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CLIMATE CRISIS AND THREATENED SPECIES: THE LEGAL FRAMEWORK IN BRAZIL

CRISE CLIMÁTICA E ESPÉCIES AMEAÇADAS: NORMATIVIDADE FEDERAL BRASILEIRA

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Abstract
This article examines the impacts of climate change on biodiversity and endangered species in Brazil in light of growing scientific evidence that global warming already poses concrete threats to the planet's ecological balance. The study assumes that, although Brazil has an extensive legal framework for environmental protection, there are significant gaps in the integration between climate policy and endangered species conservation. The research aims to: present climate scenarios projected for Brazil based on IPCC and PBMC reports; reveal the number of threatened species and the Red List Index (RLI) from IUCN; and critically analyze the Brazilian federal legal framework regarding both climate policy and biodiversity protection. Through literature review, scientific data analysis, and legal research, the findings show Brazil as one of the most climate-vulnerable countries, with severe risks to biodiversity. Despite a

Resumo
Este artigo analisa os impactos das mudanças climáticas sobre a biodiversidade e as espécies ameaçadas no Brasil diante da crescente evidência científica de que o aquecimento global já impõe riscos concretos ao equilíbrio ecológico do planeta. O estudo parte da hipótese de que, embora o Brasil disponha de um vasto arcabouço legal para a proteção ambiental, há fragilidades normativas na integração entre políticas climáticas e conservação de espécies ameaçadas. A pesquisa busca apresentar os cenários climáticos projetados para o Brasil pelos relatórios do IPCC e do PBMC; expor o número de espécies ameaçadas e o Índice da Lista Vermelha da IUCN; e analisar criticamente a normatividade federal vigente, tanto na política climática quanto na legislação ambiental. Utilizando revisão bibliográfica, dados técnico-científicos e análise normativa, os resultados indicam que o Brasil é um dos países mais vulneráveis aos efeitos climáticos, com riscos severos à biodi-

robust set of environmental laws, the national climate policy still lacks direct and effective mechanisms to safeguard endangered species. It is concluded that future legal advancements must bridge this legal framework gap by aligning conservation strategies with climate projections.
Keywords: Environmental Law; threatened species; red list index; climate change; climate policies.

versidade, ao passo que a legislação climática federal ainda apresenta respostas indiretas à proteção das espécies. Conclui-se que, apesar da robustez legislativa em biodiversidade, é necessário avançar em mecanismos legais que integrem cenários climáticos às estratégias de conservação.
Palavras-chave: *Direito Ambiental; espécies ameaçadas; índice da lista vermelha; mudanças climáticas; políticas climáticas.*

Introduction

Global warming is a scientifically well-documented phenomenon, confirmed by a wide range of studies and specialized institutions. Numerous global and national reports and analyses have been warning about this process over the years, most notably the six reports produced by the Intergovernmental Panel on Climate Change (IPCC), the most recent of which was released in 2023, as well as contributions from the Brazilian Panel on Climate Change (PBMC).

The IPCC's Sixth Assessment Report states that there is no longer any doubt about the role of human activity in the recent warming of the atmosphere, oceans, and land surface. These changes have been rapid, significant, and widespread. The average global temperature increased by 1.09°C from 2011 to 2020 relative to the pre-industrial era (1850-1900), and it is highly likely that 1.07°C of this total is directly attributable to human activities.

Global warming has triggered a climate crisis, evident in the increased frequency and severity of extreme events, such as stronger hurricanes, record-breaking heatwaves, and shifting rainfall patterns. These phenomena directly impact ecosystems, biodiversity, and human communities. This reality has also sparked debate about potential "tipping points" in the Earth system, which could lead to irreversible changes and push the planet into less hospitable conditions, highlighting the urgent need for both mitigation and adaptation measures to address the issue, under the risk of facing severe consequences for humanity.

Among the most significant impacts of climate change is the worsening biodiversity crisis. Recent assessments by specialized organizations demonstrate the direct link between climate change and biodiversity loss, emphasizing the risk of mass species extinction. This scenario illustrates how these two crises are mutually reinforcing and aggravating one another, underscoring the alarming and

accelerating decline in global biodiversity.

This article is based on the hypothesis that, although Brazil shows an extensive legal framework for biodiversity protection, it contains significant gaps in the integration between climate policies and the conservation of threatened species, resulting in legal insufficiencies to address the climate scenarios projected for the 21st century.

In this regard, the central research question aims to answer to what extent is the current Brazilian federal legal framework sufficient to protect threatened species in light of projected 21st century climate scenarios, aiming to highlight theoretical aspects of the interconnection between climate change, its impacts on biodiversity and threatened species, and how future scenarios place Brazil in a position of vulnerability, requiring, among other actions, the development of legal framework support for the protection of endangered species.

Our article has the specific objectives to answer the following questions: According to the IPCC, what climate scenarios might Brazil face in the 21st century? What are the impacts of these scenarios on biodiversity and endangered species? What is Brazil's Red List Index? What is the number of threatened species and the significance of that data? Do Brazil's national climate policy and federal legislation provide sufficient legal frameworks to protect threatened species in light of projected climate scenarios?

The study also aims to provide a systematic and spatial characterization of the IPCC's Sixth Assessment Report and the climate scenarios projected for Brazil, for 2050 and 2100. It further seeks to explain and present the Red List Index developed by the International Union for Conservation of Nature (IUCN) and the number of threatened species in the country. Lastly, it offers an overview of federal legislation regarding the legal attributes and instruments mobilized to protect threatened species, including an analysis of national climate policies.

This investigation is relevant due to the urgent nature of projected climate impacts and Brazil's responsibility as a country that harbors approximately 15% of the world's known species, yet faces climate scenarios that could lead to the extinction of many of them.

