



IMPACTS OF URBAN GROWTH ON BIODIVERSITY

Class #2 | Urban Ecology

McDonald et al. (2019) — Nature Sustainability

Overview of the Paper and Its Objectives

- ✓ McDonald et al. (2019), Nature Sustainability
- ✓ Systematic review of n = 922 studies
- ✓ Assesses **direct AND indirect impacts** of urban growth on biodiversity
- ✓ Identifies **critical research gaps**
- ✓ Scope: **global**, across biomes and regions



Urban Growth as a Global Driver of Biodiversity Change



1.2–1.8M

km² Urban Expansion

2000–2030



**2.9B →
5.2B**

Urban Population

2000 to 2030



+1.2B

New Urban Residents

by 2030

Key Context:



Cities concentrate economic activity, consumption, and waste



Interacts with climate change, invasive species, and pollution



Urbanization is one of the fastest-growing land-use changes globally

Why Research Gaps Matter for Restoration Ecology

- ⚠ **Knowledge gaps** translate into weak policy and misplaced priorities
- ⚠ Most studies from **high-income countries** ≠ where most growth occurs
- ⚠ **Indirect impacts** (food, energy, pollution) are larger but poorly studied
- ⚠ Urgency in **biodiversity-rich regions** of the Global South
- ⚠ Restoration planning requires **robust, representative evidence**



Geographic mismatch between research and impact

Global Patterns of Urban Population Growth

Urban population grew from **2.9 billion (2000)** to **4.0 billion (2015)**, expected to reach **5.2 billion by 2030**

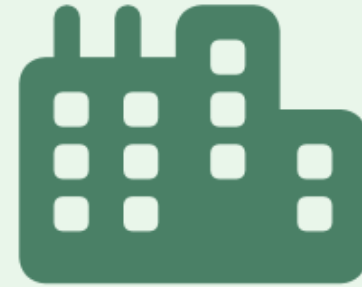
Top countries driving urban growth (projected new urban residents by 2030):

Projected Urban Population Growth by Country (2015-2030)

| | | | | |
|--|--|--|--|--|
| | | | | |
|--|--|--|--|--|

Projected Urban Expansion to 2030 and Beyond

- Urban land area will expand by **1.2–1.8 million km²** by 2030
- 290,000 km²** of natural habitat forecast to be converted (2000–2030)
- 190,000 km²** already converted between 1992–2000
- Expansion often occurs at **urban fringe** in ecologically sensitive areas
- Urban sprawl vs. compact city** models → very different biodiversity outcomes



Different urban forms have distinct biodiversity impacts

Spatial Mismatch: Urban Growth vs. Biodiversity Hotspots

30

Priority ecoregions contain 78% of vertebrate endemics threatened by urban growth

