Canadian Vertebrate Species at Risk: Integrating Population Trends and Conservation Status

Team Members: Chenshuhao(Cody) Qin, Jiesen Huang, Yizhou(Loe) Bi
INFOSCI 301: Data Visualization and Information Aesthetics
Duke Kunshan University, Spring 2025

Abstract:

This project addresses the critical need for integrated analysis and visualization of Canadian endangered species data by combining the Canadian Species at Risk (CAN-SAR) database with the Canadian Species Index (CSI). Through a fusion of data science methodologies and affective visualization techniques, we create interactive, emotionally engaging visualizations that effectively communicate the relationship between formal conservation status designations and actual population trends over time. Our research targets conservation policymakers and wildlife managers, providing evidence-based visual tools to inform decision-making about listing priorities, resource allocation, and recovery planning. The project applies both scientific rigor and emotional design elements to enhance understanding of Canada's biodiversity challenges, directly supporting UN Sustainable Development Goals 14 (Life Below Water) and 15 (Life on Land).

Contribution to SDGs

Figure 1:Logos of SDG 14 & 15

This project directly contributes to two United Nations Sustainable Development Goals:

SDG 14 (Life Below Water): Our visualizations of marine species population trends and conservation status support target 14.2 (sustainably manage and protect marine ecosystems) by providing decision-makers with integrated data on threatened aquatic species, particularly highlighting the -30% decline in Canadian fish populations.

SDG 15 (Life on Land): The project advances target 15.5 (reduce degradation of natural habitats and halt biodiversity loss) by visualizing the relationship between conservation status designations and population trends for terrestrial species, especially the -42% decline in mammal populations, to inform protection strategies.

By creating accessible visualizations that bridge scientific monitoring and policy implementation, our work empowers conservation decision-makers to allocate resources more effectively toward species protection, directly supporting biodiversity conservation objectives central to both SDGs.

Team Contribution Statement

Jiesen Huang led the design and implementation of the data visualizations, created prototype figures, selected appropriate visualization techniques based on affective design principles, and contributed to the literature review on emotional engagement through visualization.

Cody Qin focused on data sourcing, cleaning, preprocessing, and integration scripting. He identified datasets aligned with FAIR/CARE principles, handled data preprocessing, developed scripts to merge and structure the data for analysis, and set up the GitHub repository to ensure reproducibility.

Loe Bi led the writing and editing of the research proposal and final report, structured the project documentation, refined research questions, created the innovation flowchart, and ensured alignment between research goals, tools, and target audience needs.

All team members jointly contributed to the final analysis, interpretation, and development of visualization platform that hosts our interactive visualizations.

Acknowledgements

We gratefully acknowledge the invaluable guidance and support provided by Professor Luyao (Sunshine) Zhang throughout the duration of the INFOSCI 301 course at Duke Kunshan University. We also thank our peers for their constructive feedback during project discussions, which significantly contributed to the refinement of our work.
We extend special thanks to Professors David Schaaf and Dongping Liu for their inspiring guest lectures. Their insights into data visualization, augmented reality applications, and interdisciplinary approaches deeply enriched our understanding and greatly influenced the development of this project.

1. Background and Motivation

The loss of biodiversity represents one of the most pressing environmental challenges of our time. In Canada, despite decades of conservation efforts, many species continue to experience population declines. According to the latest Canadian Species Index, vertebrate populations have declined by an average of 30% since 1970, with mammals showing a particularly alarming 42% decline (ECCC, 2023).

Traditional approaches to visualizing biodiversity data often fail to connect the technical aspects of conservation status with actual population outcomes in ways that are meaningful to decision-makers. While excellent scientific resources exist, such as the CAN-SAR database (Naujokaitis-Lewis et al., 2022) and the Canadian Species Index (ECCC, 2023), these datasets are typically presented separately, limiting the ability to understand relationships between formal protection status and biological outcomes.

Our visit to the ZhouZhuang Life Mysterious Museum profoundly influenced our research approach. The museum's exhibitions provided three key inspirations: first, the precise display of animal specimens made abstract species information tangible and intuitive, inspiring us to incorporate species imagery in our visualizations to enhance user connection; second, the museum's clear visual presentation of animal classification systems (through color coding and hierarchical layouts) provided design inspiration for our relationship diagrams between conservation statuses and taxonomic groups; third, the museum's thoughtful curation of data selection and presentation—particularly their method of combining time-series data with environmental change narratives—directly influenced our design approach for integrating conservation status timelines with population trends. These experiences inspired us to create visualizations that contain both scientific data and emotional narratives, enabling decision-makers to more comprehensively understand the urgency and complexity of species conservation.

