BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF NATURAL RESOURCES

IMPACT OF CLIMATE CHANGE ON *RYNCHOPS FLAVIROSTRIS*.

MODESTA T TSONZIWA

B200881B

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE (HONOURS) DEGREE IN NATURAL RESOURCES MANAGEMENT.

JUNE

DECLARATION

The undersigned certify that they have read this research project and have approved its submission for marking in relation to the department's guidelines and regulations.

Student: Modesta T. TSONZIWA

Signature ..... Date: 25/09/24

Supervisor: Jimu L.

Signature ..... Date: 25/9/24

Chairperson W. MHLANGA

Signature ..... Date: 25/9/24

DEDICATIONS

To my lovely mom.

ACKNOWLEDGEMENTS

I am greatly indebted to my supervisor Prof L. Jimu for his assistance and guidance during the entire study.

I appreciate the efforts of my husband Tendai B Njiri and the financial support by my parents. I would also like to extend my gratitude to my classmates and friends for their unconditional love and support throughout the study. Above all, I thank God for making this work a success.

ABSTRACT

Birds play a pivotal role in the ecosystem through pollination, pest control and improving biodiversity. However, several avian species have been on the decline as a result of climate change which affects habitat quality due to shifts in temperature and rainfall. This study looked at where these birds might live in the future, considering how climate change could affect their habitat. Distribution data was obtained from the Global Biodiversity Information Facility and it was cleaned removing duplicate data using excel. These points were then modelled using R and RStudio v 12.1-402. Results showed that *Rynchops flavirostris* is most sensitive to high precipitation. The probability of occurrence in response to bioclimatic variables showed that the African Skimmer availability is mostly influenced by precipitation of warmest quarter (Bio18) and temperature seasonality (Bio 04) accounting for 50% and 8% influences respectively. The habitat suitability under RCP 8.5 expands in the central and eastern Africa due to predicted continuation of future greenhouse gases emission from climate change compared to the predicted current suitability. Therefore, the researcher recommends including other factors like land use and vegetation cover in future research to get a more complete picture. Additionally, similar studies on other bird species facing climate change threats are important.

Key words: *Rynchops flavirostris*, bird species; climate change; habitat suitability; precipitation; species modelling; temperature.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONOMYS AND ABREVIATIONS

BIO	Bioclimatic variable
BIODIVERSITY	Biological Diversity
CO^2	Carbon dioxide
ENM	Ecological Niche Modelling
GBIF	Global Biodiversity Information Facility
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
AUC	Area Under Curve
%	Percent
°C	Degrees Celsius

CHAPTER 1: INTRODUCTION

1.1 Background to The Study

The African Skimmer (*Rynchops flavirostris*) is a distinctive bird species found primarily in sub-Saharan Africa. It is characterized by its striking appearance, with a black cap and back, white underparts, long wings, and a bright yellow bill. They are also highly gregarious, often forming large flocks during nesting and migration periods (Olsen, et al 2010). African Skimmers are primarily found in river systems (Martin, 2007). It is an intriguing bird species with unique adaptations that allow them to thrive in their watery habitats.

The African skimmer is a medium-sized bird, measuring 37-43 cm in length with a wingspan of 105-125 cm (Clancey, 1996)). These birds get their name from their distinctive feeding behavior, where they skim the surface of the water with their lower mandible submerged, catching small fish and other aquatic prey (Kushlan, & Hancock, 2005). They have a unique bill structure, with the lower mandible being longer than the upper, which allows them to feed in this unique way (Zusi, 1996). African skimmers nest in colonies, often on sandy or rocky islands or beaches. They lay 2-3 eggs per clutch, and both parents take turns incubating the eggs and feeding the chicks. These birds are known to be highly social and often forage and roost in large groups.

However, they also face various threats, including habitat loss, degradation, and disturbance caused by human activities such as dam construction and sand mining. Conservation efforts are crucial to protect these fascinating birds and ensure their survival for future generations (Olsen, et al 2010).

1.2 Problem Statement

The African skimmer is a migratory waterbird species that breeds along major rivers and lakes in central and southern Africa. Its population has declined in recent decades due to various threats including habitat loss, pollution, and disturbance. The global population of African skimmers was estimated to be around 20,000-30,000 individuals in the 1970s (Crivelli et al. 1988). By the late 1990s, the population had declined to an estimated 10,000-15,000 birds (Birdlife International 2022). Between 2000 and 2018, the population is estimated to have decreased by 30-49% (Birdlife International 2022).

1.3 Justification

Niche modeling is used to find locations that are good for species conservation and can offer important insights into the factors determining their occurrence (Santini et al., 2012). Using this modeling technique, we may create management plans that effectively assure their existence and gain a deeper understanding of their biological niche. Niche modeling is used to determine the precise habitat needs for African Skimmers by taking into account a number of bioclimatic factors such as temperature, humidity, rainfall etc. This information can be used to identify potential sites for their conservation or restoration by focusing on regions with similar environmental characteristics.

1.4 Aim

Determine the impact of climate change on the future distribution of the African Skimmer.

1.5 Objectives

1. To accurately delineate the suitable habitat for the African Skimmer, enabling conservation efforts to focus on protecting and restoring these areas.
2. To predict impacts of climate change on the habitat of the African Skimmer.
3. To determine bioclimatic factors that regulate the distribution of the African Skimmer.

1.6 Research Questions

1. What are the key environmental factors influencing African Skimmer (*Rynchops flavirostris*) habitat selection?
2. How does climate change affect African Skimmer (*Rynchops flavirostris*) habitat suitability?
3. What bioclimatic variables, influence the geographic distribution and habitat preferences of the African Skimmer?

