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The Impacts of Climate Change on Biodiversity Shifts in Texas Over the Past 75 Years

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ABSTRACT

Currently, there is a major lack of research into the regional relationships between biodiversity trends and climate change, resulting in biodiversity protection policies that are based on global understandings rather than local conditions. To investigate a specific regional relationship, this research follows the question: How are statewide mean temperature anomalies associated with species richness in Texas across the study period? This research was completed utilizing a correlational time-series analysis to analyze the correlation between species richness (measure of biodiversity) and temperature anomaly (measure of climate change).

The data were collected from two separate online databases, the Global Biodiversity Information Facility and the NOAA National Centers for Environmental Information Climate at a Glance Statewide Time Series, and then were separated into five year bins. Each bin contained a single temperature anomaly average and an effort standardized species richness value, which were then able to be compared utilizing linear regression and a Pearson correlation. This resulted in a correlation coefficient of $r = -0.31$ and a R^2 value of about 0.095 (the proportion of variation explained by the fitted linear model), indicating that temperature anomaly only accounts for a small portion of the variability of biodiversity. These results suggest a more complicated relationship between biodiversity variance and climate change in the Texas region than suggested by global studies, and show that biodiversity changes in Texas are likely influenced by numerous other factors.

LITERATURE REVIEW

Introduction

The impact of climate change on the ecosystems of our planet is becoming more manifest with each passing decade. Climate change, the long-term shift in Earth's average weather patterns, has been characterized by a rapid global warming since the mid-20th century. It has significantly contributed to reductions in global biodiversity (the variety of life on Earth) by altering habitats through extreme weather events, sea-level rise, warming ocean temperatures, ocean acidification, and species range shifts.

Although these effects have been documented across the world, their relationship with biodiversity may differ substantially at regional scales. Texas provides a particularly relevant setting for examining this

variation because its ecosystems range from the deserts of the Trans-Pecos to the forests of East Texas and the coastal wetlands of the Gulf of Mexico. These environments experience different climatic conditions and environmental pressures, suggesting that statewide biodiversity trends may not follow the same patterns observed in global studies.

While the Holocene was characterized by relatively stable climatic conditions, human activity, chiefly industrialization and the release of greenhouse gases, coupled with habitat degradation, has led to a dramatic loss of species (Svenning et al., 2024). Examining how biodiversity has changed alongside rising temperatures in Texas may therefore provide insight into how these broader environmental trends are reflected at a regional scale.

A less obvious impact of the loss of biodiversity is the degradation of ecosystems that can act as protective factors against further increases in climate change. Stated differently, reductions in biodiversity, such as the loss of forest cover, can independently accelerate the rate of climate change (Williams & Newbold, 2020). This has led many experts to conclude that climate change and biodiversity loss create positive feedback loops that amplify each of their effects. As climate change's impacts increase, biodiversity is reduced, which in turn contributes to increases in climate change that continue to fuel this unending cycle (Reid & Huq, 2005). Thus, as climate change accelerates, the loss of biodiversity is likely to accelerate to catastrophic levels in the near future (Trisos et al., 2020).

However, the relationship between climate change and biodiversity loss may vary depending on local geography, land use, and other environmental pressures. In Texas, differences in precipitation, land use, and ecosystem composition create conditions under which species may respond differently to increasing temperatures. For example, the state's coastal wetlands are affected by sea-level rise and changes in sediment supply, while its inland ecosystems experience different combinations of climatic and human pressures. Additionally, Texas' position along major migratory bird routes introduces seasonal variation in the species recorded within the state. Together, these factors suggest that statewide temperature trends may not correspond directly to changes in recorded species richness, highlighting the need for long-term regional analyses that account for the limitations of biodiversity data.

Biodiversity Loss, Its Impacts, and Protections Against It

For several millennia, human activity has been directly related to habitat and biodiversity loss, with this relationship intensifying alongside industrialization, fossil fuel use, and the conversion of natural land for agriculture and human habitation. Beyond the climate–biodiversity feedback loop discussed in the introduction, land-use change can affect species by altering the habitats on which they depend. Williams and Newbold (2020) describe how intensive human land use alters landscape composition and can interact with local climatic conditions. For example, the removal of native vegetation decreases evapotranspiration and surface "roughness" (defined as the vertical and horizontal unevenness of surfaces that directly impacts species distribution), wind and water movement, and ecosystem stability. These changes can

increase surface sensible heat flux (heat transfer from the surface into the atmosphere), reduce the amount of water entering the atmosphere, and contribute to altered precipitation patterns and increased surface temperatures (Williams & Newbold, 2020).