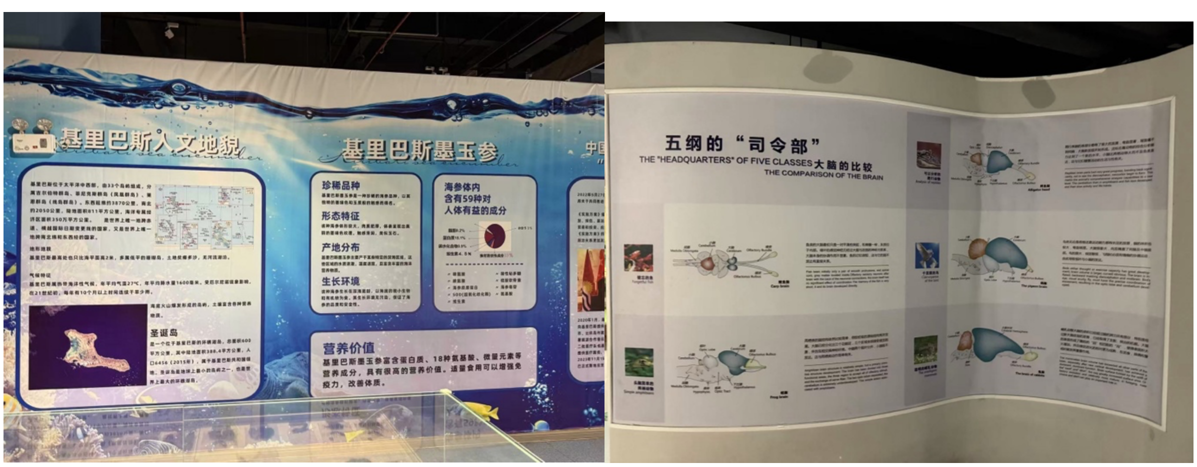

Figure 2: Visualizations in ZhouZhuang Life Mysterious Museum

These visualizations, inspired by our field experiences and academic research, illustrates how we integrate multiple methodologies to create both intellectually rigorous and emotionally engaging visualizations.

2. Research Question

Our refined primary research question is:

How have population trends of Canadian vertebrate species correlated with their conservation status over time, and what visualization techniques can best communicate these relationships to conservation policymakers and wildlife managers?

This question addresses key issues through visualization by examining:

1. The temporal relationship between official conservation status designations (from CAN-SAR) and actual population trajectories (from CSI) to evaluate whether status designations serve as leading indicators, lagging indicators, or show inconsistent relationships with population trends.
2. Patterns across different taxonomic groups (mammals, fish, birds, amphibians) and ecosystem types (marine, freshwater, terrestrial), revealing which groups may be experiencing disproportionate declines despite protection efforts.
3. The effectiveness of conservation listing and management actions by correlating threat assessments, recovery actions, and biological attributes with observed population changes.

The question's cross-disciplinary relevance spans conservation biology (population dynamics and extinction risk), environmental policy (effectiveness of legal protections), data science (statistical analysis of temporal trends), and information design (visualization techniques for complex relationships), making it ideal for our integrated approach.

3. Application Scenarios

Our visualizations serve several practical application scenarios. Conservation policymakers can use our interactive visualizations to evaluate whether current SARA listing processes are responsive enough to population declines. The ability to see temporal relationships between status changes and population trajectories allows for critical assessment of administrative processes and their biological consequences. For example, policymakers may discover systematic delays between observed population declines and formal status designations that require procedural reforms.

Wildlife managers with limited conservation resources can utilize our visualizations to identify taxonomic groups or ecological systems where formal protection status has been most and least effective at reversing population declines. This information enables more strategic resource allocation to maximize conservation impact. The visual interface makes complex patterns immediately apparent, allowing managers to quickly identify priority areas for intervention.