CHAPTER 2: LITERATURE REVIEW

2.1 Current Distribution of African Skimmer

Rynchops flavirostris' global range is limited to West, Central, East, and Southern Africa, where it lives on sandbars in broad rivers, lakes, and coastal areas (Birdlife International, 2016). The species' population number in its whole range is estimated to be between 7,000 and 13,000 in West and Central Africa and 8,000 and 12,000 in East and Southern Africa (Wetlands International, 2002). The African skimmer has been observed to be diminishing in its natural habitat (Birdlife International, 2016). It is classified as near threatened on the International Union for Conservation of Nature (IUCN) Red List (Birdlife International, 2016) due to its limited population size and reduction in habitats. According to Coppinger et al. (1988), there were around 1,428 birds in the upper and mid-Zambezi Valley of Zimbabwe in 1987.

2.2 Breeding and Nesting Behavior of African Skimmers

Rynchops flavirostris are fascinating bird species known for their unique feeding behavior and specialized breeding and nesting habits (Birdlife International 2021). African Skimmers breed during the dry season when water levels are low, typically between September and February in southern Africa. African Skimmers prefer to nest on sandbars or riverbanks along large rivers and lakes. They typically select sites that are exposed and free from vegetation to provide clear lines of sight for their feeding behavior (del Hoyo et al., 1996) African Skimmers are colonial nesters, meaning they breed in groups or colonies that can range in size from a few pairs to several hundred pairs. These colonies often consist of mixed species, including terns and gulls. The nests of African Skimmers are simple scrapes in the sand. The male initiates the nest-building process by scraping a shallow depression with his breast and feet (Birdlife International 2021). The female then joins in, helping to deepen the scrape and shape it into a proper nest (del Hoyo et al., 1996). After completing the nest, the female African Skimmer lays a clutch of 2-3 eggs. The eggs are usually pale buff or light brown with dark blotches, providing camouflage against the sandy background. The eggs are incubated by both parents, taking turns to keep the eggs warm and protected. The incubation period for African Skimmer eggs is around 20-24 days. Both parents actively participate in incubation, with one bird incubating while the other forages for food (Hockey et al., 2005)

The incubation period is a critical time for the nesting African Skimmers. During this period, the adults take turns incubating the eggs and protecting the nest from potential threats. They may also engage in nest defense displays to deter predators or intruding birds (del Hoyo et al., 2016). Once the eggs hatch, the parents care for the chicks. African Skimmer chicks are covered in down and are precocial, which means they are relatively mature and mobile shortly after hatching. They can walk, swim, and even feed themselves to some extent, but they still rely on their parents for protection and food. African Skimmers have a unique feeding behavior where they fly low over the water with their lower mandible skimming the surface (Hockey et al., 2005). They use their specialized bill to catch small fish near the water's surface. The parents regurgitate the fish to feed their chicks, which often gather in groups for feeding. The chicks fledge, or leave the nest, at around 4-5 weeks of age. They are capable of flight at this stage and gradually become independent (Hockey et al., 1996). After fledging, the young birds may gather in creches, or groups, for further feeding and protection (Hockey et al., 2005). African Skimmers are highly dependent on the availability of suitable nesting and feeding sites (Birdlife International 2021). Threats such as habitat loss, disturbance, and changes in water levels due to human activities or climate change impact their breeding success. Conservation efforts focused on protecting their nesting habitats and ensuring the availability of suitable foraging areas are crucial for the long-term survival of African Skimmers (Borrow, et al 2001)

2.3 Significance of Bird Species

Bird species in the ecosystem play a significant role in the economy. Zimbabwe is known for its rich avian biodiversity, with over 670 bird species recorded in the country (Birdlife International, 2016). This diversity contributes to the overall ecological balance and reflects the health of various habitats, including woodlands, savannas, wetlands, and riverine ecosystems (Whelan et al., 2015)

Many bird species in Zimbabwe contribute to natural pest control by feeding on insects, rodents, and other small animals (Fontana et al., 2011). For example, raptors such as owls and falcons play a crucial role in keeping rodent populations in check, which helps to protect agricultural crops (Benson et al., 2006). Also, bird droppings (guano) can be employed as fertilizer due to its high nutrient content (Sekercioglu, 2014) Birds, particularly nectar-feeding species and frugivorous birds, play a vital role in pollination and seed dispersal. They facilitate the

reproduction and regeneration of plant species, maintaining the biodiversity and functioning of various ecosystems (Moreira et al., 2014).

Zimbabwe's diverse birdlife attracts birdwatchers and nature enthusiasts from around the world, contributing to ecotourism and generating revenue for local communities. Bird-focused tourism promotes conservation efforts and supports the protection of natural habitats (Tourism Zimbabwe, n.d.). Birds can serve as indicators of ecosystem health and environmental changes. Their presence or absence, population trends, and breeding behavior provide valuable information about habitat quality, pollution levels, and the impacts of climate change (Birdlife International, 2016).

2.4 Impacts of Climate Change on Bird Species

Climate change has significant impacts on African skimmers (*Rynchops flavirostris*) in Africa, affecting their habitat, food sources, and breeding patterns. These impacts are observed in various regions across the continent. Climate change influences the abundance and distribution of aquatic prey species that African skimmers rely on for food. Changes in temperature and precipitation patterns can affect the composition and productivity of fish populations, which are the main food source for skimmers (IUCN, 2020). Shifts in prey abundance may lead to reduced foraging success and reproductive success for skimmers (Delany et al., 2020)

Climate change can affect the timing of key environmental cues that trigger bird migration, such as temperature, photoperiod, and resource availability (Both et al., 2010). Changes in these signals can result in differences in the timing of migration and the presence of essential resources, impacting the survival and breeding success of migrating bird species. Changes in precipitation patterns caused by climate change can lead to reduced water availability and more frequent droughts in specific areas of Africa (IUCN, 2020). These alterations may result in the destruction of wetlands, which are crucial areas for African skimmers to breed and find food. The skimmers face limited nesting areas and prey resources due to lower water levels (IUCN, 2020).

