

# SDMs: Predicting Species Responses for Conservation Actio

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## Abstract

This collection of studies reviews climate change impacts on species distributions, emphasizing *Species Distribution Models* (SDMs). Research details observed range shifts, contractions, and expansions across diverse ecosystems, identifying vulnerable species like amphibians, reptiles, and marine life. Methodological advancements in SDMs are crucial, including integrating dynamic processes, dispersal, and citizen science data for better predictions. The findings highlight the urgency for adaptive conservation strategies, advocating for SDM outputs in protected area planning and prioritizing at-risk species to mitigate biodiversity loss under global warming. This body of work underscores the critical need for sophisticated tools and comprehensive understanding to address ecological responses to environmental change.

## Keywords

Species Distribution Models, Climate Change, Species Range Shifts, Biodiversity Conservation, Dispersal, Citizen Science, Global Warming, Ecological Modeling, Conservation Strategies, Vulnerable Species

## Introduction

This global review meticulously surveys the application of Species Distribution Models (SDMs) within dynamic environmental contexts, particularly focusing on climate change. It outlines the evolution of SDM methodologies, evaluates their predictive capabilities and limitations, and highlights critical gaps in current research. The paper emphasizes the need for more sophisticated models that integrate dynamic processes and uncertainties to improve predictions of species' responses to rapid environmental shifts [1].

This comprehensive synthesis evaluates empirical evidence of climate change-induced shifts in species distributions across diverse

taxa and ecosystems globally. The authors detail observed range contractions, expansions, and shifts, drawing insights from marine, freshwater, and terrestrial environments. The paper identifies key research priorities for better understanding and predicting these ecological responses, underscoring the urgency for adaptive conservation strategies [2].

Here's the thing, this review explores the critical intersection of biodiversity, climate change, and the role of species distribution models in informing conservation efforts. It discusses how SDMs can project future distributions under various climate scenarios, identifying vulnerable areas and species. The paper advocates for integrating SDM outputs into protected area planning and management to enhance resilience against ongoing environmental changes [3].

This review delves into the complex dynamics of terrestrial species range shifts under global warming, providing a structured overview of past observations, current trends, and future projections. It synthesizes evidence from various ecosystems and taxonomic groups, identifying common patterns and key drivers of these

shifts. The authors highlight the necessity for a mechanistic understanding of species responses to effectively predict and mitigate biodiversity loss [4].

This study employs species distribution models to forecast the future ranges of European amphibians and reptiles under various climate change scenarios. What this really means is a significant portion of these species face widespread range contractions, indicating severe vulnerability to climatic shifts. The findings provide crucial data for prioritizing conservation actions, especially for species with limited dispersal abilities or strict habitat requirements [5].

Let's break it down: this global meta-analysis projects the future of marine species distributions in the face of ongoing climate change. The research synthesizes findings from numerous studies to identify overarching trends in marine biodiversity responses, including poleward shifts and depth migrations. It offers critical insights into the potential ecological and economic impacts of these changes, emphasizing the need for robust marine conservation strategies [6].

This review investigates how citizen science data can be effectively integrated into species distribution models. It examines the strengths and challenges associated with using crowd-sourced biodiversity observations, discussing methods to address biases and improve data quality. The paper highlights the immense potential of citizen science to enhance the spatial and temporal resolution of distribution data, ultimately leading to more accurate models for conservation [7].

This article reviews the diverse methodologies used for predicting species distributions and their potential range shifts in a changing climate. It evaluates the theoretical underpinnings, applications, and limitations of various modeling approaches, from correlative to mechanistic. The paper underscores the importance of selecting appropriate models based on data availability and specific research questions to achieve reliable predictions for conservation management [8].

This meta-analysis highlights the often-underestimated importance of dispersal in accurately predicting species distributions. It synthesizes findings from numerous studies, demonstrating how dispersal capabilities significantly influence a species' ability to track suitable habitats under environmental change. The paper argues for a more explicit integration of dispersal processes into species distribution models to enhance their predictive power and relevance for conservation planning [9].

This research investigates the global drivers behind mammalian species distribution shifts when facing climate change. It identifies

key climatic and environmental factors that disproportionately influence the movement and survival of different mammalian groups. The findings provide a macro-level understanding of vulnerability, informing broad-scale conservation strategies and highlighting regions and species most at risk from climate-induced range alterations [10].