Biodiversity loss also has consequences for the human communities that depend on functioning ecosystems. Humanity depends critically on the resources provided by nature, and the loss of biodiversity can reduce the ecosystem services that support human well-being. Reductions in species richness may affect the health of communities, their food security, and economic output. People already living in poverty are often the most affected by climate change, and because biodiversity can help ecosystems and communities withstand environmental pressures, reductions in biodiversity often hit these communities the hardest (Roe et al., 2019). Whereas Williams and Newbold (2020) examine interactions among land use, local climate, and biodiversity, Roe et al. (2019) emphasize the consequences of biodiversity loss for human well-being. These studies illustrate why biodiversity change cannot be understood solely through temperature trends.

Taken together, these studies suggest that biodiversity loss, while heavily influenced directly by climate change, is amplified by human land use, economic development, and management practices. Although they examine different outcomes, they do not establish how strongly those influences are associated with recorded species richness in Texas. Research on Houston's Sims and Vince Bayou watersheds provides a more geographically specific example of land-use change. Davis and Bhaskar (2022) examined land-cover changes over approximately three decades using satellite imagery, alongside measurements of water and soil contamination. They documented increasing impervious surfaces and decreasing vegetative cover in both watersheds. Unlike Williams and Newbold's (2020) review of interactions between land use, climate, and biodiversity, Davis and Bhaskar examined environmental changes in two particular Texas watersheds. Their findings demonstrate that land cover can change substantially within the study region, but they do not establish how those changes affected statewide species richness. This distinction is relevant to the present study because temperature anomalies are examined without directly measuring land-use change.

While there is a general consensus around limiting global temperature rise (though notable discord exists in enabling measures to prevent this), international goal setting to protect biodiversity via international laws and policies, is more contentious. A paper by Collen et al., argues that international goal setting has become a major part of attempting to conserve biodiversity around the world, yet progress against reductions in biodiversity is limited, and there is still significant biodiversity decline around the world. Goals to help protect biodiversity set by the international community are making very small impacts, as they're often in direct opposition to other stated purposes , such as the expansion of agriculture to fight hunger (which is usually prioritized) (Collen et al., 2015). Similarly, an analysis by Tarlock (1993) examines how local governments protected the environment in the recent past, with their policies in the 1980s and 1990s. It describes the nature of environmental policies during this period, including parts of Texas (Tarlock, 1993). These sources approach conservation from different perspectives: Collen et al.

(2015) discuss biodiversity within broader development priorities, while Tarlock (1993) examines the role of local government in biodiversity protection. Neither source, however, measures the effects of Texas conservation policies on statewide species richness. Consequently, policy changes cannot be identified as a cause of the biodiversity patterns examined in this study.

Overall, the literature identifies climatic conditions, land use, and conservation decisions as potentially interacting influences on biodiversity. However, the studies reviewed in this section differ in their methods and outcomes: some examine ecological processes, while others focus on human development or conservation policy. Although these perspectives provide context for interpreting biodiversity change, they do not quantify the association between statewide temperature anomalies and effort-standardized species richness in Texas over the study period. The present study examines that narrower statistical relationship without assuming that temperature is the sole driver of recorded biodiversity patterns.

Climate Change's Impacts

Changes in Earth's long-term weather patterns have many harmful effects on natural phenomena and processes needed for ecosystems to thrive. Shivanna (2022) performed an analysis of the drivers of climate change as well as its subsequent impacts - altered weather patterns, increased frequency of catastrophic natural disasters, and sea level rise. Furthermore, just as biodiversity reduction has led to extreme effects on human society and development, the study also assesses how climate change has significantly impacted humanity. It illustrates how decreases in crop productivity and natural disasters have wrought incredible destruction onto society, detailing how climate change is negatively impacting both humanity and the environment in tandem (Shivanna, 2022). Although this review establishes the broad relevance of climate change, it does not measure biodiversity responses within Texas. The regional studies below examine environmental changes at geographic scales more directly relevant to this paper.