1 Methodology

This section outlines the methodological design adopted in the study, which supports the analysis of climate scenarios, the compilation of officially recognized threatened species in Brazil, and the identification of connections between these

elements and the legal provisions within federal legislation and climate policies aimed at biodiversity protection.

The study is characterized as an exploratory-descriptive investigation with a qualitative approach, complemented by quantitative elements. The methodological framework is structured around three integrated lines of inquiry: (1) analysis of projected climate scenarios; (2) assessment of the conservation status of Brazilian species; and (3) critical analysis of the federal legal framework.

Data collection on climate scenarios was primarily based on the IPCC's Sixth Assessment Report (2023a), regarded as the most up-to-date and reliable source for global climate projections. Selection criteria included projections specific to South America and Brazil, focusing on RCP 2.6 (optimistic scenario) and RCP 8.5 (pessimistic scenario), considering time horizons of 2050 and 2100. As complementary sources, the reports from the Brazilian Panel on Climate Change (PBMC, 2014a, 2014b) were used, offering analyses tailored to the national context.

For biodiversity data, two main sources were employed: the IUCN Red List (2023) and the ICMBio Biodiversity Conservation Status Assessment System (SALVE) (2024). Inclusion criteria encompassed species classified as *Critically Endangered* (CR), *Endangered* (EN), and *Vulnerable* (VU), following international standards for extinction risk classification. The choice of these categories is justified since they represent the most critical threat levels, thus requiring priority attention in conservation policies.

The legislative research covered the period from 1967 to 2024, beginning with Law No. 5,197/1967 (Fauna Protection Law) through to the most recent provisions. Selection criteria for legal instruments included: federal legislation with a direct impact on the protection of threatened species; national climate policies interfacing with biodiversity conservation; and implementation instruments (decrees, ordinances, and plans).

Regarding the review of legislation related to climate change and the protection of biodiversity and threatened species, the following Brazilian instruments were analyzed: National Policy on Climate Change (Law No. 12,187/2009); Law No. 5,197/1967; Decree No. 76,623/1975; Law No. 6,938/1981; Law No. 7,643/1987; Decree No. 2/1994; Law No. 9,605/1998; Decree No. 3,607/2000; Law No. 9,985/2000; Decree No. 4,339/2002; Law No. 11,428/2006; National Plan on Climate Change; Law No. 11,959/2009; Regulation of the National Climate Change Fund (Decree No. 9,578/2018); Law No. 12,651/2012; Law No. 13,123/2015; National Adaptation Plan to Climate Change; and the National

Biodiversity Strategy and Action Plan.

Research sources included the Federal Legislation Portal, the Official Gazette of the Federal Government, and the Planalto database. Exclusion criteria were as follows: state and municipal provisions (due to the federal scope of the research); legislation that were repealed without replacement; and legal instruments not directly related to species protection or climate policy.

The categorical content analysis technique was applied to systematically identify: instruments for the direct protection of threatened species; mechanisms for integrating climate policy and conservation; legal gaps and overlapping mandates; and temporal alignment between scientific advancements and legislative responses.

The categorization process followed three stages: (1) pre-analysis (organization and systematization of material); (2) material exploration (coding and categorization); and (3) results treatment (inference and interpretation). This approach enabled the identification of patterns, trends, and gaps in the legal framework under review.

A diachronic comparison of legal developments was conducted to identify trends in the strengthening or weakening of protection measures, the incorporation of climate science into legislation, temporal alignment between scientific advancements and normative responses, and the evolution of public policy instruments over time.

The correspondence was assessed between projected climate scenarios and existing legal instruments; between the threat level of species and the robustness of protection mechanisms; between international scientific recommendations and national policies adopted; and between implementation capacity and the magnitude of identified challenges.

Based on the collected data, maps, graphs, and analytical tables were prepared. These data enabled the identification of how information on threatened species and the legal provisions established in national climate policy and federal biodiversity protection legislation are interrelated, highlighting advances, limitations, and gaps in this legal and institutional framework.

2 A brief overview of what Brazil may face due to climate change in the 21st century

Regarding the projected scenarios for Brazil in the context of 21st century climate change, this section presents a critical analysis that goes beyond the mere

presentation of numerical data, aiming to understand the systemic implications of these scenarios for national biodiversity.

Chart 1. Summary of climate change scenarios for Brazil in the 21st century

References	Characterizations
IPCC (2013)	Rise in average temperatures Optimistic scenario (RCP 2.6): +0.6°C to +2°C (Amazon and the rest of the country) Pessimistic scenario (RCP 8.5): + 3.6°C to +5.2°C (Amazon) +2.2°C to +7°C (rest of Brazil).
IPCC (2023a)	Likely rise in average temperatures, particularly with more intense warming projected for the Amazon region; Probable increase in hot nights and decrease in cold nights across most regions
Alexander *et al.* (2006), Marengo and Camargo (2008), Rusticucci *et al.* (2010), Marengo (2007), Marengo *et al.* (2009a), Skansi *et al.* (2013).	Rising temperatures; Increased frequency of extreme events.
PBMC (2014a)	Significant changes in rainfall indices and temperatures

Source: elaborated by the authors.

The integrated analysis of IPCC (2023a) data with the specific projections from PBMC (2014a) indicates that Brazil will face not only gradual changes but also extreme events capable of dramatically accelerating extinction processes. The climate scenarios projected for Brazil reveal a complex array of impacts that go beyond numerical estimates of temperature rise.