As climate change alters environmental conditions, African skimmers may need to shift their ranges to find more suitable habitats (IUCN, 2020). However, their ability to shift ranges could be limited by factors such as habitat availability, human disturbance, or the presence of

competing species. Inadequate range shifts could lead to population isolation and increased extinction risk. Changing climatic conditions can force bird species to shift their ranges to find suitable habitats (Sekercioglu et al., 2008). As temperatures increase, species may move toward higher elevations or latitudes to find suitable climates. However, the ability to shift ranges can be limited by habitat availability, geographic barriers, and human land use patterns (IUCN, 2020).

2.5 Ecological Niche Modeling

Ecological Niche Modeling (ENM) is a powerful tool that enables scientists to predict the potential distribution of species based on their environmental requirements (Yackulic,2013). By analyzing species occurrence data in relation to environmental variables, ENMs can provide valuable insights into species' ecology, conservation, and management (Hawkins et al., 2003). A presence-only modeling technique that estimates the probability distribution of a species based on the environmental conditions at known occurrence locations (Phillips et al., 2006). Ecological niche modeling has various applications in ecology, conservation biology, and climate change research. It can help in understanding species' habitat requirements, identifying regions of high species richness or endemism, assessing the impacts of environmental changes on species distributions, and guiding conservation planning and management efforts (Phillips, et al. 2006).

CHAPTER 3: MATERIALS AND METHODS

3.1 Acquisition of Occurrence Data

Species presence-only occurrence data, were directly downloaded from GBIF (https://www.gbif.org). The data was cleaned by removing outliers and duplicates using R. Bioclimatic data (https://www.worldclim.org) for projections up to 2050 and 2070 were downloaded using R.

3.2 Representative Concentration Pathways

The Representative Concentration Pathways (RCPs) are scenarios used by climate scientists to model future greenhouse gas emissions and their impact on the Earth's climate. The RCPs are named according to radiative forcing target level for 2100. The radiative forcing estimates are based on the forcing of greenhouse gases and other forcing agents (Weyant et al. 2009). The four RCPs include one mitigation scenario leading to a very low forcing level (RCP2.6), two medium stabilization scenarios (RCP4.5/RCP6) and one very high baseline emission scenarios (RCP8.5). Two extreme scenarios, RCP2.6 and RCP8.5 were used in this study. RCP 2.6 assumes a significant reduction in emissions and a stabilization of atmospheric CO2 concentrations, while RCP 8.5 assumes a continuation of current emission trends leading to a significant increase in greenhouse gas concentrations. These two will determine the future of our planet and the well-being of all living organisms. (Moss, et al. 2010) as shown below in (figure 1).

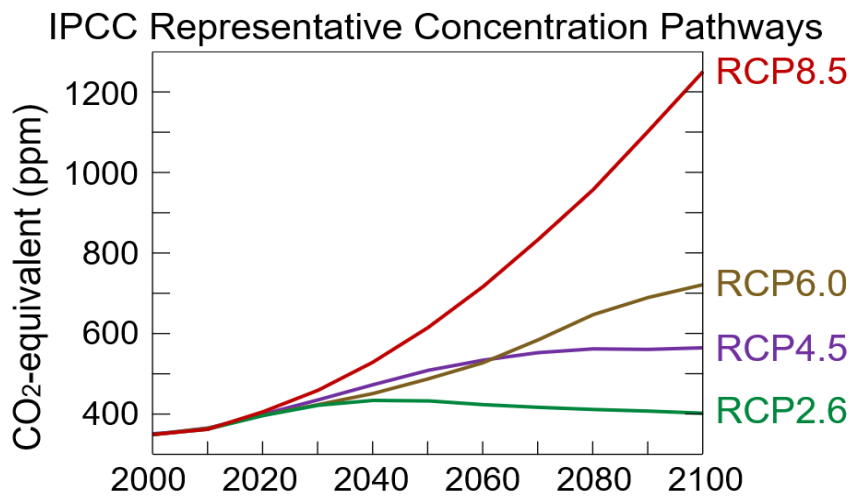


Figure 1 RCP Models used in ecological niche modelling

3.3 Bioclimatic Variables

Bioclimatic variables presented in table 3.1 were used to predict the distribution of the African Skimmer.

Table 3.1: Climatic variables relevant to habitat suitability.

Variable number	Variable
Bio 01	Annual mean temperature (°C)
Bio 02	Mean diurnal temperature range (mean (period max-min)) (°C)
Bio 03	Isothermally (Bio 02 ÷ Bio 07)
Bio 04	Temperature seasonality (C of V)
Bio 05	Max temperature of warmest week (°C)
Bio 06	Min temperature of coldest week (°C)
Bio 07	Temperature annual range (Bio 05 – Bio 06) (°C)
Bio 08	Mean temperature of wettest quarter (°C)
Bio 09	Mean temperature of driest quarter (°C)