Many studies have examined how climate change has impacted coastal/wetland environments like that of the Texas Gulf Coast region. An analysis by Scavia et al. explains how drivers of climate change impact coastal systems in varying ways (specifying ecosystems like estuaries and wetlands), not always following the patterns set by global studies. It also details how the rapid growth of human populations has increased demand for coastal and marine resources, increasing both the stress on those resources and their vulnerability to climate change and variability. Shorelines are experiencing major changes in sediment deposition and erosion, coastal wetlands (critical refuges for wildlife) are being threatened by rising sea levels, and estuaries are facing exacerbated stresses imposed by a constantly changing nitrogen cycle (Scavia et al., 2002).

Armitage et al. (2015) provides a Texas-specific test of how multiple environmental pressures can affect coastal habitats. Using Landsat satellite imagery, they measured changes in mangrove and salt marsh area along the Texas Gulf Coast between 1990 and 2010. Mangrove area increased by approximately 74%, while salt marsh area declined by approximately 24%. However, mangrove expansion accounted for only

about 6% of the observed salt marsh loss; the authors identified conversion to tidal flats or water, likely associated with relative sea-level rise, as a more substantial contributor. Whereas Scavia et al. (2002) review pressures on coastal ecosystems broadly, Armitage et al. quantify changes in specific Texas habitats. Their findings demonstrate why an observed regional ecological change should not automatically be attributed to a single climatic factor. Because they measured habitat area rather than statewide species richness, their results provide environmental context for the present study rather than a directly comparable biodiversity trend.

Furthermore, Duenas et al. evaluated the adverse effects of increasingly severe climate events (specifically ENSO and La Nina events) on the biodiversity and health of populations on the Galapagos islands. They highlight different animal responses to climate events, and break down which animals are most affected by ENSO and La Nina events. It examines the differences in effects faced by each category of animal and finds that overall, almost every category has been significantly impacted by increases in severity of ENSO and La Nina effects, decreasing the overall biodiversity of the islands (Duenas et al., 2021). Dueñas et al. (2021) offer a contrasting example of how climate variability can affect wildlife within a defined region. However, the Galápagos Islands differ substantially from Texas in geography and ecological composition, and the study examines particular climate events rather than a statewide, multidecade association between annual temperature anomalies and recorded species richness. It therefore demonstrates the value of examining ecological responses at a regional scale, not that Texas should exhibit the same response.

Texas's position along Gulf Coast migration routes introduces another consideration when interpreting species-occurrence records. Cohen et al. (2021) used eight years of weather-radar observations from 12 sites along the Gulf and Atlantic coasts of the southeastern United States to examine where migrating birds stop during spring and autumn. They found seasonal differences in stopover habitat use: birds concentrated closer to the coast in spring and farther inland in forested landscapes during autumn. Unlike Armitage et al. (2015), who measured coastal habitat area, Cohen et al. measured migratory bird movement and stopover behavior. Their findings do not quantify changes in Texas's statewide species richness, but they illustrate why the timing and location of observations can affect which species appear in occurrence datasets. Because the present study combines records across species groups and five-year intervals, it cannot distinguish changes in resident biodiversity from changes in migration-related observations.

These studies show that the ecological outcomes examined in regional research differ considerably: Armitage et al. (2015) measure habitat conversion along the Texas coast, Cohen et al. (2021) examine seasonal migratory behavior across the southeastern United States, and Dueñas et al. (2021) review wildlife responses to climate variability in the Galápagos. Their findings identify processes that may affect ecological communities or the species recorded in a region, but none directly measures the association between Texas-wide temperature anomalies and effort-standardized species richness over the period

examined here. This distinction motivates the present analysis while also establishing an important limitation: a statewide correlation cannot isolate the individual processes identified by these studies.

Conclusions

The literature from the field of climate study and environmental science presented above contributes to the concept of a general correlation between climate change and biodiversity losses. It emphasizes a cyclical and complex relationship between these factors, and establishes that climate change, land use, and other environmental pressures can influence ecosystems. However, this literature is limited as the studies differ in geographic scale, methods, and outcomes. Given that biodiversity loss can also be influenced by numerous factors other than climate change, such as land use, conservation policy, and sampling differences, it is possible that regional patterns do not follow the same trends present at the global scale. Trisos et al. finds that climate change is the major driver of biodiversity loss globally, but Scavia et al. shows that regionally complex ecosystems respond differently, and it is unknown which pattern holds for Texas over a multi-decade time series. These studies provide important context for Texas biodiversity, but their findings cannot be directly equated with changes in statewide species richness derived from occurrence records. Therefore, there is a gap in the literature regarding how biodiversity loss and climate change interact over multiple decades within a single geographic region. It is essential to examine how these factors are related at specific regional levels to understand how local environmental pressures influence biodiversity trends, which would enable the design and implementation of region-specific conservation strategies.