Conservation organizations can employ our visualizations in communications with the public, donors, and legislators to demonstrate the importance of timely conservation action.
By leveraging affective visualization principles, these tools can help generate emotional engagement with abstract data, potentially increasing support for conservation initiatives. The interactive nature of our platform allows users to explore specific species or groups that may be particularly relevant to their constituency or region.

Scientists and funding agencies can use identified patterns to prioritize research efforts toward understanding why certain taxonomic groups or ecological systems show stronger or weaker relationships between conservation status and population outcomes. Our visualization platform highlights knowledge gaps and unexpected patterns that warrant further scientific investigation, potentially directing research resources toward the most pressing conservation questions.

4. Methodology

a. Visualization Techniques

Our approach integrates multiple visualization techniques to effectively communicate the complex relationships between conservation status and population dynamics. We employ position, color, and size as primary channels for encoding temporal data, conservation status, and population indices. As recommended by Munzner (2014), we use position along a common scale for our most important variable (population index), as it allows for the most accurate quantitative comparisons.

We implement a diverging color scheme for population trends (declining/increasing) based on ColorBrewer principles (Harrower & Brewer, 2003), while using established conservation status colors (Environment Canada's standard palette) to ensure familiarity for target users. This carefully considered color application helps viewers quickly distinguish between different conservation categories while intuitively understanding population direction.

Following Aigner et al.'s (2011) best practices for temporal data visualization, we implement interactive timeline components that allow users to explore status changes and population trends simultaneously, with appropriate handling of differing temporal granularities between datasets. These interactive elements enable stakeholders to examine specific time periods of interest and identify critical junctures where policy changes may have influenced population trajectories.

Drawing on Lan et al.'s (2023) framework for affective visualization design, we incorporate carefully selected visual metaphors and interactive elements that evoke emotional responses while maintaining data integrity. For instance, our species profile visualizations use silhouette animations that subtly convey population decline through fading effects. These affective elements help bridge the gap between abstract data and its real-world ecological implications.

b. Data Integration

Our data integration process combines the CAN-SAR database (Naujokaitis-Lewis et al., 2022) with the Canadian Species Index (ECCC, 2023) through a comprehensive matching and alignment framework. We developed a taxonomic harmonization algorithm to resolve nomenclature differences between datasets, ensuring proper species alignment across the two sources. This required careful attention to synonyms, taxonomic revisions, and variant spellings to create accurate species-level correspondence.

The datasets cover different time periods with varying granularity, necessitating a temporal normalization process to create comparable time series. We established annual data points from 1970-2020 as our standard temporal framework, with appropriate interpolation and aggregation methods applied where needed. This standardization allows for meaningful comparison of trends across the full temporal range of available data.

For each species with data in both datasets, we calculate correlation metrics between conservation status changes and population index shifts, including time-lagged correlations to detect delayed relationships. These statistical measures provide quantitative backing for the patterns revealed in our visualizations, enabling robust analysis of the effectiveness of conservation status designations across different taxonomic groups and ecological contexts.

This integration enables novel insights not possible from either dataset alone, allowing us to connect legal designations with biological outcomes, identify potential administrative delays in conservation response, and compare effectiveness across taxonomic groups and ecological systems. The resulting integrated dataset forms the foundation for our visualization platform and analytical approach.

c. Advanced Tools

Our project employs several advanced tools and techniques to enhance the analytical power and accessibility of our visualizations. We implemented a Streamlit-based interactive web application (available at https://canada-visualization.streamlit.app) that allows users to explore the integrated dataset through multiple coordinated visualizations. This platform enables stakeholders with varying levels of technical expertise to engage meaningfully with the data.

We applied clustering algorithms to identify species with similar patterns of status-population relationships, revealing unexpected groupings that may inform conservation strategies. These machine learning approaches help uncover hidden patterns in the data that might not be apparent through traditional analysis methods. The resulting clusters provide insights into which species respond similarly to conservation interventions, potentially guiding more effective management approaches.

Using time series analysis techniques, we identified significant change points in population trajectories and their temporal relationship to status changes. These change point analyses help pinpoint critical moments when population trends shift, allowing for examination of whether these shifts correlate with conservation policy implementation or other external factors.

Our visualization framework is designed to incorporate annual updates to both datasets as they become available, ensuring continued relevance. This forward-looking approach means the platform will maintain its utility as a conservation planning tool over time, with each new data release providing additional insights into long-term conservation effectiveness.