Bio 10	Mean temperature of warmest quarter (^{o}C)
Bio 11	Mean temperature of coldest quarter (^{o}C)
Bio 12	Annual precipitation (mm)
Bio 13	Precipitation of wettest week (mm)
Bio 14	Precipitation of driest week (mm)
Bio 15	Precipitation seasonality (C of V)
Bio 16	Precipitation of wettest quarter (mm)
Bio 17	Precipitation of driest quarter (mm)
Bio 18	Precipitation of warmest quarter (mm)
Bio 19	Precipitation of coldest quarter (mm)

3.4 Modelling and Model Performance

A combination of software tools and computer languages enabled it to be easier to analyze data, manipulate images, and conduct detailed analyses. The use of MS Office 2016 enabled me to organize data, construct tables, generate figures, and put the study findings into a well-structured report. The R-Statistical software, combined with RStudio, provided a full platform for undertaking advanced statistical analysis and data modeling. The extensive range of statistical tests, regression techniques, and modeling approaches available in R permitted the data from numerous angles and identify useful findings (Maronna, et al 2019). The raster, rgdal, maps, and mapdata packages produced high-quality maps and spatial visualizations that helped users understand the geographical context and the relationships between variables. The dismo package facilitated the study of potential habitats and environmental factors that influence the distribution of the species being studied (Hijmans, 2017). The rJava package enabled it to be easier for installing Java-based libraries and tools into the R environment, allowing users to enhance their analytical and processing capabilities. The maptools and jsonlite packages provided tools for working with geographical and JSON data, respectively (Cambon, 2021). These programs improved the ability to customize, research, and visualize data, resulting in a more complete and informative analysis. The model performance was assessed with the Area Under Curve to see how close it was to 1.0

CHAPTER 4: RESULTS

4.1 Variable Contribution

(Figure 2) outlines the contribution of climatic variables to the African Skimmer sensitivity. It can be seen that the African Skimmer availability is mostly influenced by precipitation of warmest quarter (Bio18) and temperature seasonality (Bio 04) accounting for 50% and 8% influences respectively.

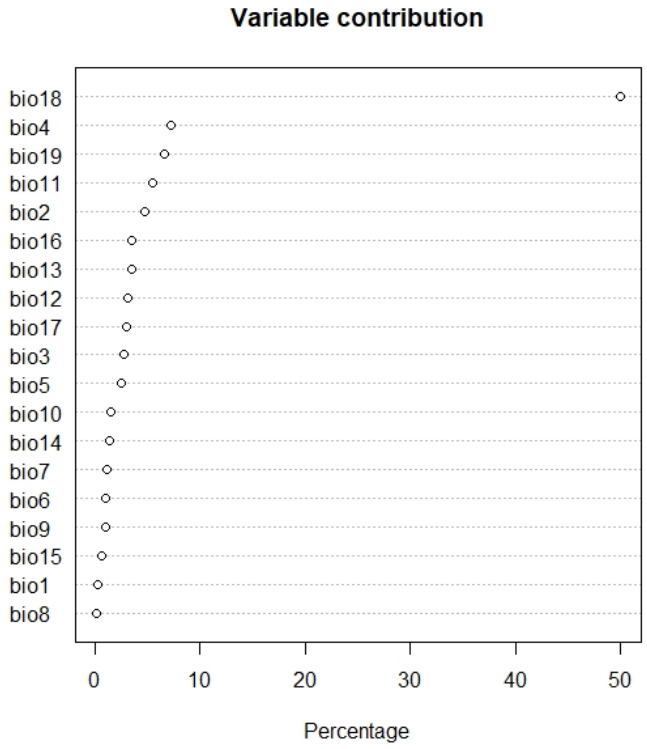
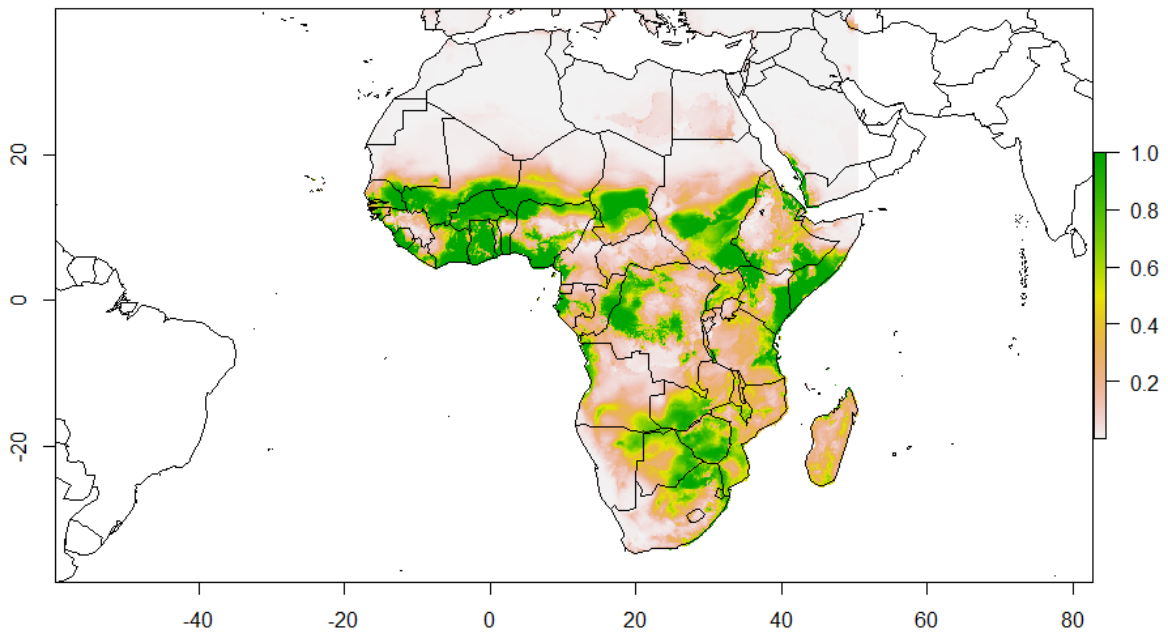


