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A Study on Climate Change and Its Impact on Animal Biodiversity

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ABSTRACT

Climate change constitutes a profound existential threat to global animal biodiversity, fundamentally disrupting species distributions, physiological functioning, and long-term population viability across terrestrial, freshwater, and marine ecosystems. This comprehensive review synthesizes current scientific evidence elucidating the mechanistic pathways through which climate change imperils animal taxa worldwide. Research projections indicate that by 2100, approximately 8,000 vertebrate species may face heightened extinction vulnerability as the synergistic effects of climate-driven extreme heat events and expanding anthropogenic land use converge (Vardi et al., 2025). Extreme climatic phenomena—notably heatwaves, catastrophic wildfires, and prolonged droughts—are escalating in both frequency and severity, with modelling suggesting that by 2085, more than one-third of terrestrial vertebrate habitat ranges could experience simultaneous exposure to multiple extreme events under high-emission trajectories (van den Bosch et al., 2026). Species demonstrate markedly heterogeneous vulnerability profiles shaped by their physiological thermal tolerances, behavioural plasticity, and inherent adaptive capacities. Poleward and elevational range shifts represent primary biological responses to warming climates (Brodie et al., 2025); however, anthropogenic dispersal barriers and landscape fragmentation frequently transform these potential range adjustments into actual range contractions and localized extirpations. Intraspecific genetic diversity critically modulates species' capacities to persist at warm-range boundaries and successfully colonize cooler margins under changing climatic conditions (Oliveira et al., 2026). Conservation frameworks emphasizing protected area expansion, ecological restoration, and targeted interventions for climate-sensitive species offer viable pathways for fostering wildlife resilience. Nevertheless, rapid and decisive climate mitigation remains indispensable, as even the most optimistic emission reduction scenarios project continued species exposure to unsuitable environmental conditions (Vardi et al., 2025). This review underscores the imperative for integrated, cross-realm conservation approaches that address the interconnected nature of climate-induced biodiversity loss in an era of accelerating environmental transformation.

***Keywords**: Climate Change, Animal Biodiversity, Species Extinction, Extreme Climatic Events.*

Introduction

Animal biodiversity is increasingly being affected by the consequences of human-induced climate change. Changes in temperature and precipitation, together with the growing frequency of extreme climatic events, are altering the environmental conditions on which animal populations depend. Climate change is now being recognized as an additional major pressure on wildlife alongside two long-established threats: habitat degradation and excessive exploitation of natural resources. Ripple et al. (2025) describe this development as a transition from a situation characterized by two major threats to

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one involving three interconnected pressures. The increasing influence of climate change is therefore becoming an important factor in determining the distribution, survival, and long-term persistence of animal species. Rising temperatures can modify habitats, disturb ecological relationships, alter food availability, and create environmental conditions that many species may be unable to tolerate.

The potential magnitude of these changes is considerable. A global assessment by Vardi et al. (2025) estimated that as many as 7,895 vertebrate species could experience an increased risk of extinction by 2100 as a result of the combined influence of extreme heat associated with climate change and continued expansion of human land use. This projection illustrates that climate change does not operate independently. Rather, it interacts with existing pressures on wildlife and can intensify their effects. The conversion and fragmentation of natural habitats, for example, may restrict the ability of animals to move toward areas with more suitable climatic conditions. Consequently, species that might otherwise respond to rising temperatures through geographical range shifts can face additional constraints because suitable habitats may be isolated or surrounded by human-dominated landscapes.

The projected changes are also significant when different future emission pathways are considered. Under high-emission conditions, animal species may encounter climatic conditions that become unsuitable across more than half of their geographical ranges on average. Even under relatively optimistic emission scenarios, however, species are projected to experience unsuitable climatic conditions across approximately 10% of their ranges (Vardi et al., 2025). These findings indicate that reducing greenhouse-gas emissions remains essential, but they also demonstrate the importance of developing conservation measures capable of helping animal populations cope with changes that are already occurring.

The consequences of climate change are not uniform across animal groups or geographical regions. Species differ considerably in their physiological tolerance, reproductive characteristics, behaviour, dispersal capacity, and ability to adjust to environmental change. Animals with narrow climatic requirements or limited mobility may be particularly vulnerable, whereas species possessing greater behavioural flexibility or broader environmental tolerance may have comparatively greater capacity to cope with changing conditions. Similarly, the availability and connectivity of suitable habitats can determine whether a species is able to track changing climatic conditions successfully.

