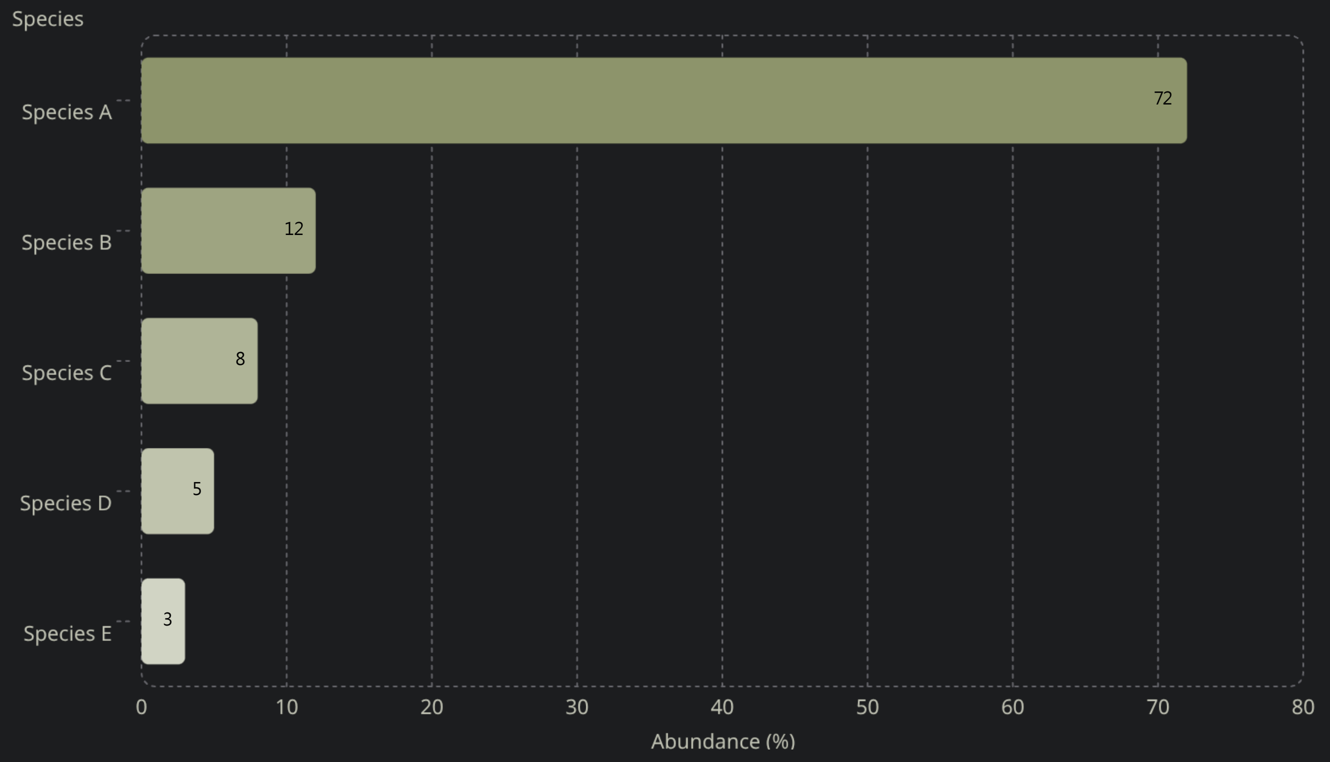
The total number of species present — the most widely used metric, but often insufficient on its own.

Evenness

How abundances are distributed among species. Two communities with **the same richness can have very different functional structures** if one is dominated by a few species.

Equal richness ≠ equal structure. Evenness reveals what richness hides.

Shannon vs. Simpson: Two Views of Diversity



Shannon Index (H')

Sensitive to **richness and rare species**. An additional rare species increases the index even if it is only slightly abundant.

Simpson Index (D)

Sensitive to **dominance**. It decreases sharply when one species monopolizes resources.

Urban Interpretation

Cities tend to favor a few dominant generalist species — the Simpson index captures this pattern of functional degradation more effectively.

Fragmentation and Urban Diversity

Effect on Shannon

Fragmentation may **not immediately reduce richness** — species persist in isolated patches for some time (extinction debt).