Figure 2 Bioclimatic variable % contribution

4.2 Projections Under the RCP 8.5 Model

The predicted distribution is mostly concentrated in parts of Zambia, Ghana, Kenya as shown below in (Figure 3). The maps indicate high distribution in the southern region of Africa. The suitability expands in the central and eastern Africa covering parts of due to predicted continuation of future greenhouse gases emission from climate change compared to the predicted current suitability. However the African Skimmer is predicted to have decreased its habitat suitability in parts of Botswana, Angola and Namibia by the year 2070 as indicated below in figure



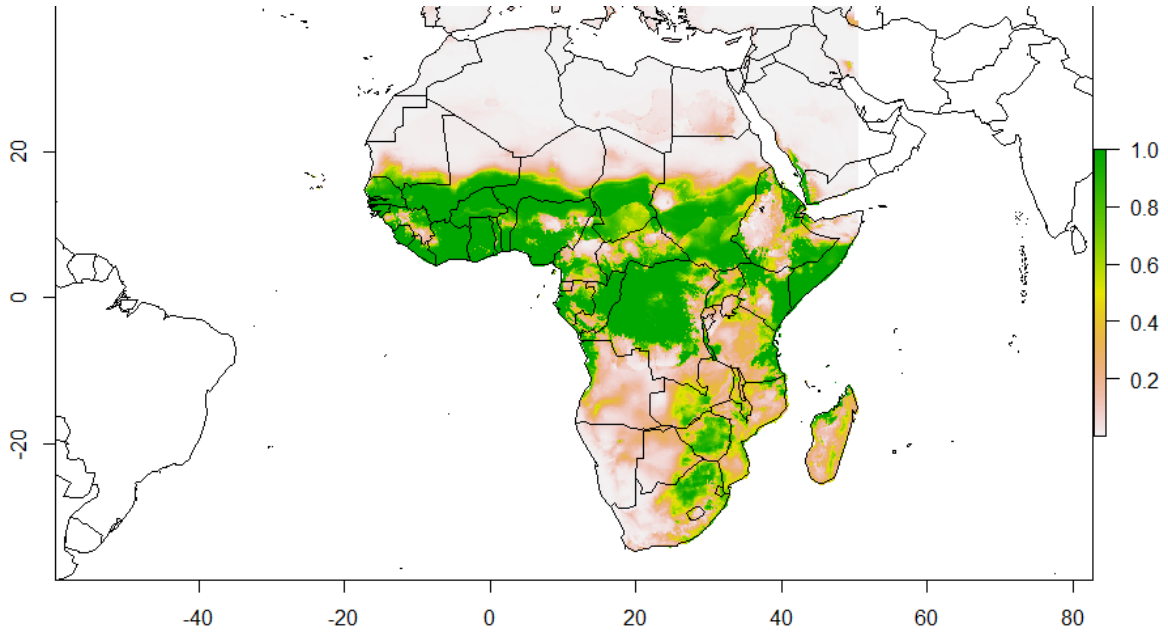


Figure 3 2050 and 2070 maps under RCP 8.5 respectively

4.3 Projection Under RCP 2.6 Climate Change Model.

Comparatively, there is less expansion than reduction in suitable distribution from current to 2070. In 2050 the distribution will increase covering parts of Zambia, Botswana, Zimbabwe and Mozambique as shown in (Figure 4) by a suitability value of 1.0 due to favorable bioclimatic variables such as temperature and rainfall. However, in 2070 it is predicted to have decreased its distribution in parts of Mozambique, Congo as the model predicted a suitability value of 0.2