While the optimistic scenario (RCP 2.6) projects an increase from 0.6°C to 2°C, the pessimistic scenario (RCP 8.5) anticipates increases of up to 7°C in some Brazilian regions. This range does not merely represent a quantitative difference, but a qualitative transformation of ecosystems. As argued by Manes *et al.* (2021), the difference between 1.5°C and 3°C of warming may determine the survival or extinction of approximately one-third of terrestrial endemic species.

To contextualize these projections, the IPCC's Fifth Assessment Report (2013) classified some scenarios as Representative Concentration Pathways (RCPs), which assess the magnitude of change in the Earth system's radiation balance (Moss *et al.*, 2010). The RCPs are designated based on their total radiative forcing, expressed in W/m^2, expected to be reached during or near the end of the 21st century.

The concept of radiative forcing, introduced by the IPCC in 2007, refers to the measure of a given factor's influence on the energy balance between incoming and outgoing energy in the Earth-atmosphere system, serving as an indicator of that factor's relevance in driving climate change (IPCC, 2007). When radiative forcing is positive, it indicates a tendency toward surface warming; when negative, it results in cooling.

Positive radiative forcing on Earth reflects the climate system's absorption of energy (IPCC, 2013). This positivity results from increased concentrations of greenhouse gases (GHGs)—a phenomenon observed since 1750 (IPCC, 2013).

According to Marengo (2007), Marengo *et al.* (2009a), and the reports of PBMC (2014a) and IPCC AR6 (2023a), as a consequence of global warming, some regions of Brazil and South America will experience significant increases in average temperatures.

Although historically resilient, the Amazon is now approaching what Steffen *et al.* (2015) identify as a "tipping point". Analysis of IPCC (2023a) data reveals that the region could undergo irreversible transformations, converting vast areas of forest into savannas, with catastrophic consequences for endemic species. Regardless of changes in annual precipitation indices, an intensification of extreme climatic events is anticipated in the region.

With less than 12% of its original cover remaining, this biome exemplifies how fragmentation amplifies climate impacts. The inability of many species to migrate altitudinally or latitudinally creates scenarios of inevitable local extinction, particularly for mountaintop species that depend on cooler temperatures. These biomes—over 50% of which have already been converted—face shifts in precipitation regimes that may fundamentally alter their structure and composition. Historical adaptation to seasonality does not ensure resilience to changes in the intensity and timing of rainfall.

Regardless of changes in annual precipitation indices, the worsening of extreme weather events is anticipated. The AR6 projections indicate expected temperature increases and altered rainfall distribution patterns across various regions of Brazil (IPCC, 2023a). These scenarios corroborate earlier publications by Alexander *et al.* (2006), Marengo and Camargo (2008), Rusticucci *et al.* (2010), Marengo (2007), Marengo *et al.* (2009a, 2009b), and Skansi *et al.* (2013), as well as reports from the Brazilian Panel on Climate Change (PBMC, 2014a, 2014b).

3 The impacts of climate change on biodiversity and vulnerable species

The effects of climate change on biodiversity have been thoroughly documented in recent literature, and the scope and intensity of these impacts exceed previous estimates from IPCC assessments (IPCC, 2023a; IPBES, 2018). The consequences for terrestrial, marine, and freshwater ecosystems result from both gradual processes—such as ocean acidification, sea level rise, temperature increases, and shifts in rainfall seasonality—and extreme events, including heatwaves, intense rainfall, droughts, and wildfires, among others (IPCC, 2023a).

Thomas *et al.* (2004) employed an approach that explored three methodologies to estimate extinction risk as potentially related to species' geographic range sizes. Based on mid-range global warming scenarios up to 2050, the authors projected that 15%–37% of species in their sample of regions and taxa would be *committed to extinction*[1]. The average results from the three methods and two dispersal scenarios indicated that minimum global warming would result in lower extinction projections (–18%) compared to mid-range (–24%) and maximum change scenarios (–35%) (Thomas *et al.*, 2004).

The pioneering methodology presented by Thomas *et al.* established an important paradigm by correlating geographic distribution with extinction risk. However, its application to the Brazilian context reveals significant nuances. While the authors project that 15%–37% of species may be committed to extinction globally, the Brazilian reality presents additional complexities that could amplify these percentages. The country's immense biodiversity, concentrated in already fragmented hotspots, suggests that the author's projections require more regionalized analysis to assess risks to Brazil's endemic species, particularly those with restricted distributions in the most threatened biomes.

Malcolm *et al.* (2006) presented results highlighting the potential severity of global warming impacts on biodiversity hotspots[2]. Under the most extreme warming scenario, projected extinctions could impact 39%–43% of biota, potentially resulting in the loss of about 56,000 endemic plant species and 3,700 endemic vertebrate species (Malcolm *et al.*, 2006).

From a methodological standpoint, Pacifici *et al.* (2015) emphasize that both mechanistic and correlative models can yield appropriate results when estimating species' extinction risk. The most effective approach for predicting extinction risk in the context of climate change would involve combining population-level

[1]Expression coined by the authors.

[2] Sites that are home to exceptionally high numbers of animal and plant species.

data—such as trends, survival, and fertility—with evolving environmental factors, such as precipitation and sea ice extent, and projecting those changes into the future (Pacifici *et al.*, 2015).

Cahill *et al.* (2013) reinforce such projections by suggesting that climate change may become one of the primary drivers of species extinctions on Earth. The authors highlight abundant evidence of local extinctions directly resulting from climate change, based on a widespread pattern of range contraction at the warmer edges of species' areas of occurrence (low latitude and low altitude). Their conclusion stems from a comprehensive review of scientific literature that examined the immediate causes of local extinctions linked to climate change (Cahill *et al.*, 2013).