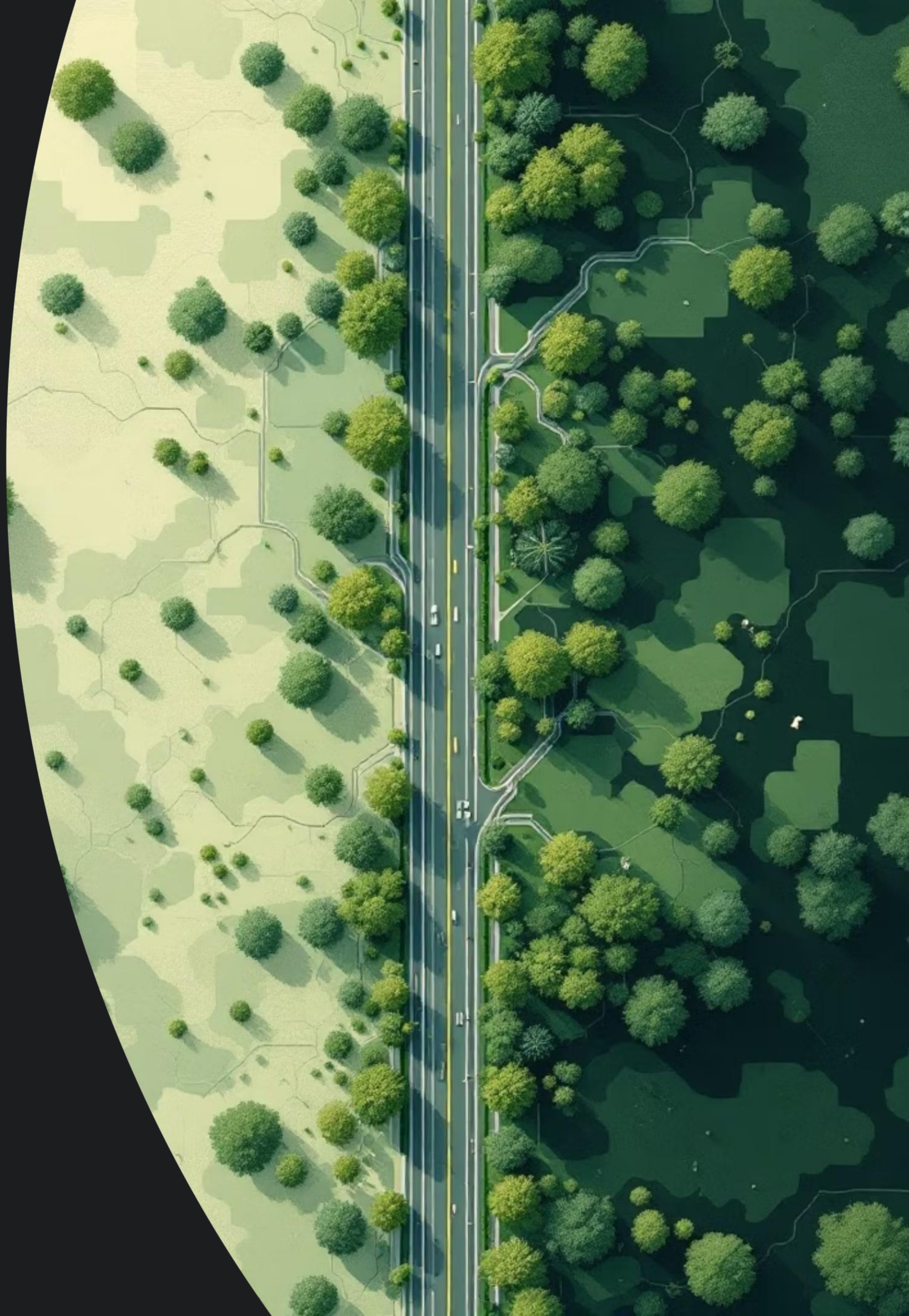
Effect on Simpson

Fragmentation **increases dominance** quickly — specialist species disappear and generalists expand, sharply reducing the Simpson index.

Key Message

Shannon → moderate change
Simpson → sharp decline

Using species richness alone can **mask the real functional degradation** caused by fragmentation.



Vegetation and Soil as Functional Indicators

Structure controls function — the spatial organization of vegetation and the properties of the soil largely determine the ecological processes that occur in a place.

Vegetation

- **Vertical stratification:** presence of multiple layers (tree, shrub, herbaceous) indicates structural complexity and support for trophic networks
- **Horizontal heterogeneity:** spatial variation in cover creates differentiated microhabitats

Soil

- **Permeability:** controls water infiltration and the risk of urban flooding
- **Compaction:** compacted soils limit edaphic fauna and nutrient cycling

Scale, Time, and Indicator Limitations

Scale Matters

- **Local scale:** captures habitat variation and community structure
- **Landscape scale:** reveals connectivity, fragmentation, and flows between patches

Temporal Variability

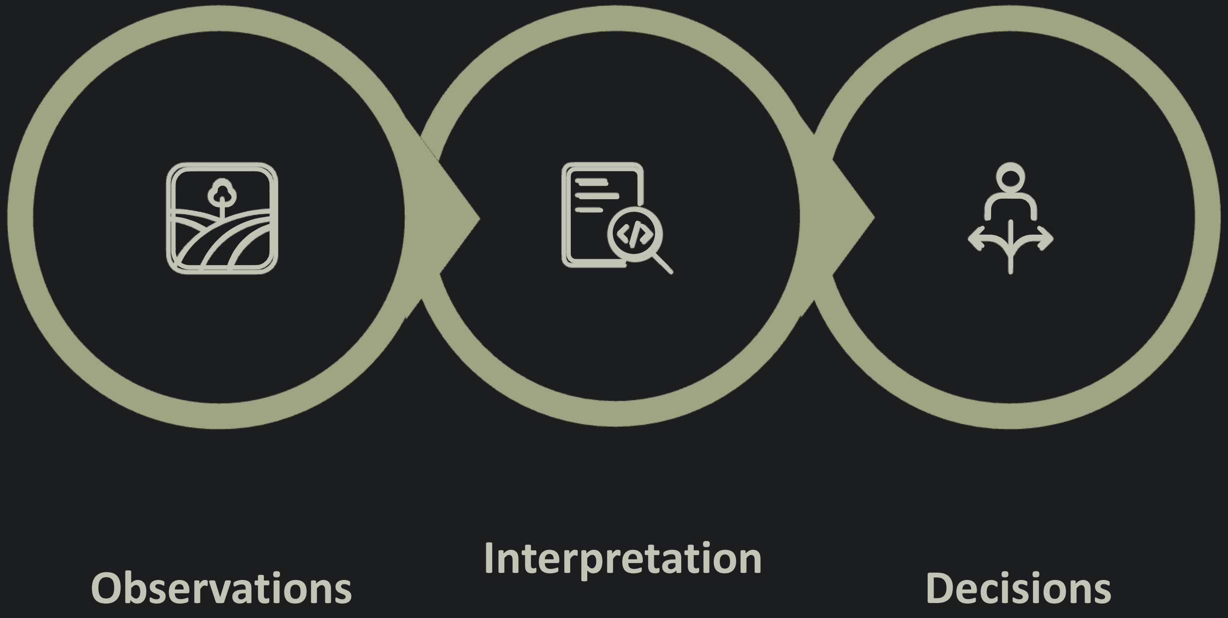
Indicators vary seasonally and interannually. A single sampling event may not represent the ecosystem's average state.

Indicators ≠ Direct Processes

Proxies infer functioning—they do not measure it directly. The degree of correspondence depends on the local context.

Synthesis: What We Infer from Patterns

> Urban ecosystems have no reference state, are measured through proxies, and are shaped by dominance and structure — functioning is always an inference.



This indicator-based approach opens the way to **systematic monitoring and adaptive management** of urban green ecosystems.

Urban Biodiversity Monitoring & Citizen Science

How community-driven observation and digital tools are transforming the way we understand life in cities — from rooftop mosses to migratory birds.

Why Biodiversity Data in Cities Matters

Urban ecosystems are dynamic, fragmented, and rapidly changing. Yet they support surprising levels of biodiversity and directly affect human wellbeing.