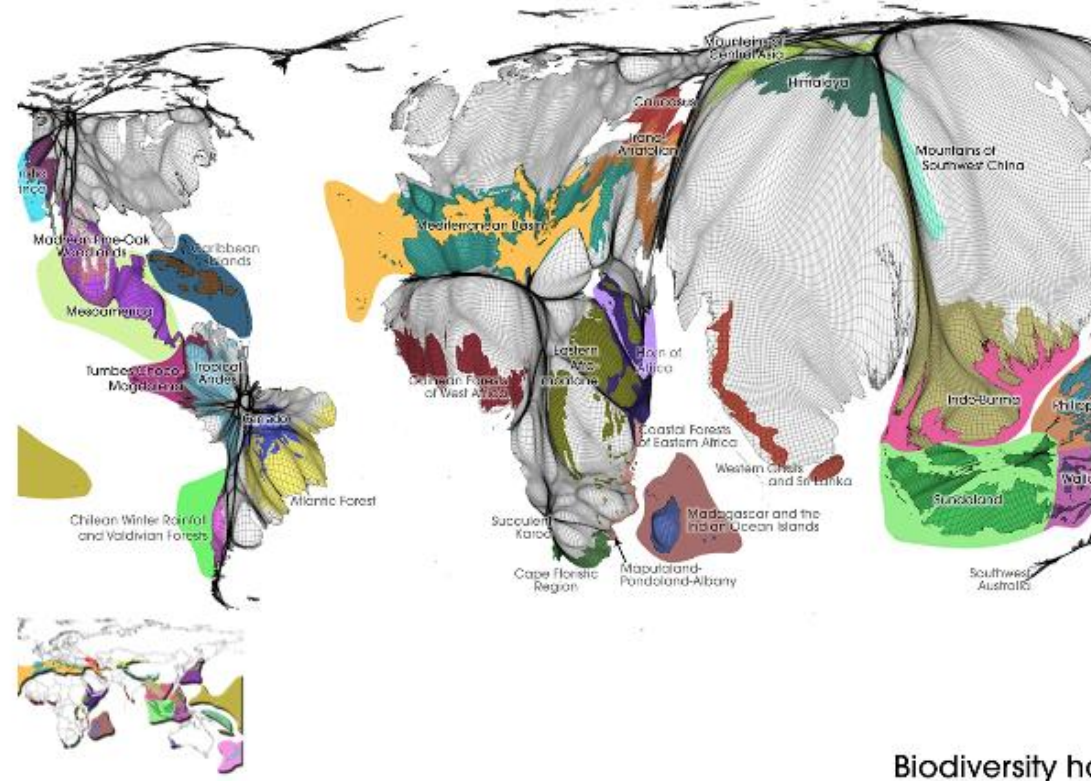
13%

Of terrestrial vertebrate ecoregional endemics under high threat

Key Findings:

- ! Many fast-growing cities lie in or near biodiversity hotspots
- ! Geographic mismatch: study locations vs. areas of greatest impact
- ! Critical need for research in high-biodiversity, high-growth regions

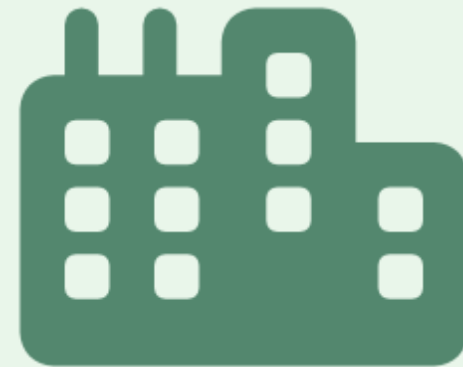
Global Biodiversity Hotspots & Urban Growth Overlap



Red/dark areas indicate biodiversity hotspots where urban growth poses greatest threats to endemic species

Direct Impacts: Land-Use Change and Habitat Conversion

- **Direct impact** = physical transformation of land to urban surfaces
- ! **290,000 km²** of natural habitat projected to be converted by 2030
- × Conversion **eliminates habitat** for native species
- + Effects include: **fragmentation, edge effects, and isolation** of populations
- 📉 **Native species decline** as habitat quality and area drop