These results were reiterated by Manes *et al.* (2021), who emphasize that climate change has significant impacts on global biodiversity. This most recent study further demonstrates that the climate crisis may lead to the extinction of plant and animal species in some of the world's most biodiverse regions. The authors show that current policies are steering the planet toward 3°C of warming. Under this scenario, approximately one-third of terrestrial endemic species and nearly half of marine endemic species would face extinction threats (Manes *et al.*, 2021).

Manes *et al.* (2021) analyzed over 8,000 climate change impact projections from 232 studies, encompassing endemic, non-endemic, native, and introduced species in terrestrial, freshwater, and marine environments. Drawing on publications that provide species identity and local context within biodiversity hotspots, their analysis covered nearly 300 hotspots across land and sea. Their results indicate that climate change poses a widespread threat to biodiversity-rich areas, regardless of climate zone, geography, or taxonomic grouping. As these areas contain a disproportionately large share of global biodiversity per unit area compared to less biodiverse regions, their conservation becomes a crucial priority. The authors state that South America will be one of the most impacted regions due to its significant biodiversity hotspots, placing up to 30% of all endemic species at high risk of extinction (Manes *et al.*, 2021).

Advani (2023) highlights the World Wide Fund for Nature (WWF) initiative that, in 2014, developed a rapid assessment tool to measure species vulnerability to climate change. According to the article, the WWF methodology was constructed by integrating components from several existing tools, including Foden *et al.* (2013), Gill, Stephens, and Cary (2013), and Williams *et al.* (2008).

WWF's objective was to create a user friendly approach accessible to conservation biologists without specialized training in climate science. The tool evaluates

species vulnerability to climate change across four dimensions: (a) sensitivity; (b) adaptive capacity; (c) exposure; and (d) other threats. Each attribute within these dimensions is rated in terms of vulnerability, categorized as high, medium, low, or unknown.

The international literature on climate change and biodiversity reveals that Brazil holds a unique position that demands specific methodological approaches. In total, three factors converge to create this uniqueness:

1. The concentration of global biodiversity within Brazilian territory (15% of known species) means that local impacts have global repercussions. Unlike countries with more dispersed biodiversity, the loss of Brazilian species represents a disproportionately large reduction in global diversity.
2. The historical rate of biome transformation in Brazil, particularly over the past five decades, has created fragmented landscapes that amplify climate impacts. This pre-existing fragmentation distinguishes Brazil from countries such as Indonesia or the Democratic Republic of Congo, where forest cover remains not fragmented as much.
3. The temporal overlap between peak deforestation and accelerating climate change creates a "perfect storm" in which species simultaneously face habitat loss and climate shifts, drastically reducing their adaptive options.

All these references and the discussion above indicate that climate change poses a serious threat to global biodiversity, increasing the extinction risk for already vulnerable species. Brazil, in particular, is highly susceptible to these changes, as will be further explored.

4 Brazilian susceptibility, the number of threatened species in the country, and the red list index

Nobre *et al.* (2016) specify that Brazil, home to a significant portion of global biodiversity, faces a substantial threat to its biological diversity due to the progressive loss of habitat caused by changes in land use, which result in territorial fragmentation. This transformation is driven by the expansion of agribusiness, land speculation, real estate speculation, urban growth, and other land occupation issues (Nobre *et al.*, 2016).

According to Artaxo (2020), Brazil harbors approximately 15% of the planet's species, distributed across a wide variety of habitats. This rich biodiversity is found in six major continental biomes: the Amazon, Atlantic Forest, Caatinga, Cerrado, Pampas, and Pantanal. Additionally, the country features large river basins—such

as the Amazon, Tocantins-Araguaia, Parnaíba, São Francisco, Paraíba do Sul, and Paraná-Paraguay—and an extensive coastline of over 8,000 km. The fundamental equilibrium of Brazilian ecosystems depends on preserving a large number of plant and animal species (Artaxo, 2020).

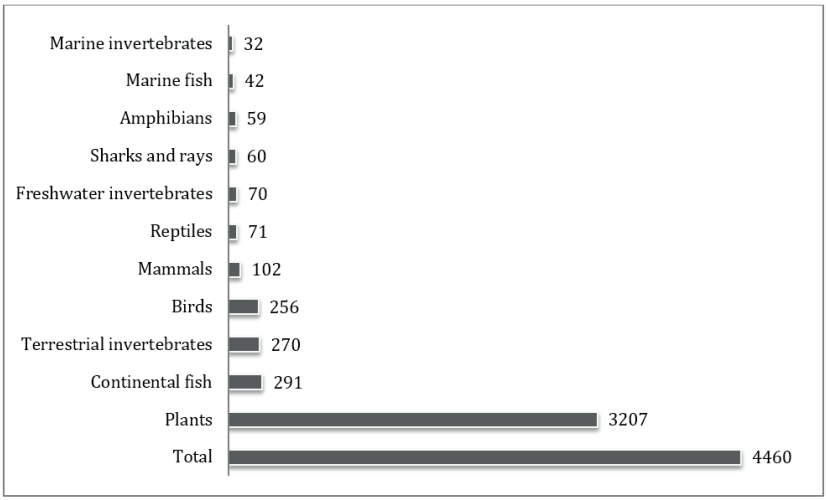
According to the IPCC (2022), up to 85% of natural systems (plant and animal species, habitats, and communities) in the region may be negatively impacted by climate change. Some Brazilian biomes, such as the Atlantic Forest, are particularly threatened, with less than 12% of their original native cover remaining, now represented by discontinuous and unconnected remnants. Ribeiro *et al.* (2009) highlight that these remaining areas are spread out in small forest fragments, which hinders, for example, species migration to adapt to environmental changes.