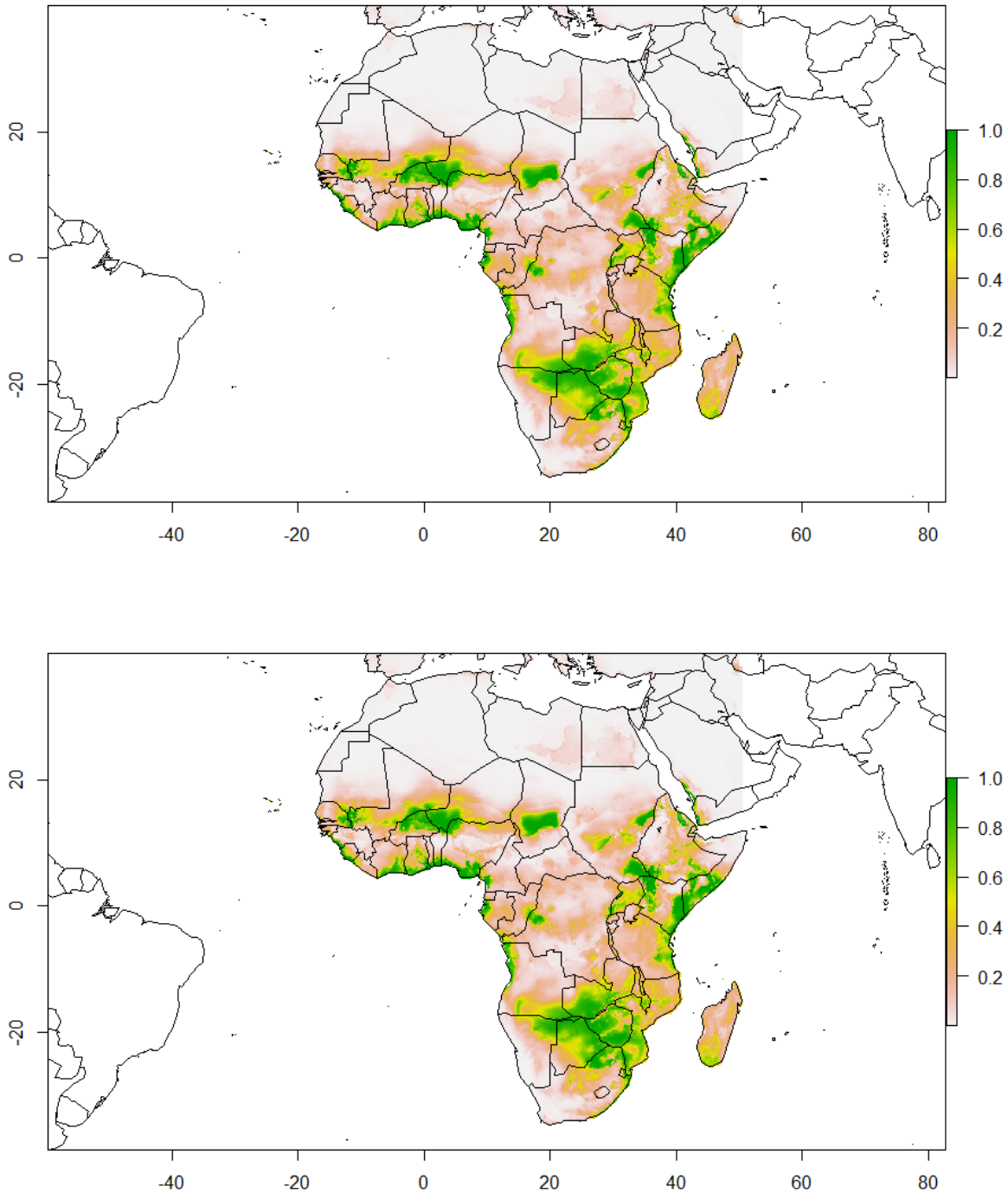


Figure 4 2050 and 2070 maps under RCP 2.6 respectively

4.4 Model Performance

The AUC produced a value of 0.958 demonstrating that the model was excellent for simulating *Rynchops flavirostris*'s future habitat predictions as shown below on (Figure 5). Therefore, the fundamental findings and outputs from the study can be relied on

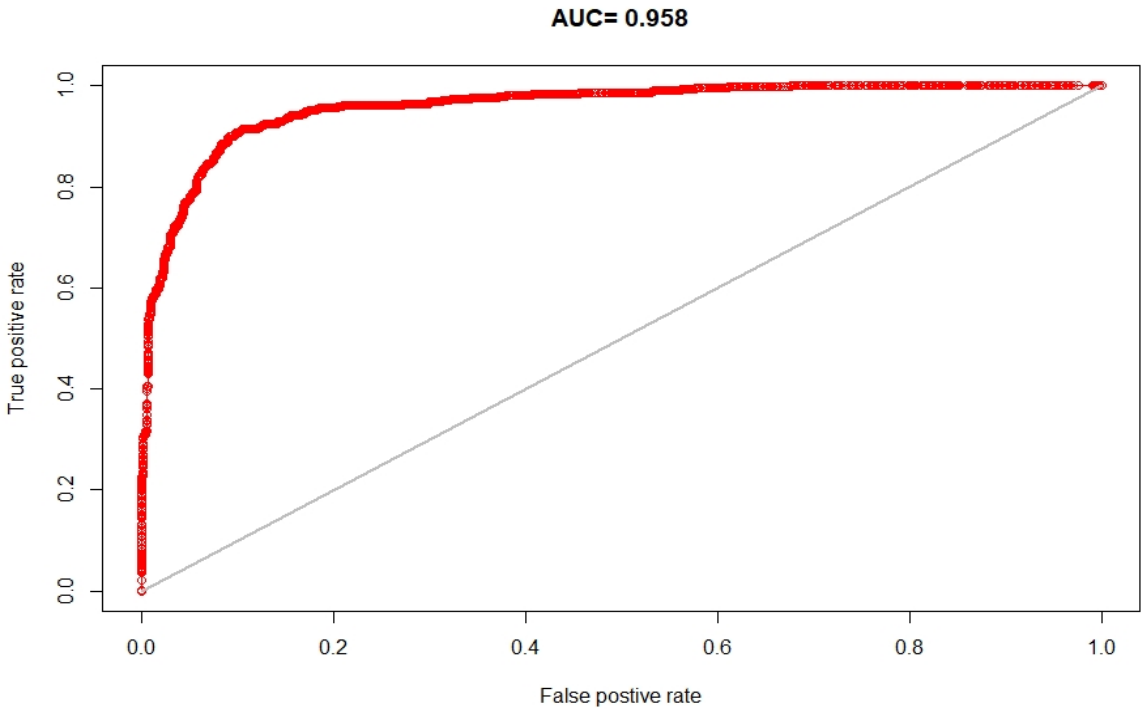


Figure 5 AUC Model

CHAPTER 5: DISCUSSION

Ecological niche modelling of African Skimmer (*Rynchops flavirostris*) indicated that rainfall pattern was the most important factor for predicting where *Rynchops flavirostris* lives. Studies showed that yearly precipitation and rainfall during the driest and coldest parts of the year were the most important factors in predicting suitable habitat (Hamer, et al 2001). This makes sense because rain directly affects rivers and lakes. Just like other studies have shown, rain is a strong predictor for where different species live (Heino, et al 2009). More rain means more water flowing into rivers and lakes, which in turn affects the health of these ecosystems. Overall, rainfall controls the amount of water in rivers and lakes, which directly impacts the physical features like sandbars that skimmers rely on for habitat. Since skimmers depend on sandbars, it's no wonder their locations are closely tied to how much rain falls each year (Weller, 1999).