The question that this research seeks to answer is: How are statewide mean temperature anomalies associated with species richness in Texas across the study period? Temperature anomaly serves as the operational measure of climatic warming, while species richness is the number of distinct species names represented in the standardized GBIF records for each time interval. The hypothesis is that higher temperature anomalies will be associated with lower recorded species richness.Given that prior studies have often relied on global datasets or short term observations, a long-term regional time series analysis utilizing standardized biodiversity measures will provide an approach to understanding how relationships vary over time within a specific environment. Because land-use change, precipitation, migration, and differences in data collection are not independently measured in the analysis, the study tests an association rather than determining whether warming caused biodiversity loss.

METHODS

To explore the extent to which reductions in species richness are related to increases in climate change in the Texas region, this study analyzes the relationship between biodiversity data and average temperature anomalies through online databases. The data being analyzed were accessed from two primary online databases, the Global Biodiversity Information Facility and the NOAA National Centers for Environmental Information Climate at a Glance Statewide Time Series. Texas was the geographic unit of

analysis, and the study compared recorded species richness with statewide temperature anomaly across corresponding time intervals.

Biodiversity Data

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF), an international open access archive of biodiversity records. The analysis used the Texas occurrence download identified in the bibliography (GBIF.org, 2026; https://doi.org/10.15468/dl.rv7gbv). Records were pooled across the taxonomic groups represented in the downloaded dataset rather than analyzed as separate species groups. Due to GBIF data (and biodiversity data in general) being unevenly distributed over time (varied inter-sample intervals) across the past 75 years , it was necessary to analyze biodiversity and climate data in five-year intervals. Placing data into five year bins enables comparison across decades by reducing the effects of short-term fluctuations and inconsistent sampling intensity. This study is geographically confined to the Texas region selected in the GBIF database, both to enable a better understanding of overall biodiversity trends and to provide a consistent regional perspective of the relationship between species presence and climate change. Fossil records, entries lacking spatial or temporal information, and duplicate observations were all removed prior to analysis.

Additionally, because GBIF yields presence data (rather than monitoring counts), biodiversity is measured utilizing species richness (the number of unique species observed during the period), a metric widely utilized in ecological research. In this study, richness was operationalized as the number of distinct scientific names in the standardized occurrence records for each interval. However, species richness derived from occurrence records is highly sensitive to sampling effort, meaning that periods with more observations would appear to have higher biodiversity even if true biodiversity did not change. The recent digitization of data, alterations in sampling, new interests in biodiversity, and proliferation of citizen science in recent decades all contribute to this bias. Therefore, to accurately compare species richness throughout the period, species richness comparisons across time also required standardization for effort (Chao & Jost, 2012).

Climate Data

Climate data were gathered from the NOAA National Centers for Environmental Information Climate at a Glance Statewide Time Series database. This database provides standardized, historical climate records from long-term observations and homogenization via established climatological procedures. Statewide annual mean temperature anomaly values for Texas were utilized as the primary climate variable. Temperature anomaly was operationalized as the difference between Texas's annual mean temperature and the reference-period average specified in the NOAA dataset (NOAA, 2026). Temperature anomalies help to represent deviations from a historical average, and are often used in climate research because they isolate long-term trends and reduce influence of geographic variation among monitoring stations (Hansen et al., 2010). Temperature anomaly was chosen as the primary indicator of climate change because increasing average temperature is one of the most consistent and well-documented drivers of ecological

change, and has been directly linked to shifts in species distribution and abundance, migration patterns, and extinction risks in numerous ecological studies (Parmesan & Yohe, 2003). Annual temperature anomaly values were binned across five-year intervals to correspond with the biodiversity data by calculating the mean of the anomaly values across the five years, ensuring that both datasets represented the same time scale. The 2025 endpoint contains one year rather than a complete five-year interval.