The PBMC Report (2014b) shows that the Cerrado and Caatinga also face great vulnerability, with more than 50% of these biomes already converted into urban areas, pastures, or agricultural lands—many of which are degraded or abandoned. The Atlantic Forest and the Cerrado are highlighted as hotspots particularly susceptible to rapid and extensive habitat loss (PBMC, 2013).

In regions where deforestation has been more intensive, climate change has had a significant impact on biodiversity. More sensitive species, especially those that depend on cooler environments, such as mountaintop species, face major adaptation challenges due to the ongoing rise in temperatures (PBMC, 2013).

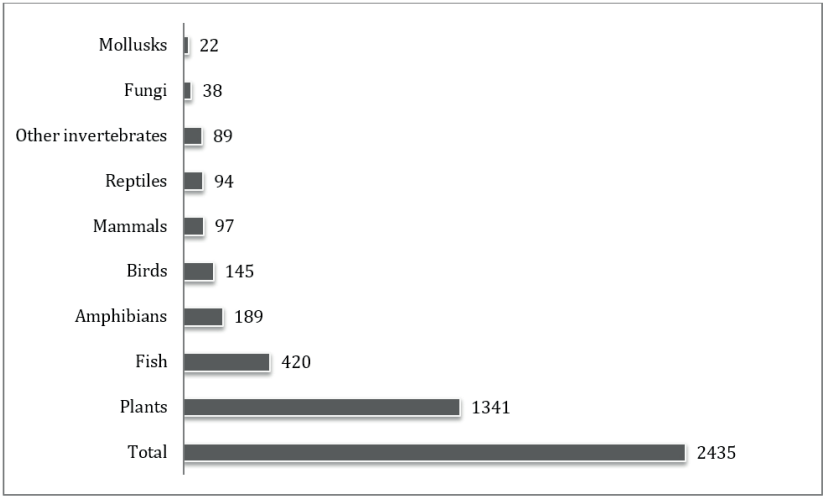
If the pace of climate change surpasses the species' capacity for migration, endemic species may disappear from the region. Humid forests are also under threat, with forecasts pointing to decreasing rainfall and longer dry seasons, especially in the southern and southeastern areas of the Amazon (PBMC, 2013). Such consequences may occur even more rapidly for species already considered threatened.

Regarding Brazil's susceptibility, it is important to note that, according to ICMBio (2024), Brazil holds 1,253 animal species classified as threatened. ICMBio has made these data available via the Biodiversity Conservation Status Assessment System (SALVE), which defines "threatened" species as those classified as *Critically Endangered* (CR), *Endangered* (EN), or *Vulnerable* (VU). For Brazilian flora, the number of threatened plant species is 3,207, bringing the total to 4,460 threatened species (ICMBio, 2024). Graph 1 details these data by species.



Graph 1. ICMBio data on endangered species in Brazil.
Source: elaborated by the authors with data from ICMBio (2024).

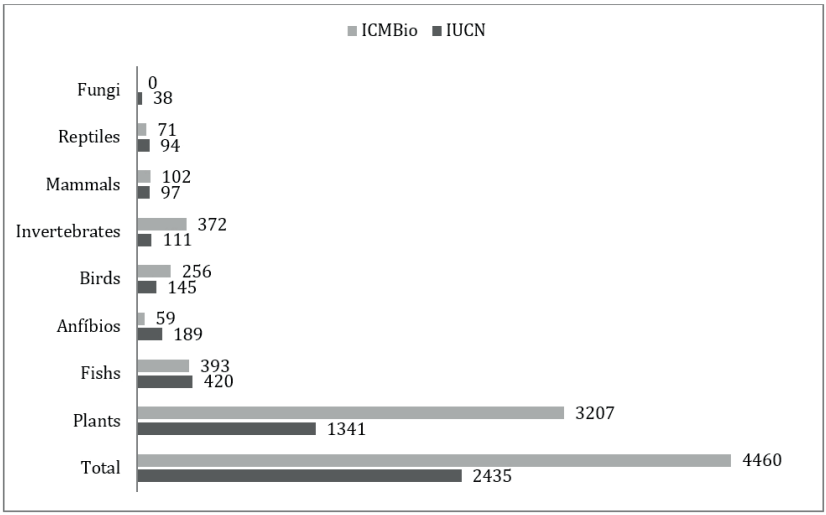
According to the International Union for Conservation of Nature (IUCN, 2023), Brazil shows 2,435 species on its Red List. The IUCN compiles data from the 1993–2023 period and, such as ICMBio, includes species listed as Critically Endangered, Endangered, or Vulnerable. Graph 2 presents an analysis of IUCN data.



Graph 2. IUCN data on threatened species in Brazil.
Source: elaborated by the authors with data from IUCN (2023).

The number reported by IUCN is lower than the figure from the Brazilian agency, which may indicate greater precision in national data collection, particularly with regard to threatened plant species.

It is also worth noting that there are differences in the categorization of species used to present these data. If these classifications are standardized, it becomes possible to compare the figures provided by ICMBio and IUCN (Graph 3).



Graph 3. Comparison between ICMBio and IUCN data.
Source: elaborated by the authors.

It is important to contextualize that Brazil ranks second among South American countries in number of threatened species (Table 1).

Table 1. Ranking of South American countries by number of threatened species

Rank	Country	Number of threatened species
1st	Ecuador	2707
2nd	Brazil	2435
3rd	Colombia	1721
4th	Peru	1000
5th	Venezuela	905
6th	Bolivia	495
7th	Argentina	396

8th	Chile	306
9th	Guyana	219
10th	Uruguay	142
11th	French Guiana	141
12th	Suriname	132
13th	Paraguay	96

Source: elaborated by the authors with data from IUCN (2023).