Policy & Planning

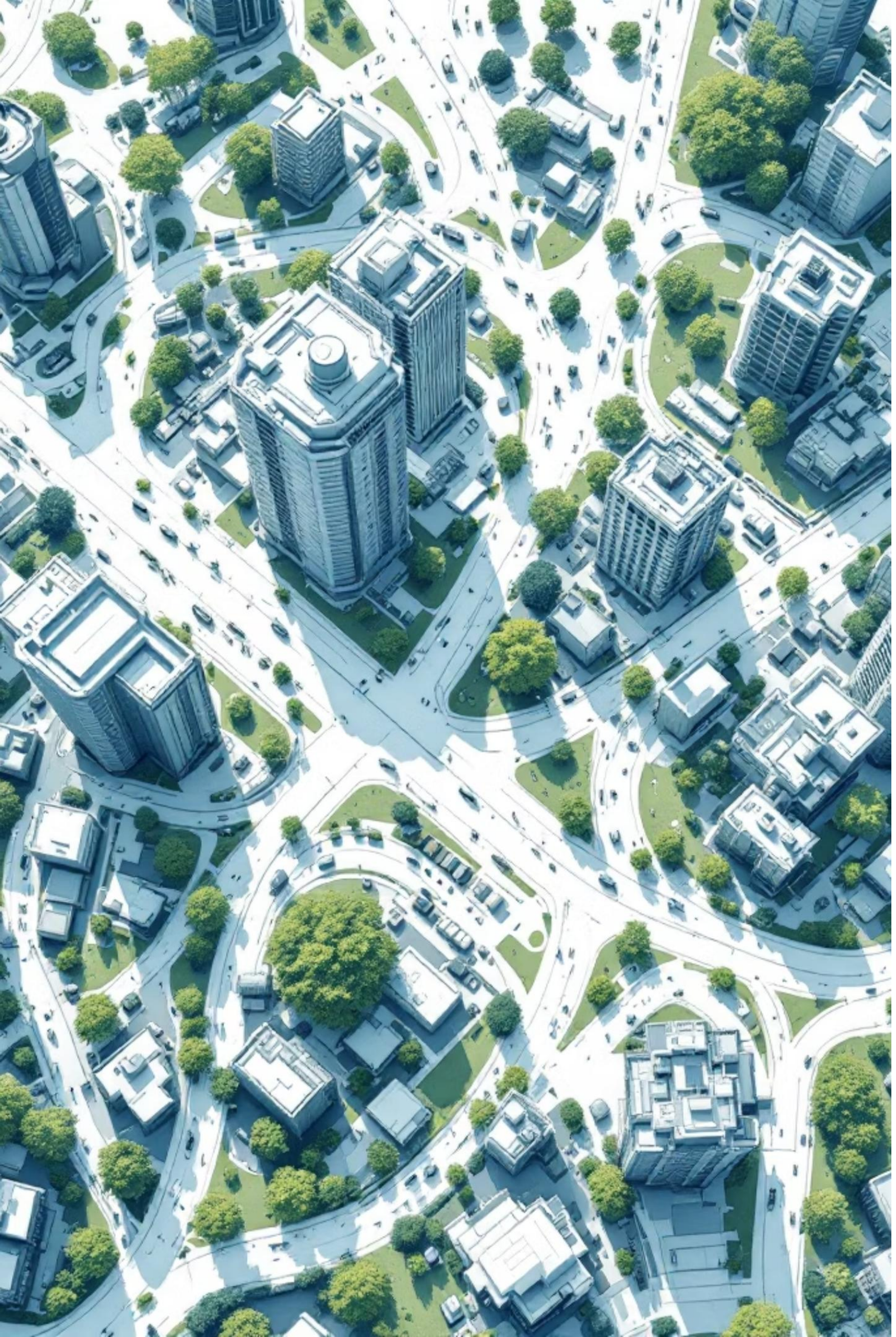
Data drives green infrastructure decisions and biodiversity action plans.

Ecosystem Services

Understanding species composition helps quantify pollination, cooling, and resilience.

Baseline Monitoring

Long-term records detect trends in urban species richness and community shifts.



Challenges in Urban Ecological Monitoring

Spatial Fragmentation

Habitats are small, isolated, and heterogeneous — hard to sample systematically.

Rapid Change

Land use shifts quickly, making static surveys outdated almost immediately.

Resource Constraints

Expert-led field surveys are costly, time-intensive, and spatially limited.

Taxonomic Breadth

No single expert covers all taxa — insects, birds, fungi, and flora each require specialists.

Citizen Science: Closing the Data Gap

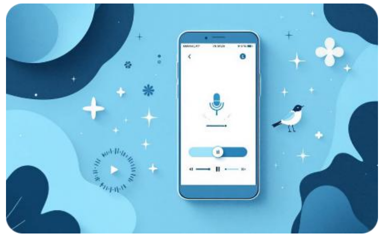
Volunteer observers — equipped with smartphones — can generate vast, spatially rich datasets that no research team could replicate alone.

700M+	100K+	370K+
Observations	**Active users**	**Species recorded**
on iNaturalist globally	contributing daily worldwide	across taxa and continents

Key Platforms & Tools

iNaturalist

AI-assisted species ID for plants, animals, and fungi. Community validation via agreements creates research-grade records.



Merlin Bird ID

Sound and photo-based bird identification by Cornell Lab. Enables passive acoustic monitoring through Sound ID.

eBird

Structured bird checklists linked to location and effort data — ideal for abundance and distribution analyses.

Other Platforms

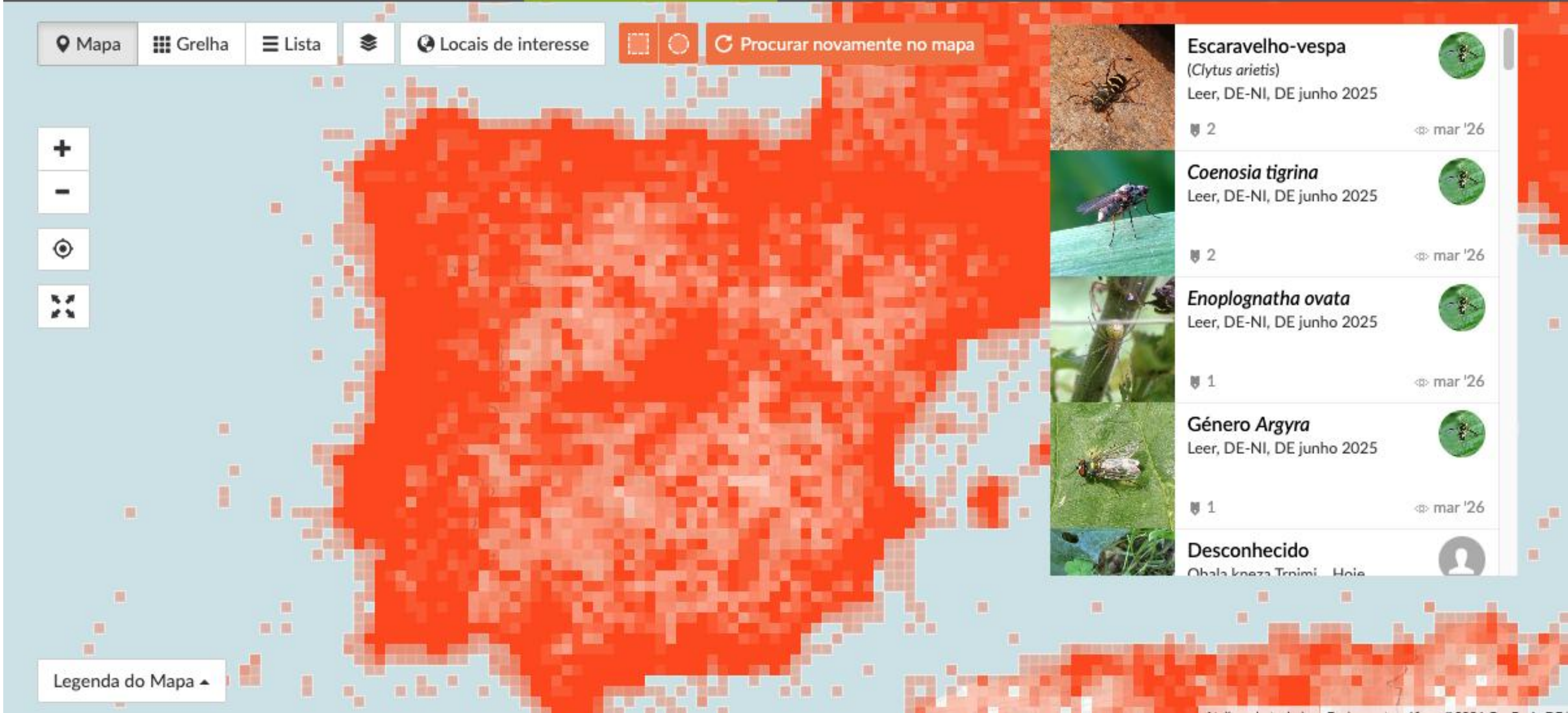
Pl@ntNet for flora, BugGuide for invertebrates, and GBIF as a global aggregator of occurrence data.