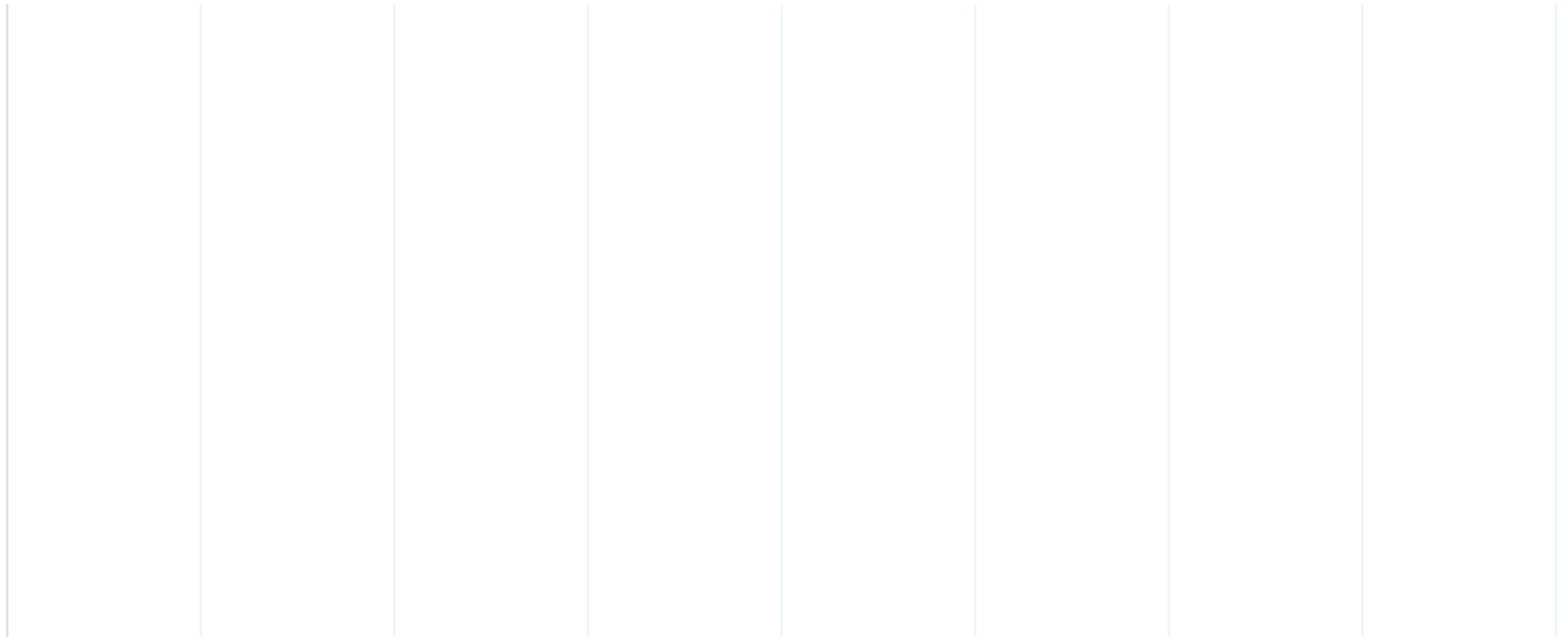


Loss and Degradation by Biome (2000–2030)






Estimated natural habitat converted to urban land use between 2000 and 2030 (km²):

Temperate and tropical forests face the **greatest absolute habitat loss**, while Mediterranean and mangrove biomes are **critically threatened**

Natural Habitat Converted by Biome (2000–2030)



Variation of Impacts Across Biomes and Regions

-  **Tropics:** Higher biodiversity loss per km² converted
-  **Temperate forests** (e.g., China, USA): Largest absolute area converted
-  **Mediterranean:** High species richness + high urban pressure
-  **Mangroves:** Acute coastal urbanization threats
-  **Context matters:** Endemism, habitat rarity, resilience



Regional variation in vulnerability and impact

Bias Toward Studies in High-Income Countries

Geographic Distribution of Direct Impact Studies



● High-Income Countries ● Middle-Income Countries
● Low-Income Countries

⚠ Critical Research Gaps:

- 🌐 72% of direct impact studies from high-income countries
- 🌐 Only 7% from low-income countries
- 🌐 Yet most urban growth and biodiversity are in LMICs
- 💰 Science follows funding, not biodiversity loss

This bias leads to systematic underestimation of global biodiversity impacts

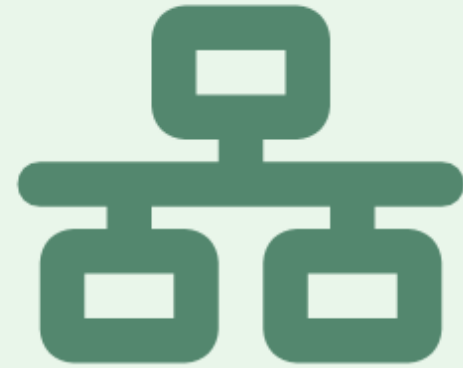
Indirect Impacts: What Are They?

Biodiversity effects mediated by resource flows

Not located in the city, but caused by urban consumption

THREE MAIN PATHWAYS:

- 1) Resource demand — food, water, energy, materials
- 2) Pollution and waste — air, water, soil, light, noise
- 3) Teleconnections via global supply chains



Resource Demand, Pollution, and Teleconnections



26.5M km²

Urban Food Demand

Cropland required (~36× urban area)



71–76%

Global CO₂ Emissions

Attributed to cities



Global

Supply Chain Reach

Teleconnections worldwide

Key Drivers and Pathways:



Urban demand drives tropical deforestation (soy, beef, palm oil, timber)