These birds seem okay with Africa's scorching summers; hence temperature was not a major factor. As the African continent gets drier and hotter, according to climate predictions, this suggests that rain changes will have a bigger impact on their habitat than rising temperatures (Lawal, et al 2019.). However, extreme hot weather can still be dangerous for these birds, even if they can handle it to some extent. Very high temperatures have been linked to stress and overheating in birds, therefore extreme heat tolerance alone might not guarantee their survival in the long run (Pipoly, et al 2022.).

The bio-climatically suitable range for the *Rynchops flavirostris* was projected to contract under the (RCP 2.6) and to expand under (RCP 8.5). The loss and gain of species suitable habitat observed in this study were a result of the different conditions under the RCP scenarios used in the projections. This study suggests African skimmers might be sensitive to climate shifts. They potentially act as indicator species, helping in tracking how biodiversity responds to climate change. Since they are already considered near threatened in Africa, future habitat loss predicted by climate models could push them towards even higher threat categories on the IUCN Red List. A shrinking skimmer population will likely impact African biodiversity. The first hit will likely be on their prey - fish that are not cichlids. With fewer skimmers, these fish might face less

predation pressure, giving them a competitive advantage. However, this could also lead to changes in the overall makeup of aquatic communities.

Rising temperatures associated with climate change have indirect effects on the African skimmer, such as changes in the composition of aquatic ecosystems (Plowright et al., 2021). These factors further threaten the species' survival and disrupt the delicate balance of its natural habitat and increased prevalence of diseases or parasite, (Plowright et al., 2021). Rising sea levels and increased coastal erosion on the nesting sites of the African skimmer. These birds typically nest on exposed sandy or shingle banks along rivers and coastlines (Dodman & Diagana, 2006). As sea levels rise and extreme weather events become more frequent, these nesting habitats are increasingly at risk of inundation and destruction (Cramp & Simmons, 2016). This can lead to the loss of critical breeding grounds and disrupt the species' reproductive success. Additionally, changes in precipitation patterns and the frequency of droughts impact the availability of the African skimmer's preferred prey, such as small fish and crustaceans (Hockey et al., 2005). Alterations in the timing and abundance of these food sources make it more challenging for the birds to find adequate sustenance, potentially leading to reduced breeding success and population declines.

Climate change can alter the geographic distribution, abundance, and seasonality of prey species disrupting the spatial and temporal overlap between predators and their prey, making it harder for predators to locate and access their food sources. To mitigate the impacts of climate change on the African skimmer, conservation efforts must focus on protecting and restoring the species' critical nesting and feeding grounds, as well as addressing the broader environmental challenges posed by a changing climate (Birdlife International, 2022). Ongoing monitoring, research, and collaboration between scientists, policymakers, and local communities will be essential in developing effective strategies to safeguard this unique and charismatic waterbird.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The findings of the present study indicated that *Rynchops flavirostris* does well in regions with moderate to high annual precipitation, typically between 500-1500 mm per year and they require access to large, permanent water bodies like rivers and lakes, therefore areas with reliable, year-round rainfall are ideal.

Predicted change in habitat suitability signified that there is a 0.5 likelihood of occurrence in the north eastern part of Africa and the central part of Africa dominated by protected areas. In addition, by 2050, there will be a slight decline in *Rynchops flavirostris* (African Skimmer*)* habitat quality in Zimbabwe though the likelihood of occurrence will range from 0.8-1.0. however, in 2070 the likelihood of habitat suitability in South Africa will have declined to 0.2 under 8.5 climate change model.

6.2 Recommendations

Further considerations on future climate change scenarios to assess potential shifts in the species' distribution under different climate projections.

- Further research on the African skimmer to gather additional insights and data that may improve the niche modeling process.
- Further studies should incorporate environmental predictor variables relevant to the species' ecology, such as land cover, climate, hydrology, and topography.

References

*"Rynchops flavirostris (Af*rican skimmer)". Biodiversity Explorer. Iziko Museums of South Africa.

Biodiversity Journal, Global Biodiversity Information Facility (GBIF) (2019). Species distribution data. Retrieved from https ://www.gbif.org Google Earth (2019).

Birdlife International (2021). *"Rynchops flavirostris*". IUCN Red List of Threatened Species. 2021

Birdlife International (2021). *"Rynchops flavirostris*". IUCN Red List of Threatened Species. 2021: Retrieved 12 November 2021.

Birdlife International. (2022). *Rynchops flavirostris* (African Skimmer). IUCN Red List of Threatened Species.

del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A., & de Juana, E. (Eds.). (2014). Handbook of the Birds of the World Alive. Lynx Edicions.

Birdlife International. (2022*). Rynchops flavirostris* (amended version of 2018 assessment).

Birdlife International. (2022). Species factsheet*: Rynchops flavirostris*. Retrieved from http://datazone.birdlife.org/species/factsheet/african-skimmer-rynchops-flavirostris

Both, C., van Asch, M., Bijlsma, R. G., van den Burg, A. B., & Visser, M. E. (2009). Climate change and unequal phenological changes across four trophic levels: constraints or adaptations? Journal of Animal Ecology.

Cambon, J., Hernangómez, D., Belanger, C., & Possenriede, D. (2021). tidygeocoder: An R package for geocoding. Journal of Open-Source Software

Clancey, P. A. (1996). The birds of southern Africa. Revised edition. Trustees of the John Voelcker Bird Book Fund.