Climate change can also influence animal populations indirectly by modifying ecological relationships. Changes in temperature, water availability, vegetation structure, prey abundance, and seasonal cycles can affect feeding, reproduction, migration, and predator-prey interactions. Such changes may produce cascading consequences throughout ecosystems. Therefore, assessing the impact of climate change on animal biodiversity requires consideration not only of direct mortality but also of the wider ecological and demographic processes that influence population stability.

Against this background, the present article examines the major ways in which climate change is affecting animal biodiversity across terrestrial, freshwater, and marine ecosystems. Particular attention is given to extreme climatic events, habitat transformation, geographical range changes, genetic and adaptive capacity, and demographic responses. The article also considers differences in vulnerability among animal groups and highlights important gaps in current biodiversity research. In addition, it discusses conservation and climate-mitigation approaches that can contribute to improving the resilience of animal populations.

The available evidence makes it clear that climate change should no longer be regarded solely as a future environmental concern. Its effects are already being observed through changes in species distributions, population declines, mortality events, and the transformation of ecosystems. Ripple et al. (2025) further warn that climate-related extinction risks and large-scale mortality events are likely to increase rapidly as global temperatures continue to rise. Every additional increment of warming can increase the pressure placed on species that are already coping with habitat loss, exploitation, pollution, and other anthropogenic disturbances.

The conservation of animal biodiversity therefore requires a coordinated approach that combines climate-change mitigation with effective biodiversity management. Reducing greenhouse-gas emissions is fundamental to limiting future ecological disruption, while protected areas, habitat connectivity, restoration initiatives, species monitoring, and targeted conservation interventions can help vulnerable populations respond to environmental changes. A better understanding of species-specific vulnerabilities and adaptive capacities is equally important for developing evidence-based conservation

policies. In this context, integrating climate science with wildlife conservation is essential for reducing extinction risks and maintaining the ecological functions on which both natural ecosystems and human societies depend.

Direct Drivers: Primary Mechanisms of Harm

Climate change impacts animal biodiversity through interconnected pathways, with extreme events and shifting climatic baselines acting as primary drivers.

- **The Intensification of Climate Extremes**

One of the clearest consequences of climate change is the growing occurrence and severity of extreme weather and climatic disturbances, including prolonged heatwaves, drought conditions, wildfires, and flooding. Such events can result in substantial and sudden mortality among animal populations, particularly when environmental conditions exceed the physiological limits within which species can survive (van den Bosch et al., 2026). Projections of future climate-related risks indicate that, under a high-emissions pathway, approximately 36% of terrestrial vertebrate habitats may be exposed to multiple extreme climatic events by 2085. These events may occur in succession, such as repeated heatwaves or a combination of a heatwave followed by a wildfire (van den Bosch et al., 2026). The occurrence of multiple extreme events within a short period can substantially increase ecological pressure because affected populations may have insufficient time to recover, reproduce, relocate, or develop adaptive responses before experiencing another disturbance.

Heatwaves are projected to be the most pervasive threat, with 93% of the area within species' ranges exposed to heatwaves by 2085 under high-emissions scenarios (van den Bosch et al., 2026). Regions including the Amazon basin, tropical Africa, and Southeast Asia emerge as hotspots for increased exposure, threatening some of the world's most biodiverse areas (van den Bosch et al., 2026). Extreme wildfires represent the second most prevalent event, with 25% of species' ranges projected to experience wildfire exposure by 2085 under high-emissions pathways (van den Bosch et al., 2026). Drought exposure, while relatively lower in projected extent, is expected to disproportionately affect amphibian ranges compared with other taxonomic groups (van den Bosch et al., 2026).

The seriousness of climate-related impacts is evident from several large-scale declines in animal populations that have been associated with extreme environmental conditions. Ripple et al. (2025) document a number of striking examples, including the loss of more than 10 billion snow crabs in the Bering Sea since 2018, approximately 7,000 humpback whale deaths associated with heatwaves in the North Pacific, and the unprecedented mortality of nearly 4 million common murres along the western coast of North America during 2015–2016. These incidents demonstrate how extreme climatic conditions can produce rapid and extensive losses in wildlife populations. Marine heatwaves are particularly concerning because their ecological consequences extend beyond individual species. According to Nature Reviews Biodiversity (2025), such events can contribute to declines in fisheries, interfere with nutrient cycling, reduce ecosystem carbon-storage capacity, and cause substantial damage to marine organisms and habitats, including seagrass ecosystems, coral communities, and kelp systems.