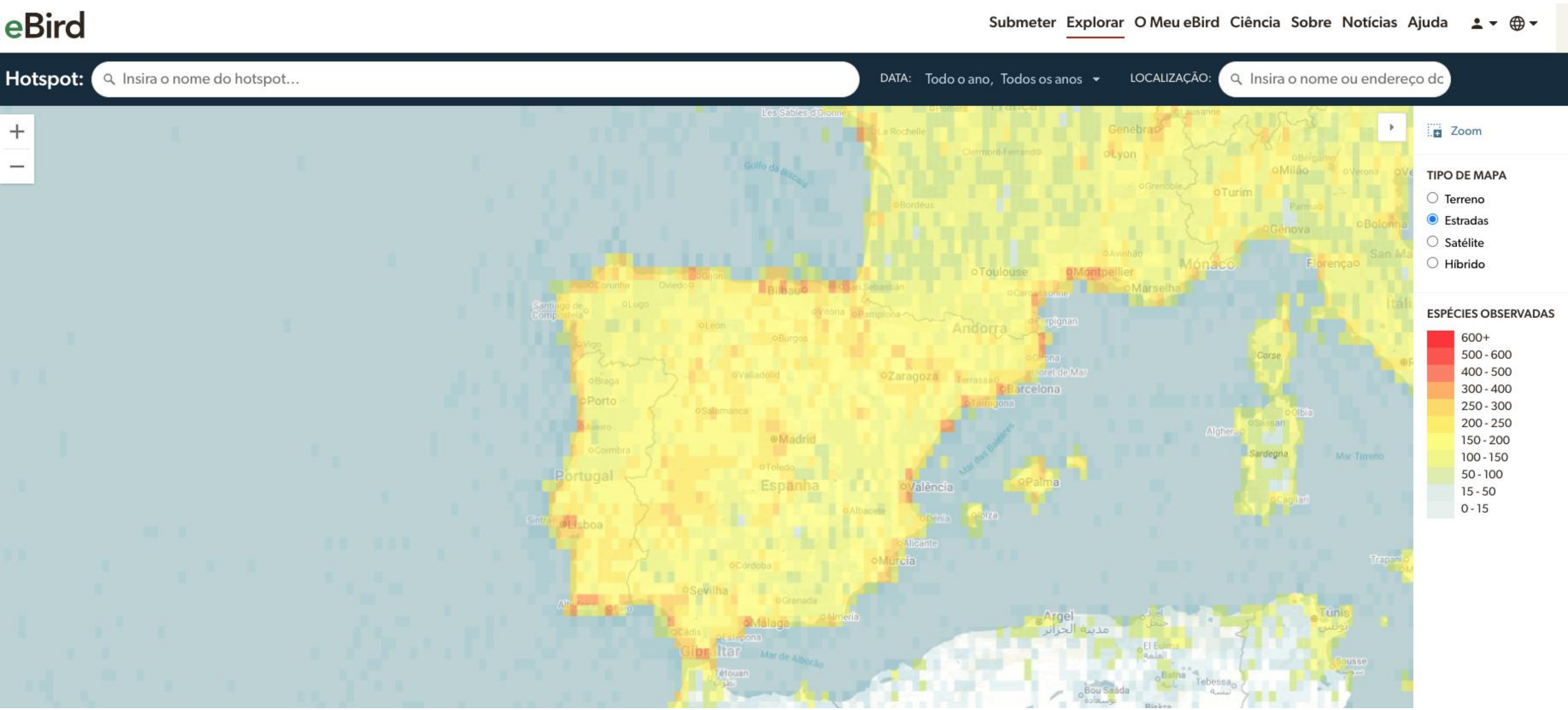
Observações

Species | Localidade | Ir | Filtros

O Mundo

300.987.388 OBSERVAÇÕES | **557.858** ESPÉCIES | **481.621** IDENTIFICADORES | **4.065.463** OBSERVADORES




eBird
Submeter
Explorar
O Meu eBird
Ciência
Sobre
Notícias
Ajuda
Hotspot:
Insira o nome do hotspot...
DATA:
Todo o ano, Todos os anos
LOCALIZAÇÃO:
Insira o nome ou endereço dc
Zoom
TIPO DE MAPA
Terreno
Estradas
Satélite
Híbrido
ESPÉCIES OBSERVADAS
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100 - 150
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Golfo da Biscaia
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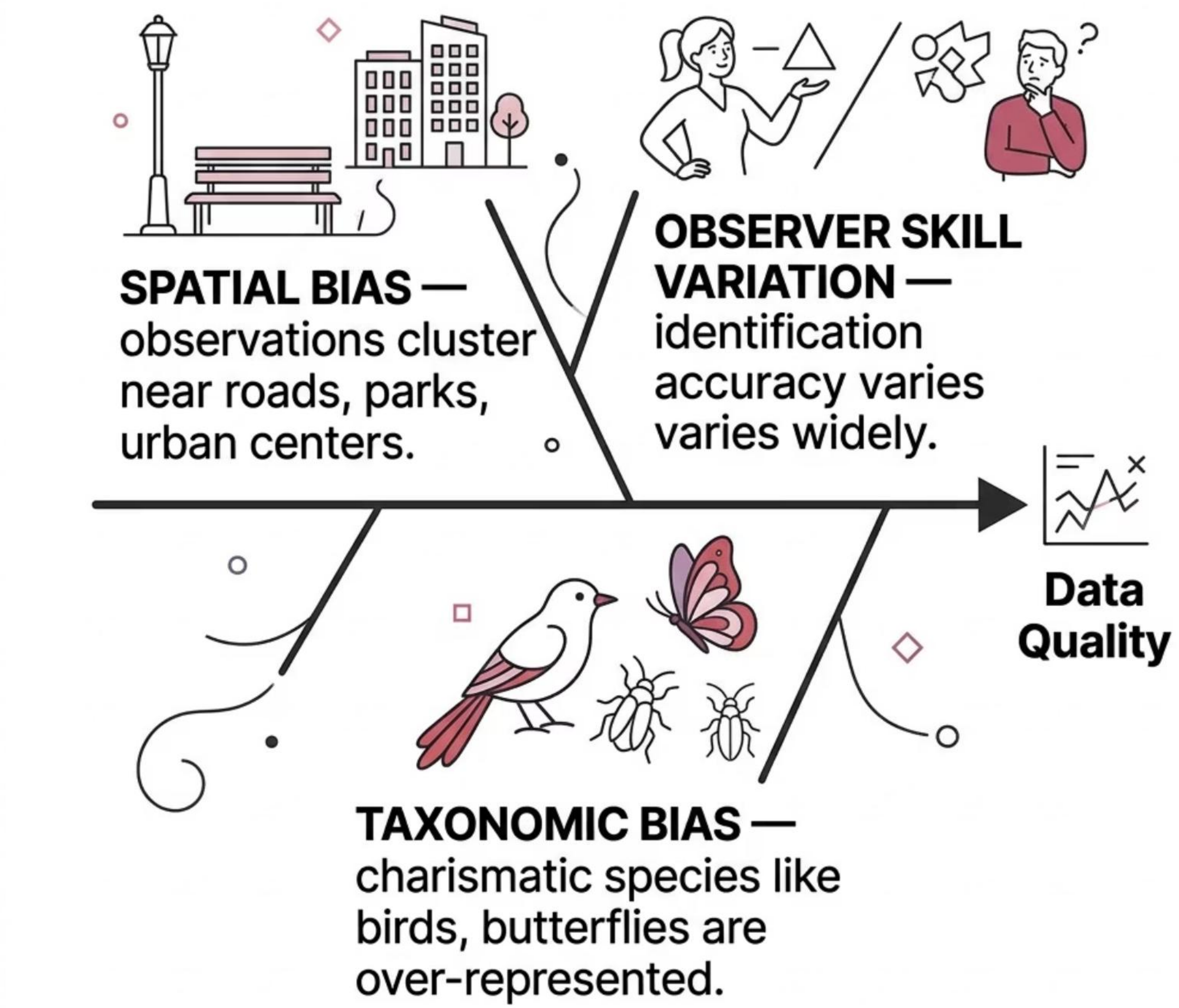
Espanha
Porto
Lisboa
Madrid
Sevilha
Málaga
Valência
Barcelona
Zaragoza
Bilbau
Andorra
Toulouse
Montpellier
Marselha
Mónaco
Lyon
Genebra
Turim
Milão
Génova
Florença
Palma
Corse
Sardegna
Mar Tirreno
Argel
Túnis
Múrcia
Alicante
Córdoba
Granada
Salamanca
Valladolid
Burgos
León
Braga
Coimbra
Aveiro
Toledo