## Description

The pressing issue of climate change is driving significant shifts in species distributions across the globe, a phenomenon extensively documented and analyzed through various scientific lenses. One primary tool for understanding and predicting these changes is Species Distribution Models (SDMs) [1, 3, 8]. These models have evolved considerably, offering insights into how species might respond to dynamic environmental contexts [1]. However, their predictive capabilities are not without limitations, underscoring a continuous need for more sophisticated approaches that can integrate complex dynamic processes and inherent uncertainties [1]. Researchers are particularly focused on improving predictions for species responses to rapid environmental shifts, which is crucial for effective conservation planning [1, 3].

Empirical evidence comprehensively demonstrates climate change-induced shifts in species distributions across a wide array of taxa and ecosystems, including marine, freshwater, and terrestrial environments [2, 4, 6]. Observations detail range contractions, where species lose habitat, as well as expansions and shifts into new areas [2]. For instance, a study focusing on European amphibians and reptiles projected widespread range contractions under various climate change scenarios, highlighting the severe vulnerability of these groups, especially those with limited dispersal abilities [5].

Similarly, global meta-analyses predict significant poleward shifts and depth migrations in marine species, raising concerns about ecological and economic impacts [6]. This review also delves into the complex dynamics of terrestrial species range shifts under global warming, providing a structured overview of past observations, current trends, and future projections across various ecosystems and taxonomic groups [4]. Understanding the drivers and patterns of these range dynamics, including key climatic and environmental factors influencing mammalian shifts, is essential for mitigating biodiversity loss [4, 10].

Beyond documenting observed shifts, a critical area of research involves refining the methodologies used to predict species distributions [8]. Here's the thing, a diverse array of modeling approaches exists, from simpler correlative models to more complex mechanis-

tic ones, each with its own theoretical underpinnings, applications, and limitations [8]. The choice of an appropriate model depends heavily on data availability and the specific research questions at hand [8]. One often-underestimated factor in these models is dispersal, which significantly influences a species' ability to track suitable habitats as environments change [9]. Integrating dispersal processes more explicitly into SDMs can substantially enhance their predictive power and relevance for conservation [9].

What this really means is, a vital aspect of this field is the application of these models and observations to inform conservation efforts. The findings from SDMs can project future distributions under different climate scenarios, helping identify areas and species that are most vulnerable [3]. This information is instrumental for prioritizing conservation actions, particularly for at-risk species and regions [5, 10]. Integrating SDM outputs directly into protected area planning and management strategies is advocated to build resilience against ongoing environmental changes [3]. Furthermore, innovative approaches like incorporating citizen science data into SDMs offer immense potential to enhance the spatial and temporal resolution of distribution data, leading to more accurate and robust conservation models [7]. A macro-level understanding of vulnerability, derived from identifying global drivers of species shifts, can inform broad-scale conservation strategies and pinpoint regions and species most at risk from climate-induced alterations [10].

## Conclusion

Here's the thing, current research extensively explores the impact of climate change on species distributions, using Species Distribution Models (SDMs) as a primary tool. These studies highlight observed range shifts, contractions, and expansions across marine, freshwater, and terrestrial environments, affecting diverse taxa like European amphibians, reptiles, and mammals. Scientists are continually refining SDM methodologies, evaluating their predictive capabilities, and addressing limitations by integrating dynamic processes and factors like species dispersal, which often gets underestimated. The goal is to create more sophisticated models for accurate predictions of species responses to environmental changes. Beyond modeling, researchers emphasize the urgent need for a mechanistic understanding of these shifts, identifying key climatic drivers, and incorporating empirical evidence from global syntheses and meta-analyses. What this really means is that conservation efforts critically rely on these findings, advocating for the integration of SDM outputs into protected area planning and prioritizing actions for vulnerable species and regions. Citizen science data also shows promise in enhancing model accuracy by providing higher resolu-

tion distribution data. Overall, the collective research underscores the complexity of ecological responses to global warming and the crucial role of advanced modeling and data integration in developing effective, adaptive conservation strategies for biodiversity in a changing world.

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