Procedure

Biodiversity and climate data were compared through the utilization of a correlational time-series analysis to test for statistical association. A correlational time series analysis is a statistical technique used to evaluate the relationship between time-ordered data points, by quantifying how two time series (sequences of data points recorded at specific, usually regular time intervals) move together across a period. Microsoft Excel and the Power Query application within it were utilized to organize data and perform the necessary statistical procedures. Biodiversity and temperature data were downloaded from their respective sources and directly input into Excel and Power Query respectively. It was necessary to put species data into Power Query prior to loading it into Excel to sort and clean it, especially because the initial download included over 6 million separate species occurrences. Species data were cleaned through a series of procedures that removed fossil data, duplicates, and any occurrences lacking coordinates, identification, or date.

Next, the species data were put through a rarefaction (random sampling) procedure. Rarefaction is a widely accepted method utilized to compare species richness across samples that may have unequal sampling bias as a result of increased record density (Gotelli & Colwell, 2001). For each five-year interval, the total number of occurrence records were counted, the smallest number of occurrences among all intervals (N) was identified. Each interval was then standardized by limiting the number of records considered in the study to this minimum value (in this study the N value was 31,130 species occurrences) ensuring that species richness comparisons were based on equal sampling effort across all time periods. Within each interval, occurrence records were randomly ordered, the first N records were retained, and the number of distinct scientific names in that sample was counted. This approach helps to reduce bias from increased data collection in recent decades and allows biodiversity estimates from across the entire 75-year period to be compared using equal numbers of occurrence records. Once the data were sorted into bins, they were imported back into Excel.

Annual temperature anomaly values were downloaded directly from the NOAA Statewide Time Series and uploaded to Excel. They were then aggregated into five-year intervals to correspond with the biodiversity data by calculating the mean value of anomaly values across the five years, ensuring that both datasets represented the same time scale. The 2025 value was retained as a single-year endpoint.

Effort-standardized species richness and mean temperature anomalies were treated as parallel time series across five-year intervals from 1950 to 2025. Each five-year interval resulted in a single biodiversity

estimate (species richness) and a single climate estimate (average temperature anomaly). The resulting table contained 16 paired observations, including the single-year 2025 endpoint. First, temporal trends in each variable were evaluated independently. A linear regression was utilized to determine whether the separate factors demonstrated directional patterns or trends over time. Then, to examine the association between climate change and biodiversity, a Pearson correlation was performed between species richness and temperature anomaly across their corresponding time intervals. The Pearson correlation coefficient (r) was utilized to quantify the direction and strength of the relationship between the variables. A negative correlation would indicate that as temperature increased, recorded species richness tended to decrease, while a positive correlation would indicate that as temperature increased, so did recorded species richness. This analytical framework enables the evaluation of whether long-term climatic warming trends in Texas are statistically associated with reductions in overall species richness, whilst accounting for differences in sampling efforts. It does not, however, control for other environmental variables or establish causation.

RESULTS

To understand the relationship between biodiversity and climate change in Texas, effort-standardized species richness and average temperature anomaly were calculated for each 5-year interval from 1950 until 2025. Temperature anomaly values displayed an upward and overall trend throughout the 75-year period, increasing from an average of about 0.68°C in the 1950 interval to an average of nearly 3.8°C by the end of the period. This pattern reflects the long-term warming trend that is consistent with the findings of broader climate studies.

Bin	TempAnomaly	Species Count
1950	0.68	4051
1955	0.48	5382
1960	-0.34	6032
1965	-0.26	5087
1970	-0.4	5315
1975	-0.7	5192
1980	-0.34	3198
1985	0.12	1328
1990	-0.04	2781
1995	0.9	1206

Bin	TempAnomaly	Species Count
2000	1.22	3004
2005	1.14	3903
2010	1.58	3390
2015	1.66	3722
2020	2.06	3730
2025	3.8	3349

Table 1. Summary of species richness and temperature anomaly by five-year interval.