Data Quality, Biases & Validation



How to Address These Issues

- **Research-grade filters** — platforms like iNaturalist use community agreement thresholds to flag reliable records.
- **Occupancy modelling** — statistical methods account for detection probability and uneven sampling effort.
- **Expert verification** — specialist review of flagged or rare records adds a crucial quality layer.

Expert + Citizen Monitoring: Better Together

Expert-Led Surveys

High accuracy, standardised protocols, deep taxonomic coverage — but limited in scale and frequency.

Citizen Science

Massive spatial coverage, continuous data streams, high public engagement — but variable quality.

Integrated Approach

Combining both maximises resolution and robustness — citizen data calibrated against expert baselines yields the most actionable insights.

Diversity and Distributions
Open Access
A Journal of Conservation Biogeography

METHOD | Open Access

Analytical guidelines to increase the value of community science data: An example using eBird data to estimate species distributions

Alison Johnston, Wesley M. Hochachka, Matthew E. Strimas-Mackey, Viviana Ruiz Gutierrez, Orin J. Robinson, Eliot T. Miller, Tom Auer, Steve T. Kelling, Daniel Fink

First published: 07 May 2021 | https://doi.org/10.1111/ddi.13271 | VIEW METRICS

Science

HOME > SCIENCE > VOL. 388, NO. 6746 > NORTH AMERICAN BIRD DECLINES ARE GREATEST WHERE SPECIES ARE MOST ABUNDANT

RESEARCH ARTICLE | BIRD DECLINE

North American bird declines are greatest where species are most abundant

ALISON JOHNSTON, AMANDA D. RODEWALD, MATT STRIMAS-MACKEY, TOM AUER, WESLEY M. HOCHACHKA, ANDREW N. STILLMAN, COURTNEY L. DAVIS, VIVIANA RUIZ-GUTIERREZ, ADRIAAN M. DOKTER, [...], AND DANIEL FINK +6 authors Authors Info & Affiliations

Materials and Methods

1 Overview of the trends model

We used 36 million bird checklists from eBird (*16*) collected from 2007–2021 across North America, Central America, and the Caribbean to estimate spatially-explicit species trends for 495 bird species. We also combined these single-species trends into groups across the six biomes within which they breed: forest, grassland, aridland, wetlands and coasts, Arctic tundra, habitat generalists. These groups were taken from the classification in the Partners in Flight Avian Conservation Assessment Database (*49*).

PNAS

RESEARCH ARTICLE | ECOLOGY

Global abundance estimates for 9,700 bird species

Corey T. Callaghan, Shinichi Nakagawa, and William K. Cornwell Authors Info & Affiliations

Edited by Simon Asher Levin, Princeton University, Princeton, NJ, and approved March 28, 2021 (received for review November 16, 2020)

May 17, 2021 | 118 (21) e2023170118 | https://doi.org/10.1073/pnas.2023170118

Key Takeaways

01

Data is urgently needed

Urban biodiversity is poorly documented relative to its conservation importance and policy relevance.

02

Citizen science scales observation

Platforms like iNaturalist and eBird generate spatially rich data at a scale no research team can match alone.

03

Quality requires critical thinking

Spatial and taxonomic biases are real — robust analysis must account for detectability and observer effort.