Pollution pathways: nitrogen deposition, light/noise pollution, microplastics



Telecoupling: distant ecosystems bear the cost of urban consumption

Spatial Decoupling of Urban Impacts

~3%

Cities physically occupy only ~3% of Earth's land surface

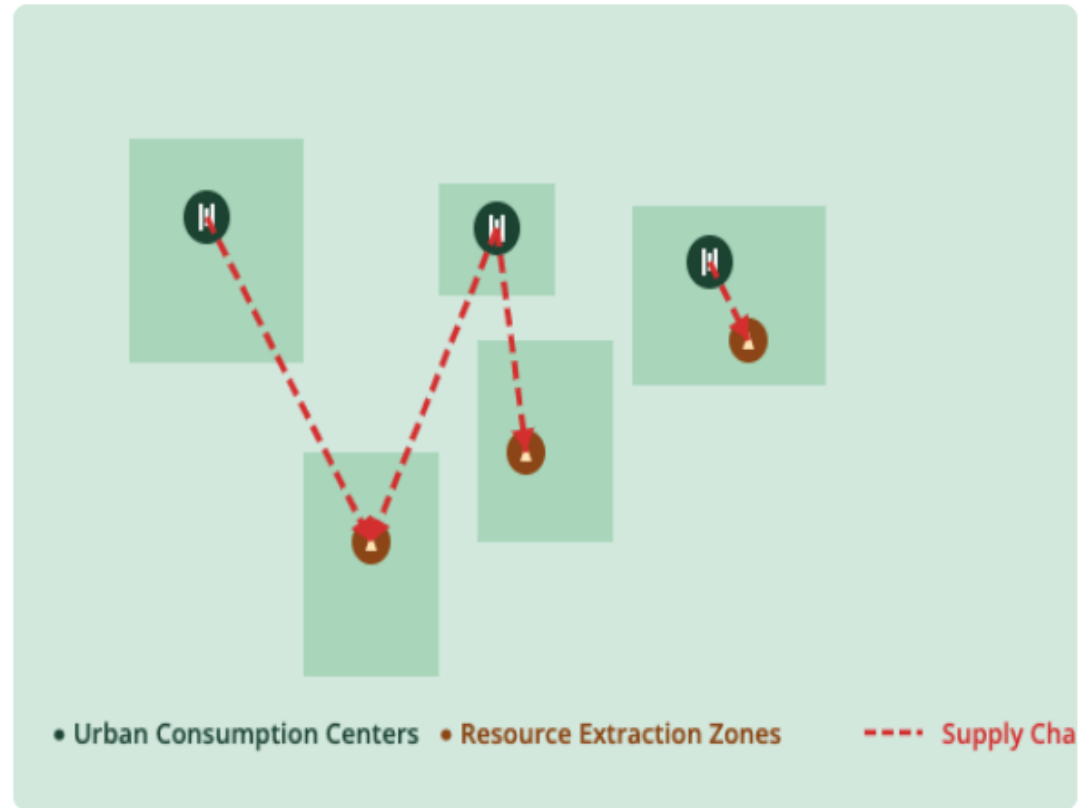
Global

Urban ecological footprints extend across the entire planet

Telecoupling Dynamics:

- Supply chains transfer environmental costs from wealthy urban areas to rural/tropical regions
- Example: European cities consuming soy from the Brazilian Cerrado
- Spatial decoupling makes **governance and accountability** extremely difficult

Urban Consumption → Distant Ecological Impacts



Cities consume resources from distant ecosystems via global supply chains, spatially decoupling impacts from consumption

Challenges Measuring Indirect Effects

- ⚠️ Only 34% of studies quantify indirect urban impacts
- ⚠️ Difficulties: tracing supply chains and attributing pollution sources
- ⚠️ No standardized accounting for urban biodiversity footprints
- ⚠️ Time lags and multi-stressor interactions hinder attribution



Biodiversity Responses: Richness and Abundance

Key declines vs. primary vegetation:


-34%

Species Richness
Light-use urban areas


-50%

Species Richness
Intense-use urban areas


-45%

Species Abundance
Light-use urban areas


-62%

Species Abundance
Intense-use urban areas

Key Patterns:



Generalists and invasive species often increase in urban areas



Specialist and habitat-sensitive species decline sharply



Urban areas support novel assemblages, not pre-existing communities

Species Turnover and Biotic Homogenization

- ✓ **Biotic homogenization:** replacement of unique local species with widespread generalists
- ✓ Cities worldwide share **similar species pools** (e.g., pigeons, starlings, rats, raccoons)
- ✓ **Beta-diversity loss** even if local richness appears stable
- ✓ **Functional and phylogenetic diversity** erode over time
- ✓ Long-term consequence: loss of **ecological uniqueness** across cities globally



Sensitivity Across Taxonomic Groups

- 🔍 **Most studied:** Birds, plants, invertebrates (especially insects)
- ❓ **Least studied:** Reptiles, amphibians, soil biota, microbiota
- 📌 **Amphibians & reptiles:** Highly sensitive to impervious cover and fragmentation
- ⚠️ **Insects:** Pollinator declines strongly linked to urban habitat loss
- ✅ **Birds:** More resilient where green spaces persist



Birds
(Resilient)



Insects
(Declining)



Amphibians
(Highly Sensitive)