Kushlan, J. A., & Hancock, J. A. (2005). The herons. Oxford University Press. Zusi, R. L. (1996). Family Rynchopidae (Skimmers). In J. del Hoyo, A. Elliott, & J. Sargatal (Eds.), Handbook of the Birds of the World Lynx Edicions.

Gichuki, N. N., & Gichuki, C. M. (1992). Breeding biology of the African Skimmer Rynchops flavirostris Schulz, H. (1983). Grundlagen einer Ökologie des Schwalbenschnäblers Rynchops flavirostris Vieillot 1819 am Tschadsee, Nordostnigeria. Die Vogelwarte,. Cramp, S., & Simmons, K. E. L. (Eds.). (1983). The birds of the Western Palearctic (Vol. 3). Oxford University Press.

Crivelli, A. J., Jerrentrup, H., & Mitchev, T. (1988). Electric power lines: a cause of mortality in Pelecanus crispus Bruch, a world endangered bird species, in Porto-Lagos, Greece. Colonial Waterbirds.

del Hoyo, J., Elliott, A., & Sargatal, J. (2016). Handbook of the Birds of the World: Volume 3, Hoatzin to Auks. Lynx .

Delany, S., Scott, D., Dodman, T., Stroud, D., & Gan, X. (2020). Climate change impacts on migratory waterbirds: status and trends. Cambridge, UK: International Waterbird Society.

Distribution and breeding biology of the African skimmer on the Upper and Middle Zambezi

Dodman, T., & Diagana, C. H. (2006). African waterbird census: Les dénombrements d'oiseaux d'eau en Afrique, 1999, 2000 & 2001. Wetlands International.

Hamer, K.C., Schreiber, E.A. and Burger, J., 2001. Breeding biology, life histories, and life history-environment interactions in seabirds. Biology of marine birds

Harare, Zimbabwe: Natural Resources Board of Zimbabwe. Dudgeon, D., Arthngton, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Leveque, C., … Sullivan, C. (2006). Freshwater biodiversity: Importance, threats, status and conservation challenges.

Heino, J., Virkkala, R. and Toivonen, H., 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. Biological Reviews,

Hijmans, R. J., Phillips, S., Leathwick, J., Elith, J., & Hijmans, M. R. J. (2017). Package ‘dismo’.

Hockey, P. A. R., Dean, W. R. J., & Ryan, P. G. (2005). Roberts Birds of Southern Africa. Trustees of the John Voelcker Bird Book Fund

Hockey, P. A., Dean, W. R., & Ryan, P. G. (Eds.). (2005). Roberts' birds of southern Africa. Trustees of the John Voelcker Bird Book Fund.

Important bird areas in Africa and associated islands. Priority sites for conservation. Conservation Series No. 11. Newbury and Cambridge, UK: Birdlife International. Fujino, J., Nair, R., Kainuma, M., Masui, T., & Matsuoka, Y. (2006).

International Union for Conservation of Nature (IUCN). (2020). The IUCN Red List of Threatened Species 2020

IPCC, 2000: IPCC Special Report on Emissions Scenarios. Prepared by Working Group III of the Moss, R. H., et al. (2010).

Lawal, S., Lennard, C. and Hewitson, B., 2019. Response of southern African vegetation to climate change at 1.5 and 2.0 global warming above the pre-industrial level. Climate Services,

Maronna, R. A., Martin, R. D., Yohai, V. J., & Salibián-Barrera, M. (2019). Robust statistics: theory and methods (with R). John Wiley & Sons.

Pipoly, I., Preiszner, B., Sándor, K., Sinkovics, C., Seress, G., Vincze, E., Bókony, V. and Liker, A., 2022. Extreme hot weather has stronger impacts on avian reproduction in forests than in cities.

Plowright, R. K., Parrish, C. R., McCallum, H., Hudson, P. J., Ko, A. I., Graham, A. L., & Lloyd-Smith, J. O. (2017). Pathways to zoonotic spillover. Nature Reviews Microbiology

Sekercioglu, C. H., Schneider, S. H., Fay, J. P., & Loarie, S. R. (2008). Climate change, elevational range shifts, and bird extinctions. Conservation Biology.

Teplitsky, C., Mills, J.A., Alho, J.S., Yarrall, J.W. and Merilä, J., 2008. Bergmann's rule and climate change revisited: Disentangling environmental and genetic responses in a wild bird population. Proceedings of the National Academy of Sciences,

The Energy Journal, SI2006(01), 343–353. Gamundani, P. T., Magadza, C. H. D., & Kativu, S. (2018). Contemporary spatial distribution pattern, breeding status and habitat suitability criteria for the African skimmer (Rynchops flavirostris; Vieillot, 1816) in the Zambezi Valley, Zimbabwe.

The IUCN Red List of Threatened Species 2022

The next generation of scenarios for climate change research and assessment. Nature.

Weinzettel, J., Hertwich, E.G., Peters, G.P., Steen-Olsen, K. and Galli, A., 2013. Affluence drives the global displacement of land use. Global Environmental Change,

Modesta_Tinotenda Tsonziwa_Final Dissertation Niche_Modelling_B200881B edited.docx

ORIGINALITY REPORT

12%	12%	8%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	onlinelibrary.wiley.com Internet Source	3%
2	www.mdpi.com Internet Source	3%
3	Submitted to Bindura University of Science Education Student Paper	2%
4	liboasis.buse.ac.zw:8080 Internet Source	2%
5	etd.aau.edu.et Internet Source	1%
6	tshe.org Internet Source	1%