04

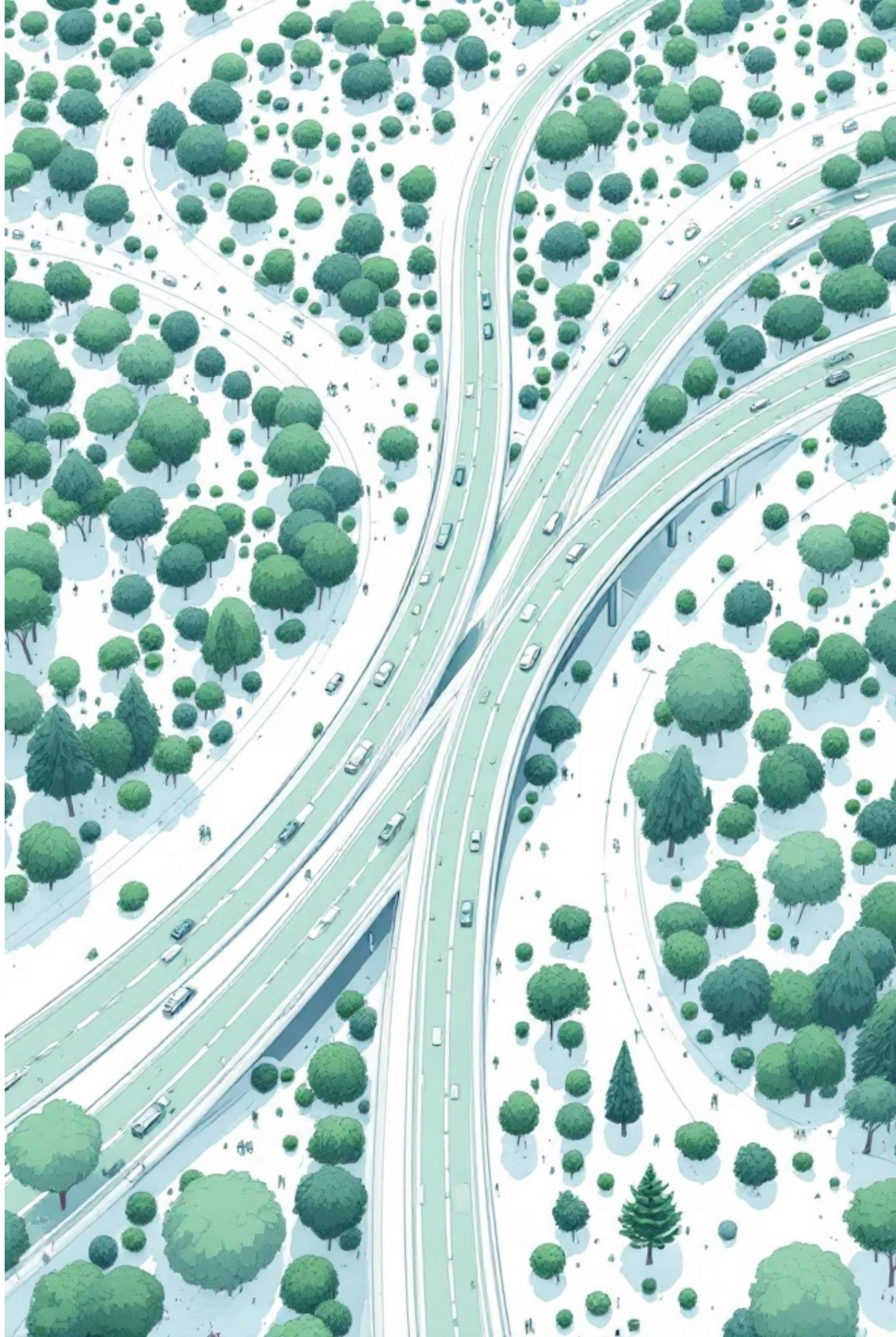
Integration is the future

Combining expert surveys, citizen observations, and remote sensing data offers the most complete picture of urban biodiversity.

Urban ecology needs all the eyes it can get — from trained ecologists to curious commuters with smartphones.

Road Ecology and Urban Connectivity

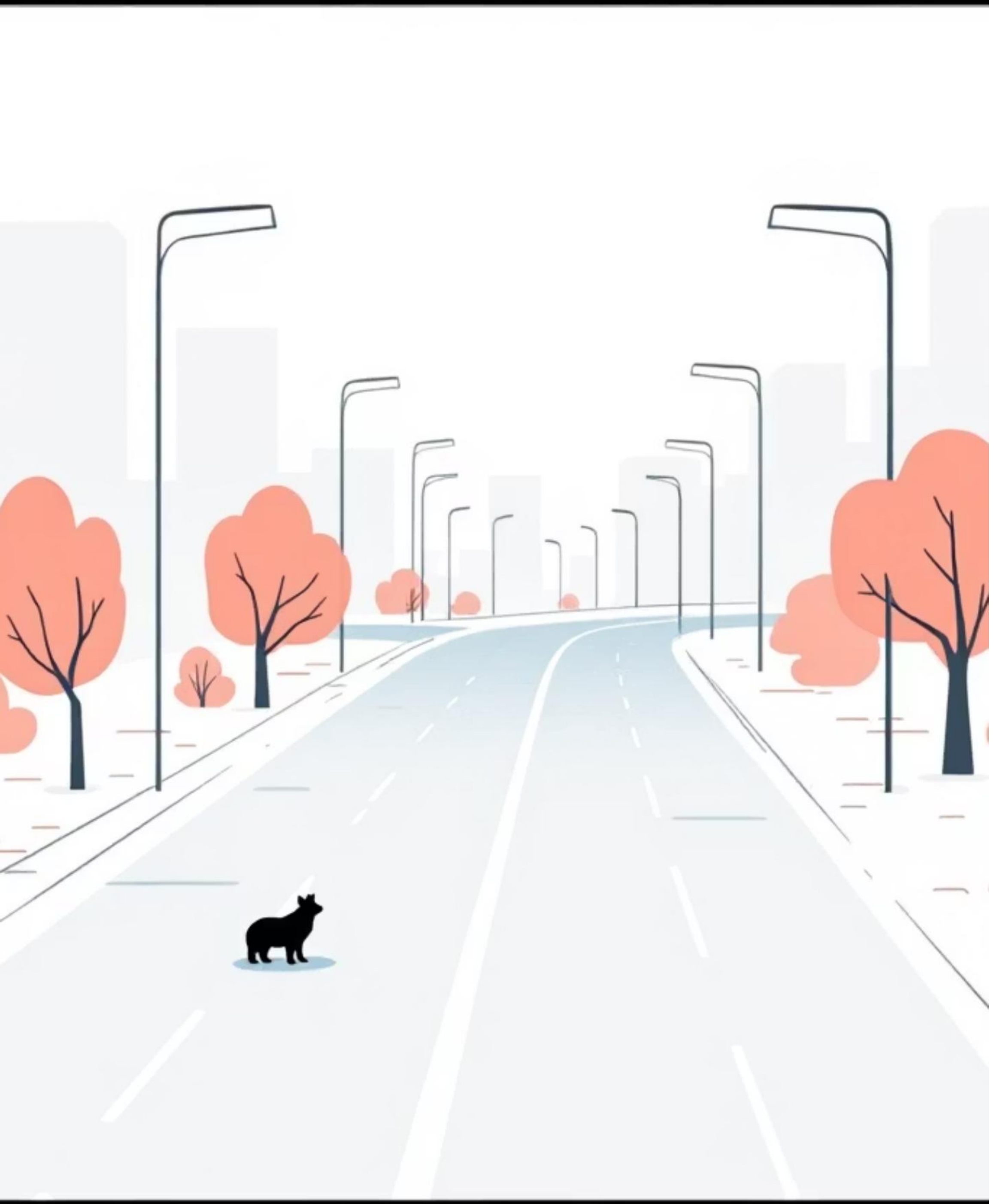
Understanding how transport infrastructure shapes ecological patterns and processes in urban environments



Roads as Ecological Barriers and Filters

Transport infrastructure creates significant barriers that fragment habitats and filter species movement. Roads act as physical obstacles, preventing or restricting animal dispersal and gene flow between populations.

These barriers are not absolute—they function as selective filters, allowing some species to cross whilst blocking others based on mobility, behaviour, and tolerance to disturbance.



Impacts on Species Movement and Mortality

Direct Mortality

Vehicle collisions cause significant wildlife deaths, affecting population viability and creating demographic bottlenecks

Reduced Movement

Animals avoid crossing roads due to noise, light, and traffic, limiting access to resources and mates

Genetic Isolation

Restricted gene flow leads to inbreeding depression and reduced genetic diversity over time

Fragmentation and Edge Effects

Habitat Fragmentation

Roads divide continuous habitats into isolated patches, reducing effective habitat area and creating smaller, disconnected populations vulnerable to extinction.