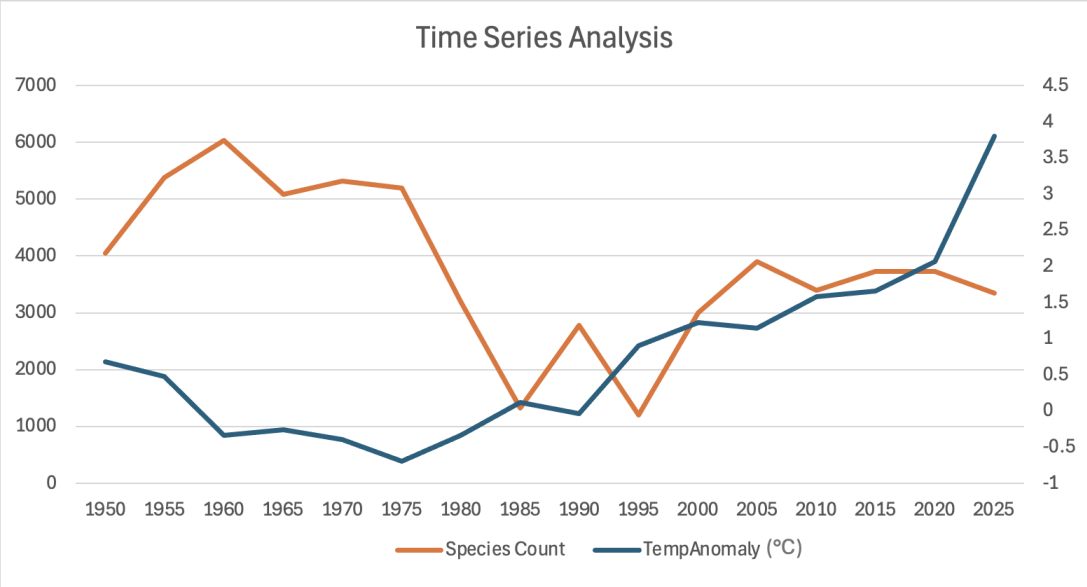

Figure 1. Time series of temperature anomaly and species richness in Texas (1950–2025).

As shown in Figure 1, the species richness didn't exactly follow a consistent pattern. Rather than a steady decline, species richness fluctuated substantially throughout the study period. After a significant decline from 1980-1995 (in which temperature anomalies remained relatively constant), it appeared to recover despite the continuing rise in average temperature anomalies. This divergence indicates that recorded species richness did not follow a consistent pattern alongside temperature anomaly, although the analysis cannot establish what caused the fluctuations. A Pearson correlation analysis was conducted to evaluate the relationship between species richness and temperature anomaly across all of the time intervals. The correlation coefficient produced was r = -0.31, indicating a weak negative relationship between the two factors. This suggests that higher temperature anomalies tend to be associated with lower species richness, however the relationship isn't strong or consistent across every time interval.

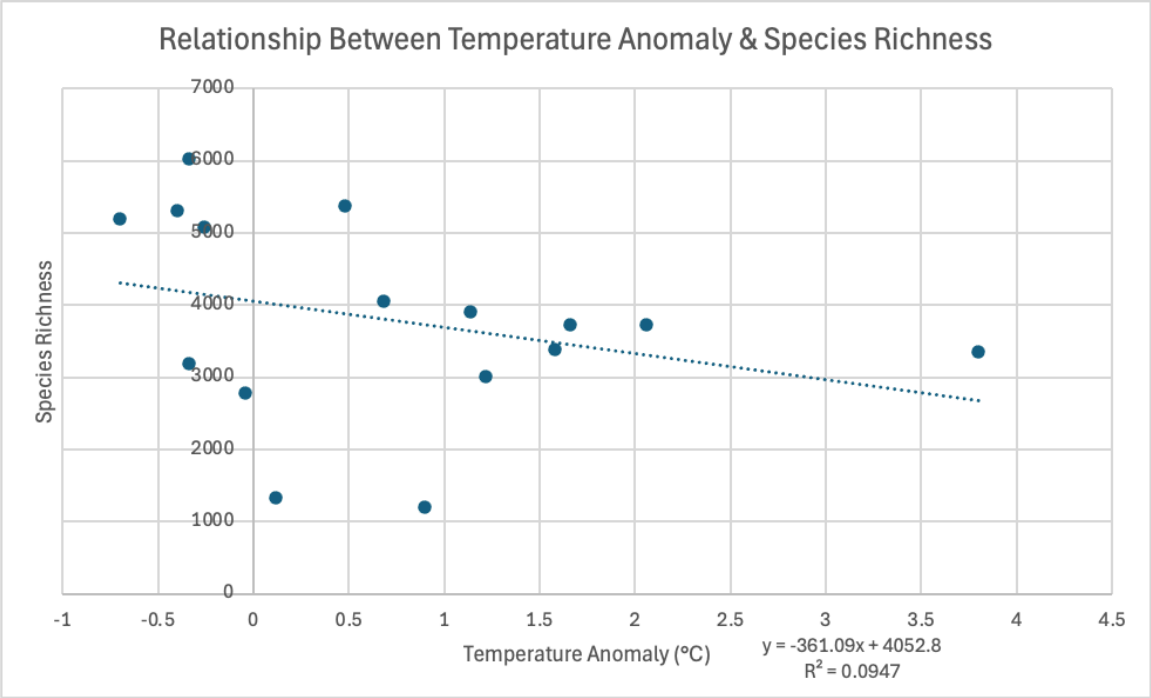

Figure 2. Relationship between temperature anomaly and species richness across five-year intervals.