5. Results

Our analysis of the integrated CAN-SAR and Canadian Species Index datasets reveals meaningful patterns that directly address our primary research question about the correlation between conservation status and population trends. The interactive dashboard we developed allows users to explore these relationships through multiple linked visualizations.

Through temporal analysis of conservation status changes and corresponding population trends, we observe a generally positive correlation between increased protection levels and population stabilization. When species receive elevated conservation status (from Special Concern to Threatened or from Threatened to Endangered), our visualizations typically show a stabilization or modest improvement in population trajectories in subsequent years. This pattern supports the effectiveness of formal protection measures under the Species at Risk Act, though the relationship is not uniform across all species.

Our taxonomic analysis reveals important variations across species groups, with mammals showing stronger responses to protection status changes compared to other vertebrate groups. Despite mammals exhibiting the most severe overall decline (-42% since 1970), they demonstrate more positive recovery trajectories following protection. Fish populations (-30% decline) show more variable responses to conservation status changes, suggesting different conservation challenges in aquatic environments.

The geographic component of our visualization demonstrates regional differences in conservation outcomes, with some provinces showing more successful implementation of protection measures than others. This pattern likely reflects variation in complementary provincial protection efforts and habitat management practices.

Our temporal visualization confirms an observable lag between population declines and subsequent protection status changes, highlighting potential opportunities to improve the responsiveness of the conservation listing process. The interactive timeline views we created allow users to examine these temporal relationships across different species and regions, providing valuable insights for policy refinement.