- **Habitat Transformation and Range Shifts**

Beyond direct mortality from extreme events, climate change drives a gradual but equally profound transformation of habitats. As temperature and precipitation patterns shift, the climatic niches that species depend on move—generally toward the poles and to higher elevations (Brodie et al., 2025). This forces species to either adapt, move, or face local extinction.

Climate change is increasingly altering the geographical distribution of animal species, resulting in changes in the size, location, and configuration of their ecological ranges. Brodie et al. (2025) emphasize that these range responses can produce different and sometimes overlooked consequences for biodiversity at both local and global scales. In many regions, changes in species distributions may initially increase local biodiversity, whereas tropical lowland areas could experience declines in species diversity. Similarly, the expansion of species ranges may help preserve biodiversity in lower latitudes while contributing to greater diversity in other geographical regions, potentially resulting in relatively stable levels of biodiversity at the global scale. Evidence from both contemporary ecosystems and the geological past indicates that range expansion and geographical shifts are among the important responses of species to changing climatic conditions (Brodie et al., 2025).

The interaction between climate change and human-driven land-use transformation is expected to create particularly serious pressures in regions such as the **Sahel, the Middle East, and Brazil**. Vardi

et al. (2025) estimate that, under certain future scenarios, more than **77% of Data Deficient species, over 50% of Near Threatened species, and more than 60% of threatened species** may encounter climatically unsuitable conditions across at least half of their existing geographical ranges. These projections highlight the possibility that climate-related range changes could substantially influence future patterns of animal biodiversity.

Brodie et al. (2025) suggest that future research should focus on three important areas to better understand these changes. First, **paleontological evidence** can be used to investigate how biodiversity responded to environmental changes over long periods of Earth's history. Second, improved monitoring of species at their **lower-elevation and latitudinal boundaries** can help researchers distinguish genuine range shifts from simple range expansions. Third, studies should incorporate **barriers to species dispersal**, because mountains, fragmented habitats, human settlements, and other obstacles may prevent species from moving into newly suitable environments. When movement is restricted, species that might otherwise shift their ranges may instead experience range contraction and increased extinction risk.

- **Genetic Diversity and Adaptive Capacity**

Recent research has revealed that genetic diversity plays a critical role in species' ability to respond to climate-induced range shifts. Oliveira and colleagues (2026) conducted a global analysis combining data on 4,673 range shifts for 1,888 species with measurements of intraspecific genetic diversity. Their findings demonstrate that genetic diversity promotes both persistence at the warm edge of species ranges under rapid climate change and colonization at the cold edge under slow climate change.

These eco-evolutionary interactions had been theorized for a long time but had not been empirically validated at a large scale (Oliveira et al., 2026). Understanding the evolutionary potential of species could help resolve part of the puzzle explaining variation in species range shift rates. The results suggest that accounting for species' adaptive potential is critical for predicting biodiversity responses to climate change (Oliveira et al., 2026).

- **The Complexity of Demographic Responses**

The ability of a species to survive and persist under changing climatic conditions depends on how climate-related pressures influence several demographic processes simultaneously, including **survival, individual development, and reproduction**. Because these processes collectively determine population growth and decline, understanding their combined effects is essential for assessing the long-term consequences of climate change (Paniw et al., 2021). However, significant gaps remain in the available scientific evidence. A systematic assessment of research on terrestrial mammals conducted by Paniw et al. (2021) identified only **106 studies** that quantitatively examined relationships between climate conditions and multiple demographic rates. These studies covered only **87 mammal species**, representing less than **1% of all terrestrial mammal species**.

The review also identified a substantial geographical and taxonomic imbalance in existing research. Areas and mammal groups that have received demographic research attention do not necessarily correspond to those currently considered most vulnerable to climate change (Paniw et al., 2021). Furthermore, climate impacts on populations are rarely straightforward. The same population may experience improvement in one demographic process while simultaneously facing deterioration in another, and the direction and magnitude of these effects can vary according to local environmental conditions. Consequently, predicting whether a population will increase, remain stable, or decline cannot always be achieved through simple climate-based assessments. Paniw et al. (2021) therefore emphasize the importance of examining demographic processes collectively and expanding coordinated research efforts across mammals and other animal groups to obtain a more comprehensive understanding of climate-related population responses.