Edge Effects

The zone adjacent to roads experiences altered microclimate, increased invasive species, pollution, and human disturbance, extending impacts far beyond the paved surface.

Road Networks as Urban Landscape Structures

01

Primary Infrastructure

Roads define the fundamental skeleton of urban form, shaping development patterns and land use

02

Habitat Configuration

Transport corridors determine patch size, shape, and connectivity of remaining green spaces

03

Ecological Corridors

Road verges and green infrastructure can function as movement pathways when properly designed

Mitigation Measures: Crossing Structures

Wildlife Overpasses

Elevated bridges covered with native vegetation provide safe passage above traffic

Underpasses

Tunnels and culverts allow species to cross beneath roads safely

Guidance Systems

Fencing directs animals toward safe crossing points and prevents random road access

Enhancing Permeability and Planning

Design Considerations

- Species-specific crossing dimensions and configurations
- Strategic placement at pinch points and movement corridors
- Integration with existing green infrastructure networks
- Vegetation management and habitat quality maintenance

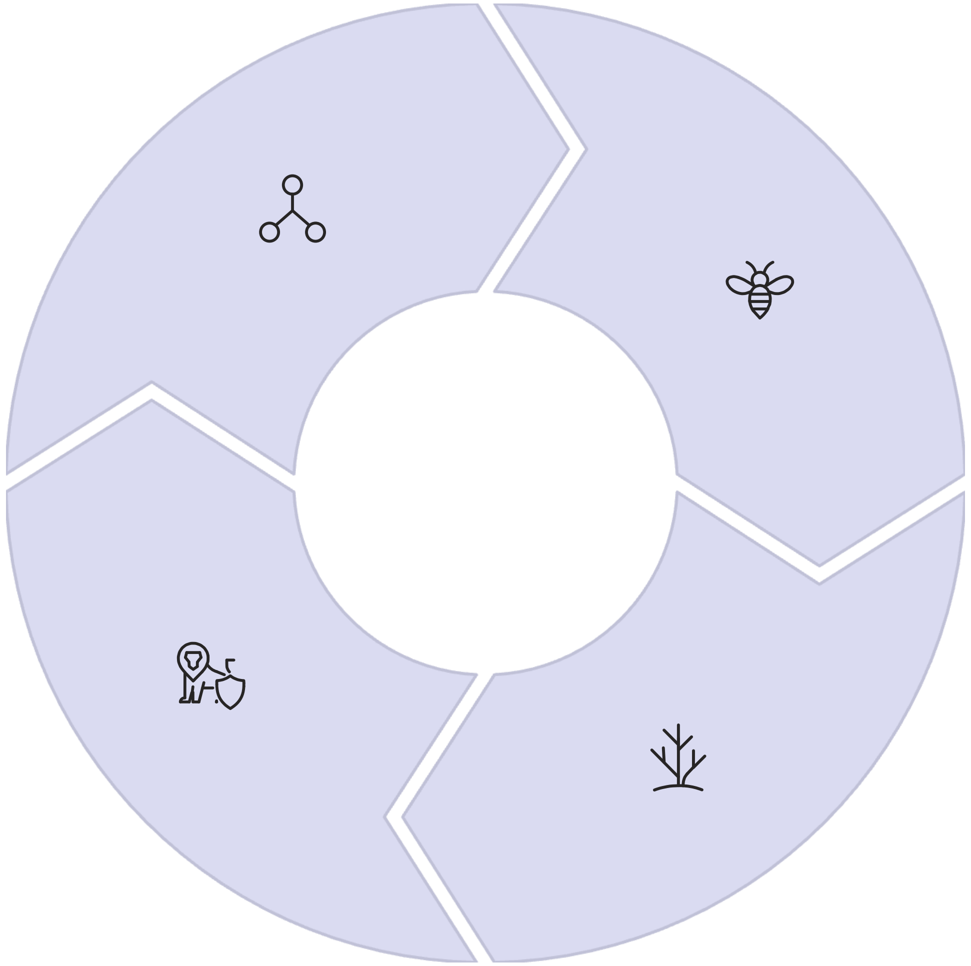
Strategic Planning

Incorporate ecological connectivity assessments early in transport planning to minimise fragmentation

Monitoring Programmes

Track crossing usage and population responses to evaluate mitigation effectiveness

Relevance for Urban Ecological Functioning



Connectivity

Facilitates species dispersal and meta-population dynamics

Ecosystem Services

Maintains pollination, seed dispersal, and pest control

Resilience

Enhances ecosystem capacity to withstand environmental change

Biodiversity

Supports diverse species assemblages and genetic health

Monitoring and Adaptive Management

Key Monitoring Approaches

- Camera traps and motion sensors at crossing structures
- Track counts and sign surveys along road corridors
- Genetic sampling to assess gene flow
- Population viability analyses
- Habitat quality assessments

Adaptive management uses monitoring data to refine mitigation strategies and improve ecological outcomes over time.