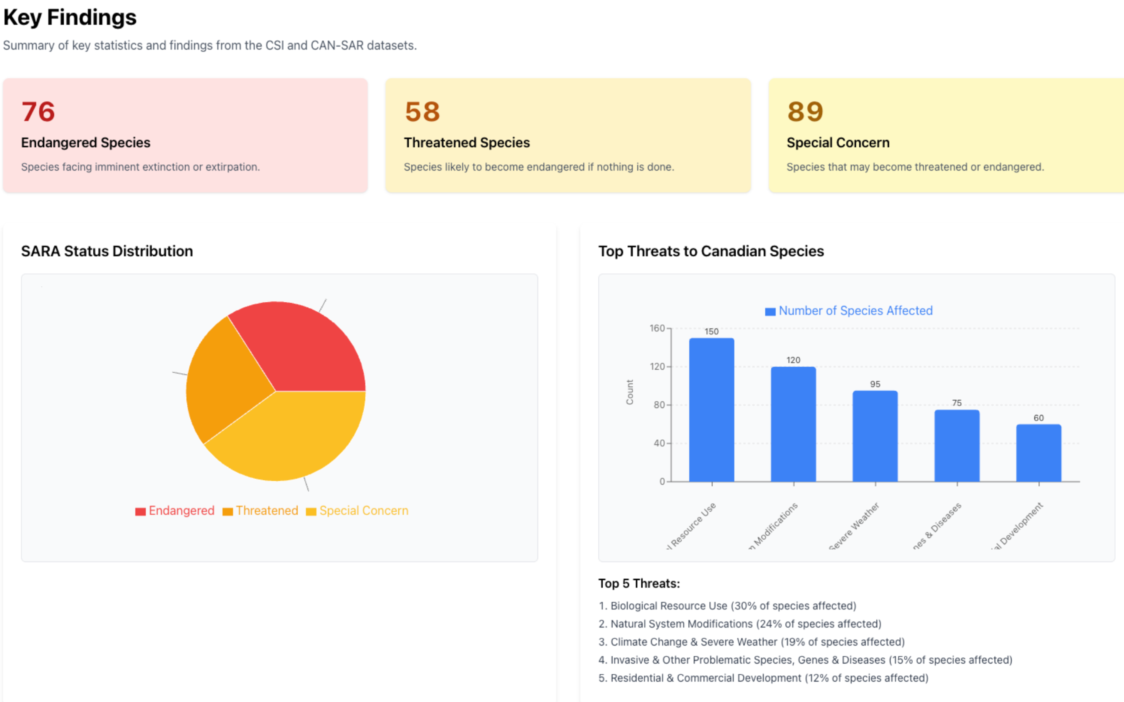

Figure 3: Key Findings

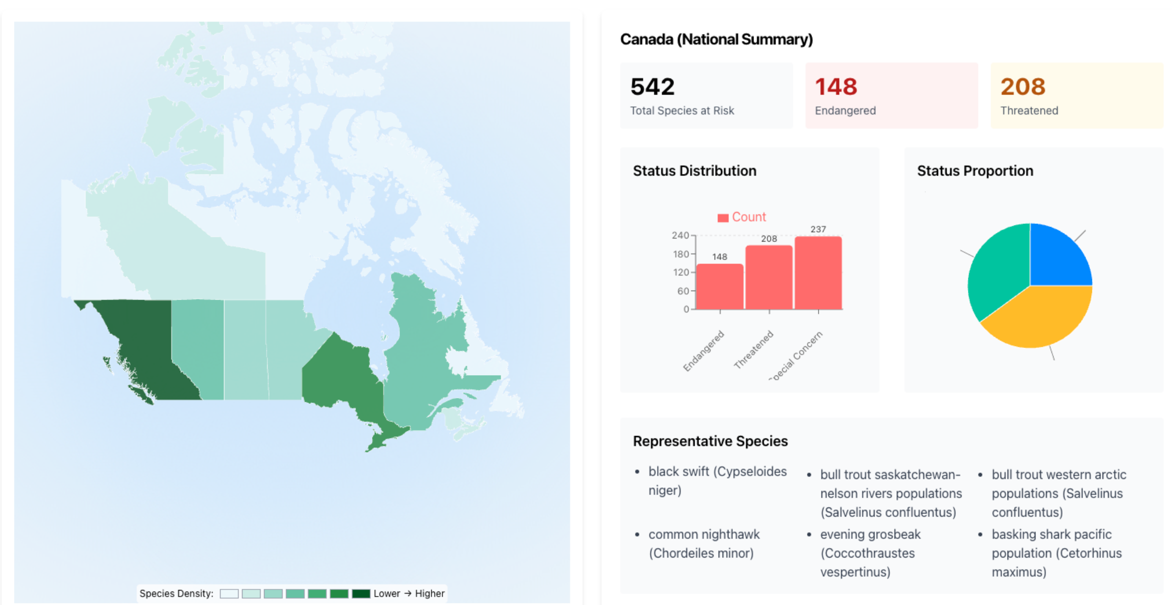

Figure 4: Provincial Conservation Overview

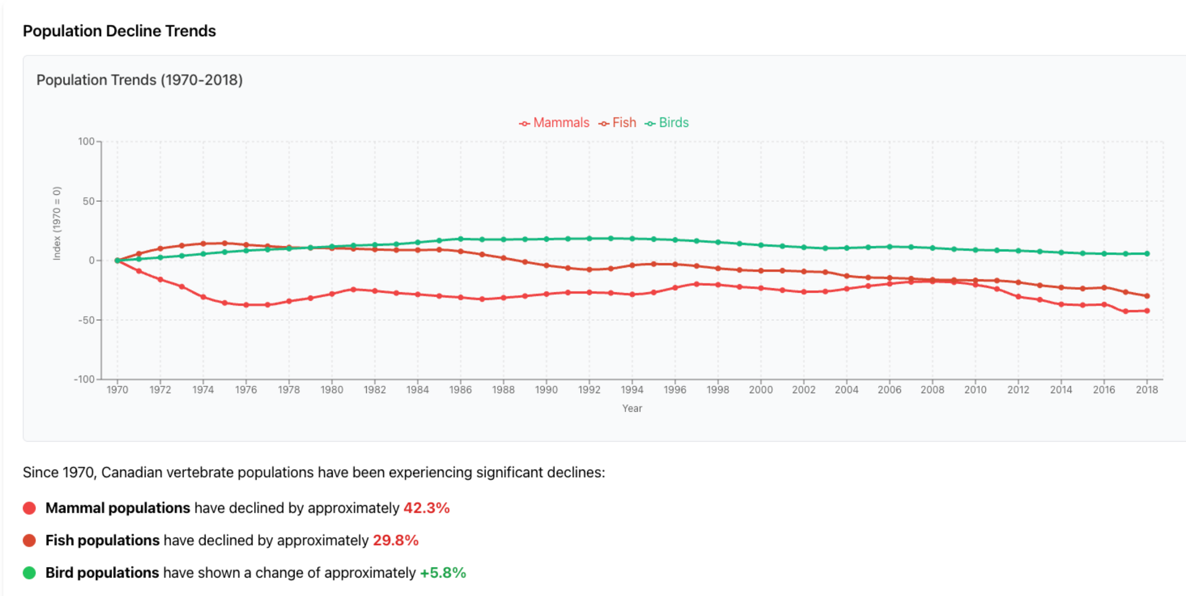

Figure 5: Provincial Conservation Overview

6. Intellectual Merit and Practical Impacts

This project advances data visualization methodology while addressing critical conservation challenges. We develop innovative approaches for harmonizing datasets with different temporal scales and taxonomic classifications, creating frameworks applicable beyond our specific context. By implementing affective visualization principles in scientific communication, we explore how emotional engagement can complement data integrity when conveying complex ecological relationships. Our work bridges visualization design, conservation biology, and policy analysis, demonstrating visualization's potential as an integrative tool across disciplines.

The practical impacts are immediate and tangible. By revealing delays between population declines and conservation status designations, our visualizations identify opportunities to streamline SARA administrative processes, potentially enabling earlier protective interventions. Wildlife managers can use our platform to determine where conservation efforts have been most effective, optimizing resource allocation in funding-limited environments. Conservation organizations can leverage our visualizations to communicate more effectively with the public, translating complex data into compelling narratives that motivate engagement. Additionally, our platform serves as an educational resource for students and researchers studying the intersection of policy decisions and ecological outcomes.

By making the relationship between conservation policy and biological outcomes visible and understandable, we provide tools that can improve biodiversity protection in Canada while contributing methodological advances to both visualization science and conservation practice.

7. Reflection on Growth and Learning

This project represents significant growth from our individual assignments to collaborative team research. The journey has enhanced our technical and collaborative skills in several ways:

The in-class activities on color theory and emotional design directly influenced our visualization approach. Particularly valuable was the workshop on creating "data experiences" rather than merely "data representations," which shaped our decision to incorporate affective elements alongside technical accuracy.