Expanding the analysis to a global perspective using IUCN (2023) data, Brazil ranks as the fourth country with the most threatened species in the world (Table 2).

Table 2. The ten countries with the most threatened species in the world

Rank	Country	Number of threatened species
1st	Madagascar	3791
2nd	Ecuador	2707
3rd	Mexico	2586
4th	Brazil	2435
5th	Indonesia	2432
6th	Malaysia	2138
7th	United States	1993
8th	Australia	1890
9th	Philippines	1765
10th	Colombia	1721

Source: elaborated by the authors with data from IUCN (2023).

The IUCN also provides a highly relevant metric: the Red List Index (RLI), which tracks trends over time in the global extinction risk of species groups. Brazil's RLI is 0.9 (IUCN, 2023).

An RLI value of 1 indicates that all species are categorized as Least Concern, i.e., not expected to become extinct in the near future. An RLI of 0 corresponds to all species being extinct. A constant RLI over time signals that the global extinction risk of the group has remained unchanged (IUCN, 2023). If the rate of biodiversity loss is decreasing, the RLI shows an upward trend. Currently, the RLI is available for only five taxonomic groups—those for which all species have been assessed at least twice: birds, mammals, amphibians, cycads, and warm-water reef-building corals.

The indexed values used to estimate Brazil's RLI include 706 mammals, 1,824 birds, 882 amphibians, 18 corals, and 5 cycad plants (IUCN, 2023).

Brazil's RLI trend is one of decline, indicating a concrete long-term risk of species extinction if no action is taken to reverse this trajectory. This is exacerbated by the country's significant number of threatened species, making it the second in South America and the fourth in the world in this regard.

These findings confirm Brazil's high susceptibility, especially when confronted with projected climate change scenarios and their consequences for biodiversity, raising the central research question: Do Brazil's national climate policy and federal legislation provide sufficient legal frameworks to protect threatened species in light of projected climate scenarios?

5 On the legal framework of the National Policy on Climate Change and biodiversity protection in federal legislation

Brazil plays a crucial role in climate change, actively participating in global forums and international conferences on the subject. As a pioneer, the country signed the United Nations Framework Convention on Climate Change in 1994.

Brazil has established instruments to address climate change, with its climate agenda developed via international discussions and strategic political positions (Fenner, 2011).

The first legislative initiative related to climate change was the Decree of July 7, 1999, which created the Interministerial Commission on Climate Change (Brasil, 1999).

In 2007, Decree No. 6.263 established the Interministerial Committee on Climate Change (CIM) and guided the preparation of the National Plan on Climate Change, in addition to creating the Brazilian Forum on Climate Change (FBMC) (Brasil, 2007).

The National Plan on Climate Change was launched in 2008, culminating in the National Policy on Climate Change (PNMC), enacted via Law No. 12.187/2009 and regulated by Decree No. 7.390/2010. The plan's main goals are to reduce deforestation, improve energy efficiency, and invest in renewable energy (Brasil, 2009c).

The PNMC is structured around the following key pillars: mitigation; vulnerability, impact, and adaptation; research and development; and training and dissemination. It aims to promote global cooperation in reducing greenhouse gas emissions and to prepare the country to face the impacts of climate change (Brasil,

2009c). The enactment of the PNMC highlights Brazil's political commitment, reflecting its concern with climate change, even in the absence of binding global treaties (Romeiro; Parente, 2011).

Sectoral specialization became necessary within Brazil's legal framework to refine the PNMC's formulations. Several sectoral plans were developed, such as the Low Carbon Agriculture Plan (ABC), the Ten-Year Energy Plan for the energy sector, and the Sectoral Plan on Transport and Urban Mobility for climate change mitigation and adaptation in the transport sector.

In 2009 and 2010, there was a surge in legislative production on climate change, including the creation of the Brazilian National Climate Change Fund by Law No. 12.114/2009, regulated by Decree No. 7.343/2010. Both instruments, provided for under the PNMC, aimed to fund mitigation and adaptation projects.

In 2016, Brazil faced a major economic, political, and social crisis that posed significant challenges for environmental policies. That year, the Brazilian National Adaptation Plan to Climate Change (PNA) was approved by Ordinance No. 150/2016, aiming to reduce vulnerability to climate change via the engagement of civil society, the private sector, and state governments (Brasil, 2016).

Given this historical overview, an analysis of the PNMC regarding the legal framework aimed at biodiversity protection reveals the following results:

- The PNMC does not explicitly use the terms "biodiversity", "threatened animals", "fauna", or "flora". The law addresses the issue indirectly or sporadically, using expressions such as "natural systems", "environmental resources", "natural biomes", "vegetative cover", "environmental systems", and "biomes". These indirect provisions are linked to the presentation of two objectives, one guideline, and two legal instruments set forth in the national policy.
- Article 4, item IV, of the PNMC, when listing one of its objectives, specifies that the Brazilian National Policy shall seek the preservation, conservation, and restoration of environmental resources, with particular attention to major natural biomes considered national heritage (Brasil, 2009c). This provision indirectly implies the goals of preserving, conserving, and restoring biodiversity.
- Similarly, item VII of the same article establishes the consolidation and expansion of legally protected areas and the promotion of reforestation and vegetation cover restoration in degraded areas as objectives (Brasil, 2009c). This provision indirectly addresses the need to restore plant species in the country.
- Article 5, item III, sets out the development of adaptation measures to reduce the adverse impacts of climate change and the vulnerability of environmental, social, and economic systems as a policy guideline (Brasil, 2009c). By addressing

the development of adaptation measures to reduce the impacts of climate change on environmental systems, the National Plan indirectly addresses the need to reduce impacts on biodiversity.