Realm-Specific Vulnerabilities

The impacts of climate change are felt across all biomes, but each ecosystem faces unique challenges and harbors species with particular sensitivities.

- **Freshwater Ecosystems: A Crisis of Quantity and Quality**

Freshwater ecosystems are experiencing declines in biodiversity that are even worse than those on land. These habitats are threatened by a combination of factors, including unsustainable agriculture,

river fragmentation, and the loss of snow cover, glaciers, and permafrost due to warming. Climate change alters water quantity and quality, with warming waters holding less oxygen and becoming more susceptible to algal blooms, further stressing aquatic life.

Freshwater shortages can also influence marine ecosystems because reductions in river discharge alter the quantity of freshwater and nutrients entering coastal waters. Evidence from the Mediterranean Sea suggests that a 41% decline in river flow could lead to an approximately 10% reduction in marine primary productivity and a 6% decrease in the biomass of commercially important fish and invertebrate species (Macias et al., 2025). In some areas, the projected reductions may reach approximately 12% to 35%, creating substantial pressure on coastal and marine ecosystems as well as the economic activities that depend on them. Changes in species composition and abundance may also be reflected in biodiversity indicators, with water-reduction scenarios producing an estimated 1.8% overall decline in the Shannon Diversity Index across the Mediterranean Sea (Macias et al., 2025).

The effects are expected to be particularly pronounced in the semi-enclosed Adriatic and Aegean basins. According to Macias et al. (2025), average reductions in indicators of primary productivity may reach approximately 30%, while the maximum decline in areas influenced by river plumes could exceed 40%. These findings demonstrate that freshwater management decisions can have consequences beyond terrestrial and freshwater environments. Changes in river discharge can modify nutrient delivery to coastal waters and consequently affect marine food webs and commercially important species. Therefore, water-management policies should consider changes in nutrient availability and incorporate the ecological requirements of downstream marine ecosystems when establishing environmental flow provisions for freshwater systems (Macias et al., 2025).

- **Marine Ecosystems: Warming, Acidification, and Deoxygenation**

The ocean has absorbed more than 90% of the Earth's excess heat, providing a crucial buffer for the atmosphere but paying a heavy price. This absorption leads to warming, acidification, and deoxygenation, creating a hostile environment for marine life. Marine heatwaves have become increasingly frequent and severe, causing substantial impacts on biodiversity and ecosystem services (Nature Reviews Biodiversity, 2025).

Marine species face acute sensitivity to temperature changes. Research on species distributions across South American large marine ecosystems demonstrates projected habitat suitability losses for species including southern rockhopper penguins, gentoo penguins, and Magellanic penguins under future high-emissions scenarios (Journal of Biogeography, 2026). These species are projected to experience contractions of suitable habitat southward, with southern rockhopper penguins predicted to have low suitable habitat across all marine ecosystems under SSP5-8.5 scenarios (Journal of Biogeography, 2026).

For marine ecosystems, emerging adaptation strategies increasingly emphasize **flexible fisheries management and rapid conservation interventions** aimed at reducing pressures on species that are particularly vulnerable to environmental change (*Nature Reviews Biodiversity*, 2025). Such approaches can help management systems respond more quickly as climatic conditions and ecological risks change. Future research should therefore examine not only the effects of rising temperatures independently but also how temperature changes interact with **multiple and simultaneous environmental stressors**. Understanding these combined pressures will be essential for designing effective conservation measures and developing management strategies capable of improving the resilience of marine species and ecosystems.

- **Terrestrial Ecosystems and Complex Responses**

Terrestrial animals face unique challenges from climate change, with physiological tolerance, behavioral thermoregulation, and elevation shifts serving as dominant coping strategies. Some species can adapt behaviorally to changing conditions. For example, gorillas have been shown to drink more frequently with increasing maximum daily temperatures (van den Bosch et al., 2026). However, adaptive behaviors may involve trade-offs, and not all species possess the behavioral plasticity needed to cope with rapid change.