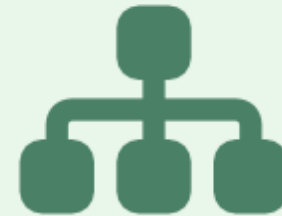


Soil Biota
(Understudied)

Differential sensitivity and research coverage
across taxa

Landscape Context and Habitat Quality

- 🏢 **Urban matrix quality** mediates biodiversity outcomes
- 🌳 **Green infrastructure** (parks, street trees, green roofs) buffers losses
- 🍃 Patches support biodiversity **if**:
 - ✓ Sufficiently large
 - ✓ Connected to natural areas
 - ✓ Dominated by native vegetation
- 🏘️ Surrounding **land use** shapes species composition



Landscape context is critical for urban biodiversity conservation

Research Gaps: Geographic Coverage

72%

Studies from North America, Europe, and Australia
(high-income countries)

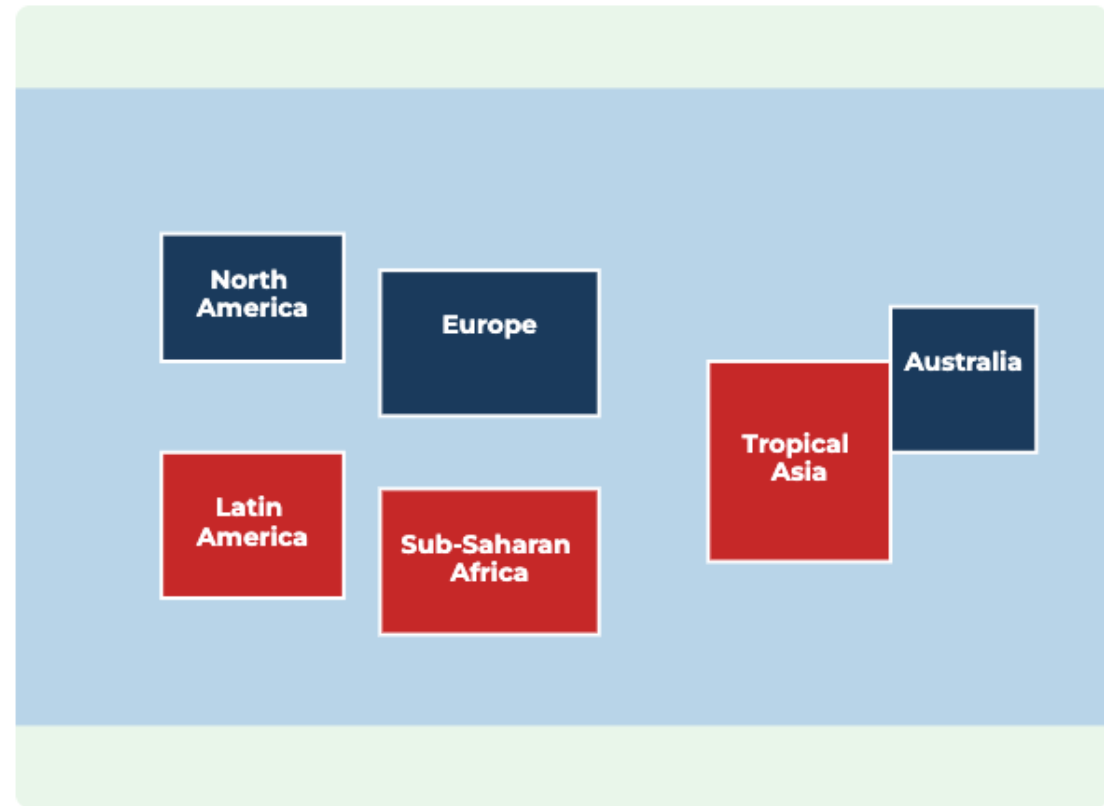
7%

Studies from low-income countries where most growth occurs

Critical Gaps:

- ⚠ Understudied regions: Tropical Asia, Sub-Saharan Africa, Latin America
- ⚠ These regions have fastest urban growth + highest biodiversity
- ⚠ Policy risk: biased, unrepresentative evidence base
- ⚠ Funding follows wealth, not biodiversity risk

Geographic Distribution of Urban Biodiversity Studies



■ Well-studied ■ Understudied

Dark blue regions are over-represented in research; red regions are critically understudied despite high biodiversity and rapid urbanization