- Finally, Article 6, item III, establishes the Action Plans for the Prevention and Control of Deforestation in biomes as instruments of the policy. This provision also indirectly aims to protect national flora (Brasil, 2009c).

Chart 2. Analysis of the legal framework related to biodiversity in the PNMC

Provisions indirectly aimed at biodiversity
Preservation, conservation, and restoration "of environmental resources, with particular attention to major natural biomes"[3] (art. 4, IV, free translation).
Restoration of plant species in the country through the consolidation and expansion "of legally protected areas and the promotion of reforestation and the restoration of vegetation cover in degraded areas"[4] (art. 4, VII, free translation).
Reduction of climate change impacts on biodiversity via the adoption of "adaptation measures to reduce the adverse effects of climate change and the vulnerability of the environmental system […]"[5] (art. 5, III, free translation).
Protection of national flora via "Action Plans for the Prevention and Control of Deforestation in biomes"[6] (art. 6, III, free translation).

Source: elaborated by the authors based on Brasil (2009c).

Despite the presence of indirect provisions related to biodiversity protection in the PNMC, Brazil shows a large body of specific federal legislation regulating various aspects of the subject. What follows is a brief historical overview, in chronological order, of federal laws aimed at biodiversity protection:

1. In 1967, Law No. 5,197 was enacted to protect wildlife, establishing rules for hunting, prohibiting commercial and unauthorized hunting, promoting the creation of biological reserves and parks, and emphasizing environmental education (Brasil, 1967).
2. Brazil ratified the Washington Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), promulgated by Decree No. 76,623/1975. CITES, by regulating and monitoring international trade in plants and animals, has provided special protection to endangered species in

[3] In the original: "dos recursos ambientais, com particular atenção aos grandes biomas naturais".

[4] In the original: "das áreas legalmente protegidas e ao incentivo aos reflorestamentos e à recomposição da cobertura vegetal em áreas degradadas".

[5] In the original: "medidas de adaptação para reduzir os efeitos adversos da mudança do clima e a vulnerabilidade do sistema ambiental […]".

[6] In the original: "Planos de Ação para a Prevenção e Controle do Desmatamento nos biomas".

order to prevent unsustainable levels of trade. It was later implemented by Decree No. 3,607/2000, which designated the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) as the administrative authority for its enforcement (Brasil, 2000a).

3. Law No. 6,938/1981 established the National Environmental Policy, setting forth its goals and mechanisms for formulation and implementation (Brasil, 1981).
4. Law No. 7,643/1987 instituted a ban on cetacean fishing in the country (Brasil, 1987).
5. The 1988 Federal Constitution, in Article 225, VII, elevated environmental protection to constitutional status, highlighting the duty to preserve biodiversity and protect fauna and flora (Brasil, 1988).
6. In 1994, Brazil ratified the Convention on Biological Diversity (CBD) via Legislative Decree No. 2/1994. Article 8 of the CBD requires countries to restore degraded ecosystems and promote the recovery of threatened species by developing and implementing appropriate plans and management strategies (Brasil, 1994).
7. Law No. 9,605/1998 defined environmental crimes related to fauna, such as illegal hunting, mistreatment, and unauthorized fishing, with specific exceptions. It includes harsher penalties for illegal acts involving endangered species (Brasil, 1998). This aggravating provision is a penal norm requiring complementary regulation, which was later provided by Ordinance No. 148/2022, listing endangered species in Brazil for legal purposes (Brasil, 2022).
8. At the turn of the century, Law No. 9,985/2000 created the Brazilian National System of Conservation Units (SNUC), aimed primarily at conserving a wide range of biological species and genetic resources, preserving and restoring the diversity of natural ecosystems, and promoting sustainable development based on natural resources (Brasil, 2000b).
9. Decree No. 4,339/2002 introduced the Brazilian National Biodiversity Policy (PNB) into the legal framework, being the most comprehensive legislation in terms of principles and guidelines on biodiversity and serving as a major focus of academic research (Brasil, 2002).
10. In 2006, the Atlantic Forest Law (Law No. 11,428/2006) was enacted, establishing guidelines for the protection and use of this biome's resources. It aims to secure citizens' and public institutions' rights and responsibilities concerning the sustainable use of the Atlantic Forest. Its purpose includes the preservation of biodiversity, human health, scenic value, water regulation, and social

stability within one of Brazil's most degraded biomes (Brasil, 2006).

11. Law No. 11,959/2009 approved the Fisheries Code, establishing the National Policy for the Sustainable Development of Aquaculture and Fisheries. It covers hunting seasons, restrictions, bans, and commercial regulations, also protecting Brazil's aquatic fauna (Brasil, 2009a).
12. More recently, in 2012, after broad public debate, the new Forest Code was enacted by Law No. 12,651, repealing the 1965 code. It redefined permanent preservation areas as forests and other forms of natural vegetation meant to shelter endangered flora and fauna (Brasil, 2012).
13. In 2015, the Biodiversity Law (Law No. 13,123) was enacted to regulate access to genetic heritage, the protection and use of associated traditional knowledge, and the fair and equitable sharing of benefits for the conservation and sustainable use of biodiversity. It governs all aspects of scientific activities, research, and the development of genetic resources from species within Brazil's biodiversity (Brasil, 2015a).
14. In addition to the aforementioned legislation, in 2017, the Brazilian National Biodiversity Strategy and Action Plan (EPANB) was presented, providing a comprehensive framework to coordinate national initiatives for biodiversity conservation. It promotes the sustainable use of biodiversity components and ensures the fair and equitable sharing of benefits. It also plays a monitoring role in tracking Brazil's progress under its Biodiversity Action Plan (Brasil, 2017).