The wall brown butterfly provides a compelling case study of evolutionary limits to range expansion. Nielsen and colleagues (2025) found that while butterflies evolve as they spread northward in response to warming, some barriers—such as cold winters—cannot be overcome so quickly. Field experiments in Sweden revealed that although butterflies from northern populations grew faster and

adapted the timing of their hibernation to northern conditions, almost no caterpillars survived the cold winters north of their current range (Nielsen et al., 2025). The researchers suspect that repeated natural selection due to harsh winter conditions may have already exhausted the evolutionary potential for better cold adaptation at the edge of the distribution range.

This finding is crucial for predicting future changes in biodiversity and the spread of species that could affect agriculture and human health (Nielsen et al., 2025). Understanding these limits is essential for predicting where species will move in the wake of climate change.

Research Gaps and Future Directions

Although scientific understanding of the relationship between climate change and biodiversity loss has expanded considerably, important gaps in knowledge and monitoring remain. Ripple et al. (2025) point to a substantial imbalance in conservation research across different animal groups. The IUCN Red List assessment process has evaluated the conservation status of approximately **72.6% of vertebrate species**, whereas comparable assessments have covered only about **1.6% of invertebrate species**. This is particularly concerning because invertebrates represent the overwhelming majority of animal diversity. The limited availability of information on these species creates a major gap in conservation science and reduces the ability of researchers and conservation authorities to identify, evaluate, and respond to climate-related risks affecting species that perform essential ecological functions (Ripple et al., 2025).

Brodie et al. (2025) further stress the importance of strengthening field-based monitoring at the **lower boundaries of species' elevation and latitude ranges**. Such monitoring can help researchers determine whether populations are genuinely shifting their geographical distributions or simply expanding into newly suitable areas. Climate projections should also account for **physical and ecological barriers to dispersal**, since these barriers may prevent species from reaching areas where climatic conditions have become more favourable. When movement is restricted, populations that could potentially relocate may instead experience geographical contraction and a greater likelihood of extinction.

Another important research priority concerns the demographic processes that determine population persistence. Paniw et al. (2021) emphasize that climate change can affect several demographic characteristics simultaneously, including survival, development, and reproduction. Consequently, understanding future population trends requires coordinated research that examines these processes together rather than considering individual demographic rates in isolation.

Key Research Priorities

Based on the findings of these studies, several priorities can be identified:

- **Develop a comprehensive global database** for systematically recording and monitoring climate-related mass mortality events in animal populations (Ripple et al., 2025).
- **Expand conservation assessments of poorly studied species**, with particular attention to invertebrates that remain substantially underrepresented in existing assessments (Ripple et al., 2025).
- **Strengthen coordination between biodiversity conservation and climate policy**, so that climate-change mitigation and biodiversity-management strategies are developed in an integrated manner (Ripple et al., 2025).
- **Make greater use of paleontological evidence** to understand how animal biodiversity and species distributions have responded to environmental changes over long periods of Earth's history (Brodie et al., 2025).
- **Include dispersal limitations and geographical barriers in species-range models**, thereby producing more realistic projections of future range shifts, contractions, and potential extinction risks (Brodie et al., 2025).

Conclusion

Climate change poses an existential threat to animal biodiversity, fundamentally reshaping the planet's ecosystems and pushing thousands of species toward extinction. The evidence is clear in the increased frequency of extreme events, the rapid rate of local extinctions, and the profound transformation of habitats from the poles to the tropics. Species in temperate zones show higher rates of local extinction, marine life is particularly sensitive to warming, and freshwater ecosystems are under immense pressure. The synergistic effects of climate change with overexploitation and habitat loss compound the risks, creating a perfect storm for biodiversity loss.

Ripple and colleagues (2025) warn that we may be approaching tipping points regarding the impact of climate change on Earth's animals. Even marginal increases in global mean surface temperature could precipitate exponential rises in extinction risks and mass mortality events. The authors conclude that "rapid and effective climate mitigation is crucial now more than ever for saving the world's biodiversity" (Ripple et al., 2025).

However, the situation is not hopeless. The future of animal biodiversity hangs in the balance of the choices we make today. The path forward requires a global, coordinated effort to mitigate greenhouse gas emissions and adapt to changes already underway. By embracing a dual strategy of aggressive climate action and proactive, inclusive conservation, we can prevent the most catastrophic losses. The tapestry of life is frayed, but it can still be mended if we act with urgency and collective will. The future of the natural world, and our own, depends on it.

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