Research Gaps: Indirect and Cumulative Impacts

- ⚠️ **Indirect footprints** are spatially larger than direct impacts, yet **only 34%** of studies measure them
- ⚠️ **Cumulative, multi-stressor impacts** are seldom quantified
- ⚠️ **Longitudinal datasets** are scarce; attribution remains weak
- ⚠️ **No integrated framework** exists to track urban ecological footprints




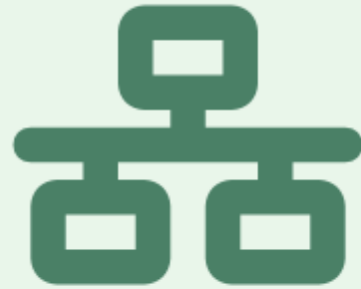
Research Gaps: Mechanisms and Long-Term Data

- ! Predominance of **short-term, observational studies**
- ! Need **mechanistic work** linking drivers → pressures → states → impacts → responses (**DPSIR**)
- ! **Long-term monitoring** essential to detect trends and recovery
- ! **Experimental restoration trials** largely absent



Research Gaps: Social–Ecological Integration

-  Biodiversity data **rarely integrated** with socioeconomic/planning data
-  Need for **interdisciplinary approaches**:
 - Ecology + Urban planning
 - Conservation + Economics
 - Remote sensing + Social science
-  **Citizen science and community monitoring underused**



Bridging disciplines for comprehensive understanding

Implications: Limits of Current Knowledge

- ⚠️ Policymakers may **systematically underestimate biodiversity loss**
- ⚠️ Global targets (e.g., GBF) rely on **incomplete evidence**
- ⚠️ Risk of **misallocating restoration resources** geographically
- ⚠️ Adopt **adaptive management and precaution** in high-risk regions

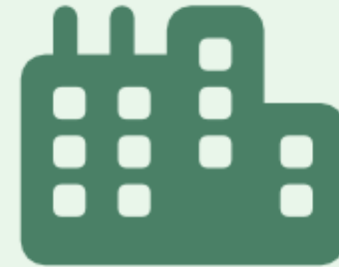


Integrating Biodiversity into Urban Planning

Biodiversity-inclusive design is feasible and increasingly practiced worldwide

Tools and Approaches:

- ✓ Green infrastructure planning
- ✓ Biodiversity net gain policies
- ✓ Urban nature-based solutions (UNbS)
- ✓ Urban protected areas



Leading City Models

Singapore • Medellín • Curitiba

Cities demonstrating successful biodiversity integration

Urban Restoration Ecology: Relevance and Practice

🎯 Address **BOTH** direct and indirect drivers

- 🌿 Direct impacts: Habitat loss and degradation
- 🌍 Indirect impacts: Consumption and resource demand

☰ Restoration Priorities

- Connectivity and patch quality
- Reduce indirect footprints
- Native species recovery
- Long-term, multitaxa monitoring
- Community engagement and co-management



Holistic approach to urban restoration

Priorities for Future Research and Monitoring

- 1 **Redirect funding** to LMIC high-biodiversity regions
- 2 **Develop accounting** for indirect urban biodiversity impacts
- 3 **Establish long-term** urban biodiversity monitoring networks
- 4 **Integrate** remote sensing, citizen science, eDNA
- 5 **Build** ecology–planning–economics partnerships
- 6 **Align research** with GBF and SDGs



Discussion Question 1



Which research gaps identified by McDonald et al. are most critical for rapidly urbanizing regions of the Global South?

Consider:

- Geographic bias in current research
- Indirect impacts vs. direct impacts
- Taxonomic coverage and priorities
- Need for long-term data and monitoring

Discussion Question 2



How can restoration ecology address BOTH direct and indirect impacts of urban growth on biodiversity?

💡 Consider:

- Habitat restoration vs. consumption reduction
- Multi-scale restoration approaches
- Urban food systems and supply chains
- Green infrastructure and ecosystem services

Discussion Question 2



How can restoration ecology address BOTH direct and indirect impacts of urban growth on biodiversity?

💡 Consider:

- Habitat restoration vs. consumption reduction
- Multi-scale restoration approaches
- Urban food systems and supply chains
- Green infrastructure and ecosystem services

Synthesis — Key Takeaways

Main findings from McDonald et al. (2019) review:

1 Urban growth is an accelerating driver of global biodiversity loss

2 Direct impacts are substantial; indirect impacts are spatially larger

3 Research skewed to high-income countries → critical knowledge gaps

4 30 priority ecoregions hold 78% of threatened vertebrate endemics

5 Restoration must operate across scales and address multiple drivers

6 Integrating biodiversity into urban planning is urgent and feasible

References



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