To provide a critical analysis, the federal legal framework reveals a paradox: a wealth of legislation coexists with weak institutional integration. Although Brazil has over 15 federal legal instruments directly related to biodiversity protection, coordination between climate policy and endangered species conservation remains fragmented and insufficient.

The National Policy on Climate Change (PNMC) refers to biodiversity only in general terms and does not provide specific mechanisms for protecting endangered species. This gap is particularly problematic given that climate projections indicate species- and region-specific impacts.

Moreover, the SNUC (Law No. 9,985/2000) and the Fauna Protection Law (Law No. 5,197/1967) do not incorporate climate vulnerability criteria when setting conservation priorities.

While Law No. 12,114/2009 established the Brazilian National Climate Change Fund (Brasil, 2009b), its budget allocation remains insufficient to address the scale of identified challenges. Additionally, the division of responsibilities

among ICMBio, IBAMA, and state agencies creates overlaps and gaps that hinder policy effectiveness.

This raises a key issue: although Brazil possesses a broad legal framework for protecting biodiversity and endangered species in the face of climate change, the mere existence of these provisions does not guarantee their effective implementation or the achievement of their stated goals. This gap opens up a critical area for scientific inquiry in the country, especially in light of the following question: Given the extensive legislation and federal support available for biodiversity protection in Brazil, what evidence exists to demonstrate the effectiveness—or lack thereof—of these legal instruments?

In this context, advancing the legal framework is essential and must establish binding mechanisms for incorporating climate scenarios into conservation policy. Moreover, it is crucial to develop legal criteria enabling the periodic reclassification of species based on changing climate vulnerability, as well as to create dedicated funding sources specifically aimed at protecting species threatened by climate change.

Conclusion

To present a conclusive characterization of the study, the initial questions proposed by the research are revisited.

The analysis partially confirms the central hypothesis of this study, revealing that Brazil has an extensive legal framework for biodiversity protection but with critical gaps in the integration between climate policies and the conservation of endangered species.

Regarding climate scenarios, there is clear evidence of rising average temperatures—up to 2°C in an optimistic scenario and up to 7°C in a pessimistic one—alongside increases in hot nights, extreme weather events, and significant changes in precipitation patterns.

The review of the scientific literature unequivocally shows that climate change poses a serious threat to global biodiversity. The examined studies highlight the various impacts of climate change on species, ranging from changes in terrestrial, marine, and freshwater ecosystems to alarming projections of extinction for endemic species worldwide.

Even moderate global warming scenarios may significantly compromise the survival of many species, with projections pointing to a potentially alarming loss of biodiversity.

In the Brazilian context, studies indicate that the country is particularly vulnerable to the impacts of climate change, with important biodiversity hotspots under threat.

The analysis of the presented data highlights the severe situation faced by biodiversity in Brazil in the face of climate change. Habitat loss due to agricultural expansion, urbanization, and other land use changes places thousands of species across all Brazilian biomes at risk. This threat is especially concerning given the unique richness of Brazilian biodiversity, which harbors a significant portion of the planet's species.

The alarming number of species at risk of extinction, according to both ICMBio and IUCN data, underscores the urgency of effective actions to protect Brazil's fauna and flora. The downward trend in the Red List Index (RLI) for Brazil further emphasizes the gravity of the situation and the need for stronger and more comprehensive conservation measures.

The reviewed studies also point to the urgent need for effective policies to mitigate the impacts of climate change on biodiversity. The lack of adequate legislation and climate-specific policies for the protection of threatened species constitutes a worrisome gap that must be urgently addressed.

Given this concerning scenario, a crucial question arises regarding the adequacy of the normative frameworks within national climate policy and federal legislation to address the challenges posed by climate change to Brazil's biodiversity.

Although the Brazilian National Policy on Climate Change (PNMC) contains only indirect references to biodiversity, a comprehensive analysis of Brazilian legislation reveals a large body of legal provisions aimed at protecting biodiversity and threatened species. From the earliest laws protecting fauna and flora to the most recent strategies and action plans, Brazil has demonstrated a continued commitment to conserving its rich environmental heritage.

The PNMC, while not explicitly addressing the term "biodiversity", includes objectives, guidelines, and instruments that indirectly support the protection and conservation of natural resources, including major biomes and national flora.

The results show that despite the number of legal instruments addressing biodiversity, there is a structural legal insufficiency that undermines Brazil's capacity to respond to projected climate scenarios for the 21st century.

This insufficiency stems from the inadequate protection afforded to threatened species in light of these scenarios and manifests in three main dimensions: (a) lack of coordination between climate and biodiversity policies; (b) absence of adaptive mechanisms in legislation; and (c) inadequacy of available financial and institutional resources.

The findings demonstrate that the mere existence of abundant legislation does not ensure effective protection when there is misalignment between emerging risks and legal instruments. Future studies are needed to assess the practical effectiveness of existing policies, the adequacy of legislation at regional, state, and municipal levels, and potential comparisons with international legal frameworks.

Thus, while Brazil has a solid legal foundation for biodiversity protection, ongoing efforts are required to ensure that these laws are properly implemented, enforced, and updated to meet emerging challenges—particularly those related to climate change. Analyzing data and evidence on the effectiveness of these laws is essential to guide more efficient and sustainable conservation policies and practices.

It is, therefore, necessary to advance efforts to assess the effectiveness of these laws. However, such effectiveness cannot be measured solely by the number or scope of laws, but also by their actual implementation and real-world impact on biodiversity conservation. Future scientific research is essential to evaluate the degree of effectiveness and compliance with these laws and to identify gaps and challenges in their application.

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