The Data Visualization Symposium expanded our understanding of how visualizations can bridge technical and emotional domains. The guest lecture by Professor David Schaaf on augmented reality applications provided inspiration for future directions, where our visualizations could potentially be experienced in immersive environments.

Perhaps most influential was our field trip to the ZhouZhuang Life Mysterious Museum, which demonstrated how scientific data could be presented with narrative elements that engage viewers emotionally. The museum's approach to combining quantitative information with personal stories directly influenced our decision to include species-specific narratives alongside population trend data.

Through this team project, we've developed a deeper appreciation for cross-disciplinary collaboration, learning to balance the technical demands of data processing (Cody), the design considerations of visualization (Jensen), and the communicative aspects of research framing (Loe). This integration of skills mirrors the very data integration at the heart of our project.

8. Supplementary Materials

Our complete project code, documentation, and additional visualizations are available on GitHub:

GitHub Repository: INFOSCI301-Final-Project

Interactive Visualization Demo: Canada Visualization App

References

Aigner, W., Miksch, S., Schumann, H., & Tominski, C. (2011). Visualization of time-oriented data. Springer Science & Business Media.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences, 100(14), 8086-8091.

Environment and Climate Change Canada. (2023). Canadian species index. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/canadian-species-index.html

Harrower, M., & Brewer, C. A. (2003). ColorBrewer.org: An online tool for selecting colour schemes for maps. The Cartographic Journal, 40(1), 27-37.

Lan, X., Wu, Y., & Cao, N. (2023). Affective visualization design: Leveraging the emotional impact of data. IEEE Transactions on Visualization and Computer Graphics, 29(1), 1-12. https://arxiv.org/abs/2308.02831

Munzner, T. (2014). Visualization analysis and design. CRC Press.
Naujokaitis-Lewis, I., Endicott, S., & Guezen, J. M. (2022). CAN-SAR: A database of Canadian species at risk information. Scientific Data, 9(1), 289. https://doi.org/10.1038/s41597-022-01381-8

Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., Raven, P. H., Roberts, C. M., & Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. Science, 344(6187).

Sutherland, W. J., Pullin, A. S., Dolman, P. M., & Knight, T. M. (2004). The need for evidence-based conservation. Trends in Ecology & Evolution, 19(6), 305-308.