Key Takeaways

Roads fundamentally restructure urban landscapes

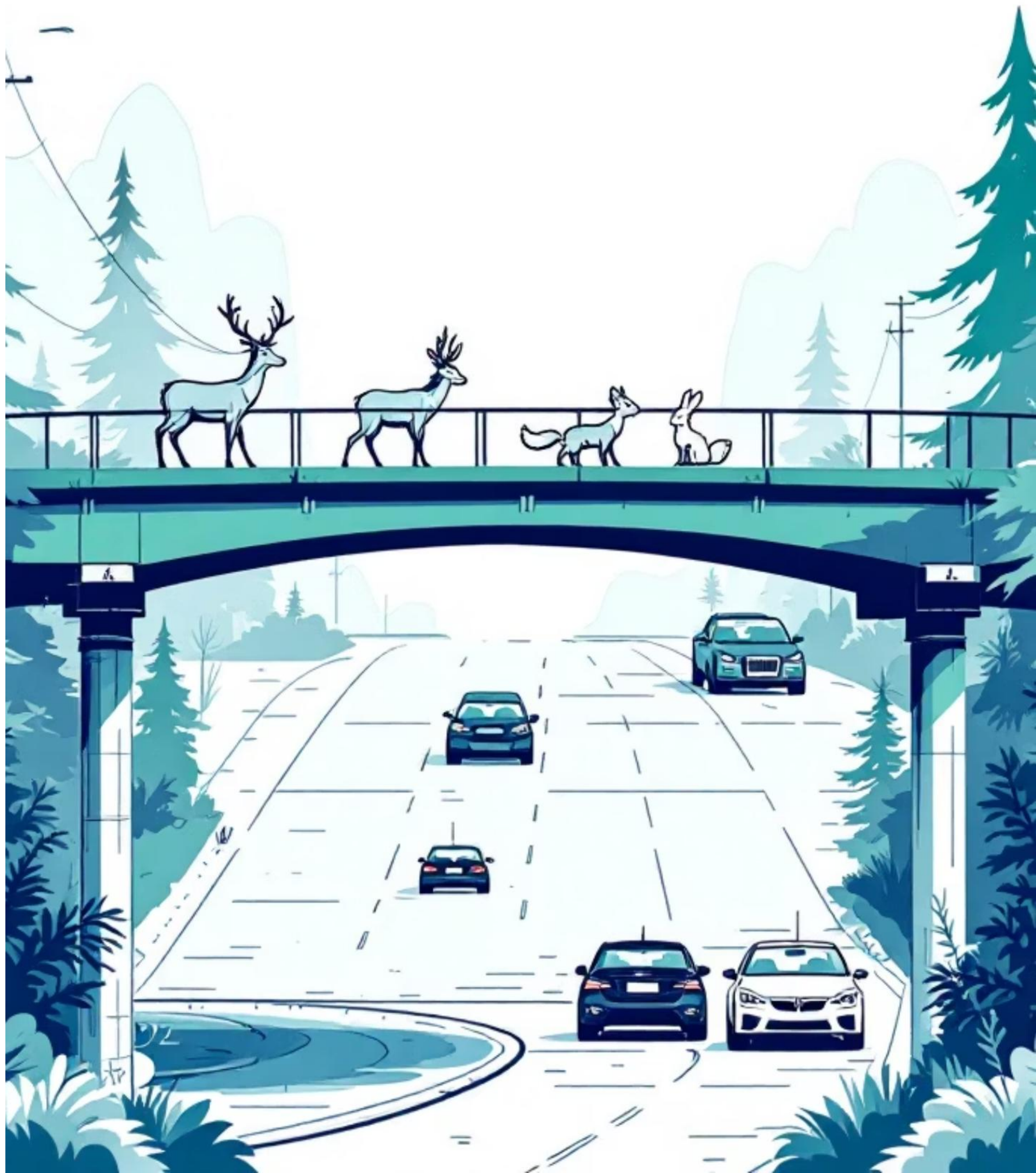
Transport infrastructure creates barriers, filters, and edge effects that profoundly alter ecological patterns and processes

Mitigation requires integrated approaches

Crossing structures, permeability enhancements, and strategic planning must work together to maintain connectivity

Monitoring informs effectiveness

Ongoing assessment of mitigation measures enables adaptive management and improved ecological functioning



Testing the Habitat Amount Hypothesis in Urban Parks (Lisbon)

Volunteers to go to parks and collect information on bird community. Aim: To examine whether bird communities in urban parks are more strongly related to the total amount of nearby green space than to the size of the park itself, following the logic of the Habitat Amount Hypothesis (HAH).

fjascensao@edu.ulisboa.pt Mudar de conta

* Indica uma pergunta obrigatória

Email *

O seu email

Name and surname *

A sua resposta

Effort - How many parks are you willing to visit? (3 points x 3 visits min) *

Study area - Lisbon metropolitan area. Sampling units: urban parks, selected to span a gradient of park size, vary independently in surrounding green space. Focal taxa: Birds. Field surveys 10-minute point count per park using Merlin. At least 3 points per park (same day); at least 3 visits per park (different days). All visits between sunrise and 10 am.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6

Enviar

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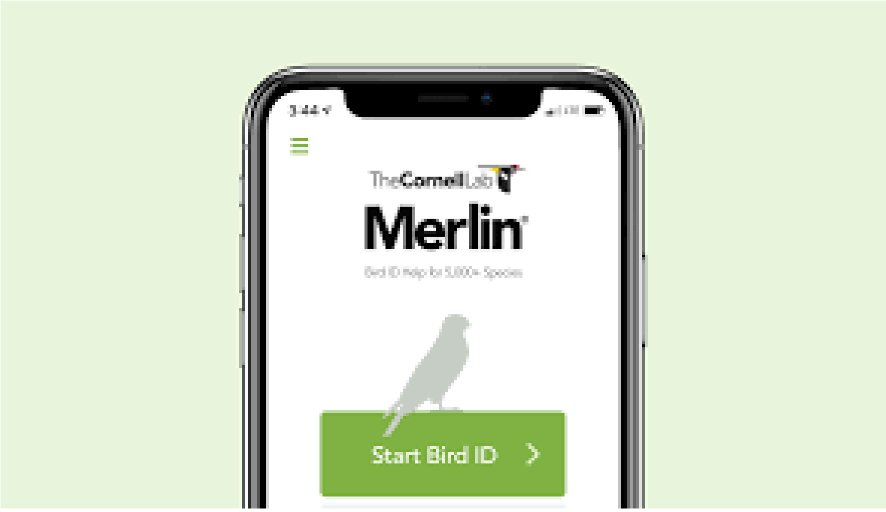

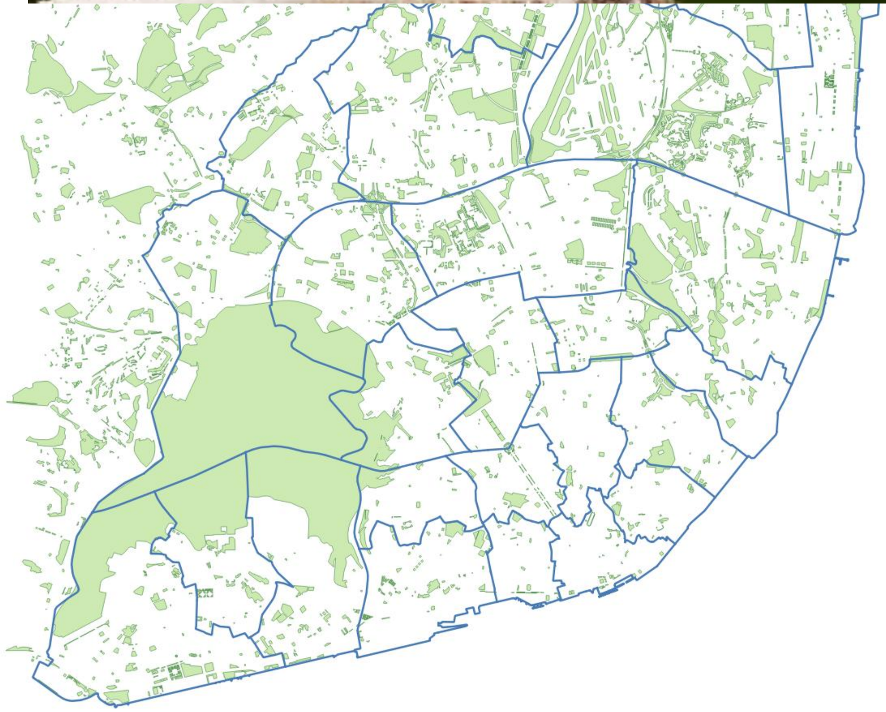

Assignment template

Anexos

- Helper.docx
- Urban_Ecology_Assignment_v2.docx

Assignment: Designing a Feasible Urban Ecology Research Project (MSc)

Objective

Develop a clear, feasible MSc thesis proposal in Urban Ecology. The project must be achievable by a single student within 6 to 12 months in an urban environment.