Further analysis utilizing a linear regression supported this finding. The regression model produced an R^2 value of about 0.095, indicating that temperature anomaly explains approximately 9.5% of the variation in recorded species richness within the fitted linear model. The regression slope was negative, about -361, suggesting an overall decline in species richness with increases in temperature anomaly. However, the relatively low R^2 value and scatter in the data (Figure 2) indicate that other variables likely play a

significant role in influencing biodiversity. Overall, these results indicate that although climate change is associated with biodiversity change in Texas, the relationship is somewhat weak and variable, suggesting the influence of additional factors. Because this is an observational correlation though, the results do not establish that rising temperatures caused the observed richness changes.

DISCUSSION

The results of this study generally support the hypothesis that increases in climate change are associated with reductions in biodiversity. More precisely, they support the predicted direction of the association between temperature anomaly and recorded species richness. However, they also suggest that this relationship is more complex at the regional level than shown by global studies. Temperature anomalies increased over time, indexing a pattern of long-term warming in Texas, in alignment with long-term warming trends around the world (Chapman & Ahmed, 2021). This also confirms that the climate data used within this study reflect the pattern of increasing global temperatures. On the other hand, species richness varied throughout the study period rather than steadily declining. Studies such as Roe et al. describe how biodiversity loss is increased by human land usage and economic developments. Therefore, fluctuations observed in species richness within this study indicate that biodiversity in Texas may be influenced by additional human factors beyond climate change. However, differences in data collection may also contribute to these fluctuations. For example, in the period 1980-1995, species richness plummeted, while temperature anomalies remained relatively constant, and then recovered as anomalies rose. Urban expansion is one possible factor to investigate, but this study did not measure land-use change and cannot determine whether it explains the observed decline.

However, previous global research has consistently displayed a strong relationship between climate change and biodiversity loss, as rising temperatures have been shown to increase habitat disruption, species migration, and ecosystem instability (Williams & Newbold, 2020). The weak negative correlation observed in this study aligns with this perspective, but varies from other established ecological studies, in the strength of correlation they suggest. While studies such as Trisos et al. predict significant global biodiversity decline with increases in climate change, this study implies that the relationship between the factors may vary by region. However, Trisos et al. (2020) model projected ecological disruption, whereas this study analyzes historical occurrence-based richness. Their findings are therefore not directly comparable measures of the strength of a temperature–richness relationship. This may show that global trends in biodiversity don't directly translate to regional ecosystems, where localized factors have a larger role on species richness.

One major factor that may explain this discrepancy is the influence of human activity on biodiversity. As shown by Roe et al. (2019) and Williams et al. (2020), biodiversity loss is heavily driven by land use changes, urbanization, and resource exploitation. The Texas region has experienced significant urban

expansion and development over the study period, likely contributing to biodiversity changes independent of climate change. For example, Davis and Bhaskar (2022) documented increasing impervious surfaces and decreasing vegetative cover in Houston's Sims and Vince Bayou watersheds. Their study provides Texas-specific evidence of land-cover change, although it does not establish that urbanization caused the statewide richness fluctuations observed here.

Additionally, regional environments like coastal and wetland environments, which are common in Texas, have been found to respond to climate change in complex ways (potentially even increasing biodiversity to an extent). Studies such as Scavia et al. (2002) and Duenas et al. (2021) show how environmental variability, extreme weather events, and ecosystem-specific dynamics can have large impacts on biodiversity in these types of ecosystems. Similarly, Armitage et al. (2015) documented increasing mangrove area and declining salt marsh area along the Texas Gulf Coast, demonstrating that different habitat types can change in different ways within the same region. Because that study measured habitat area rather than species richness, it provides context rather than a direct explanation of this study's results. Overall, the findings of this study are an extension of existing research, demonstrating that climate change is associated with recorded richness changes, but that within Texas regional scope, biodiversity is also significantly impacted by other environmental and human factors.

Limitations

This study is subject to a few limitations that should be considered in the interpretation of results. First, variability in species richness may be a result of data limitations as well as outside factors. Despite rarefaction being utilized, GBIF data is dependent on data collection practices. Technological advancements, increased accessibility of databases, and the rise of citizen science have all led to increased species reporting over the past few decades. Therefore, some of the variations in species richness may be a result of different detection, rather than actual biodiversity recovery. For example, the 1985–1995 decline might be partially a data artifact, and is not fully addressed by rarefaction. Standardizing the number of records per interval does not ensure that observations cover the same locations or taxonomic groups across time.

Additionally, the study relies on species richness as the main measure of biodiversity. Although species richness is widely used to provide insight into biodiversity, it doesn't fully account for species abundance and ecosystem health. Therefore, observing changes in species richness may not fully account for larger ecological shifts in the region. Furthermore, Texas is part of a major migratory corridor, and as a result, biodiversity measures may have been skewed by the presence of migrating animals during certain periods. Finally, the study focuses primarily on correlation rather than causation. The weak correlation found between species richness and temperature anomalies suggests that additional factors play a large role in shaping regional biodiversity trends. Because precipitation, land-use change, and sampling coverage were not independently analyzed, the study cannot determine which factors explain the remaining variation. The single-year 2025 endpoint also differs in duration from the preceding five-year intervals.

Implications

The findings of this study have had several implications for further ecological research and environmental policy in Texas. While global studies explain a strong and direct linkage between biodiversity changes and climate change, this study displays that the relationship can vary at a regional level, being weaker and more complex. The measured association is weaker in this particular dataset, although it cannot be directly compared with studies using different biodiversity measures or methods. This suggests that conservation strategies only based on global trends may not be effective or helpful at the regional level. In the Texas region, where it appears that biodiversity is impacted by numerous factors, conservation efforts should include region-specific approaches. The increase in recorded richness after the 1985–1995 decline warrants further investigation, but it cannot be attributed to conservation or ecological recovery using these data alone. This aligns with previous research into the necessity of regional approaches to conservation strategies.

Furthermore, this study shows the importance of data quality and methodology when it comes to environmental research. Although rarefaction allowed for better comparability over the study period, utilization of occurrence based data resulted in some limitations. Finally, these findings contribute to the overall field of climate science, by corroborating the idea that climate change has varying effects across regions. This variability emphasizes the need for more regional/local studies to best inform scientific understandings and policy decisions. In the Texas context, future studies could examine habitat connectivity and land-use change alongside temperature to assess their respective associations with biodiversity. Regional conservation planners in the Southern United States should not rely on global biodiversity projections as the basis for local policy, as the drivers of regional biodiversity loss may be separated from global temperature trends in ways that require independent regional monitoring.

Conclusions

Although the results of this study only demonstrated a weak negative correlation between climate change and biodiversity changes, these findings are still essential. Specifically, the correlation was between statewide temperature anomaly and standardized recorded species richness ($r = -0.31$; $R^2 \approx 0.095$). By showing variation at a regional scale compared to the global understanding, this study displays a need for further research into local factors impacting ecosystem biodiversity. The present analysis cannot determine whether climate change is the primary cause of biodiversity loss in Texas, making it necessary to investigate other potential drivers alongside temperature. In Texas, biodiversity appears to be impacted by a combination of climate change, human activity, and environmental variability. This highlights the dangers of applying global patterns to local contexts.

By addressing the gap in literature about regional analysis of climate change and biodiversity's relationship, this study gives valuable insight to the field of environmental studies. The rarefaction approach applied to a 75-year GBIF dataset provides a transferable template for other regional studies attempting to use opportunistic occurrence data for long-term trend analysis. However, its reproducibility depends on clearly documenting the download filters and random-sampling procedure. Future research should build further upon this study by analyzing additional environmental variables that have the potential to impact biodiversity, such as land-usage changes and precipitation, and by examining drivers of biodiversity change at even smaller scales, as incorporating these variables would allow for a more comprehensive understanding of the causes of biodiversity change. It should also utilize and synthesize different types of biodiversity data, such as species abundance, to allow for a more complete understanding of ecological changes. Additionally, implementing measures to account for biodiversity variance caused by migratory patterns, due to Texas' presence within a migratory corridor, should be a focus of further studies. Overall, gaining understanding of these regional relationships is necessary to develop more effective and specific environmental policies in the face of increasing climate change.

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