MAPUTO SPECIAL RESERVE

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Climate Change Vulnerability Assessment

Mozambique's Maputo Special Reserve faces biodiversity challenges as anthropogenic climate change affects the region's unique ecoregion. Mangroves, elephants, and the reserve's grassland ecosystem all face varying degrees of vulnerability as we approach the next century. This climate change vulnerability assessment will analyze each targets' sensitivity, exposure, and adaptability to the effects of climate change within the reserve utilizing the Intergovernmental Panel on Climate Change's Representative Concentration Pathway trajectories.

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Maputo Special Reserve

CLIMATE CHANGE VULNERABILITY ASSESSMENT

INTRODUCTION

Maputo Special Reserve is located in Southeast Africa.

Climate change has the potential to upend life on our planet, causing untold losses and suffering. While the world debates prevention methods, the effects of shifting temperatures, weather patterns, and sea levels have already begun to affect many poor or developing regions. Southern Africa is particularly susceptible to this shifting climate (1). Mozambique, one of the ten least developed nations (2), and currently undergoing a severe drought, is especially vulnerable. Despite this, Mozambique has continued to set aside land and resources for nature reserves such as the Maputo Special Reserve near their Southern border with South Africa. This reserve is unique. It contains one of the last coastal elephant herds in the region and has seen renewed interest since Peace Parks Foundation partnered with the government to develop ecotourism and species reintroduction programs sustainably (3). Considering these recent activities, the need to assess the Maputo Special Reserve's vulnerability to climate change is significant. Such an assessment has the potential to guide better both the government and Peace Park International's endeavors in the reserve and may inform current repopulation efforts as well as preservation projects in this region.

The reserve stretches from Maputo Bay to the border with South Africa.

This study will concentrate on the Maputo Special Reserve in Mozambique and make projections out to 2100, seventy-nine years from the current date. We will focus on elephants (which are the focus of current repopulation efforts), mangroves (a keystone to many species but vulnerable to acidification, siltation, and sea-level rise), and the grassland ecosystem that exists within the reserve. These targets represent essential cornerstones of the larger ecology in the region and serve as bellwethers for the rest of the reserve's systems. Due to pandemic travel restrictions, time and resource restrictions, this assessment is a "desk study," relying on public and private sources from a range of parties. Original geospatial map images were created as part of this study utilizing datasets from the International Union for Conservation of Nature, Climate Central's coastal digital elevation model, and the World Wildlife Fund's protected areas database.

SENSITIVITY OF TARGETS

In assessing the sensitivity of each target, attention must be paid to temperature and water shifts. Mangroves additionally require an evaluation of sensitivity to changes in sea level.

Elephants

Elephants in Mozambique face a wide range of anthropogenic threats, including poaching, habitat destruction, and human-elephant conflict. Loxodonta Africana, the subspecies prevalent in Southern Africa, requires 150 to 300 liters of water a day, leaving them susceptible to droughts and water shortages (4). With an inability to sweat, elephants are susceptible to high-temperature conditions (5). This sensitivity leaves them unable to cope with heatwaves.

Mangroves

The Maputo Special Reserves' northern coastland is home to mangrove swamps, primarily composed of the Rhizophora mucronata variety extending inland from Maputo Bay (6). These salt-tolerant trees provide habitats to many other plants and animals, prevent coastal erosion, and sequester carbon from the atmosphere. Mangroves are susceptible to shifts in sea level, temperature, and ocean acidification- all associated with climate change. Additionally, the reserve's mangals, or mangrove swamps, are vulnerable to changing ocean currents, storm surges, and altered precipitation patterns. Mangroves find themselves directly affected by surface-based and oceanic trends, leaving them sensitive to compound climate change degradation (7).

Grassland Ecosystem

Grasslands cover much of the reserve and provide essential habitat for antelope, zebra, various bucks, and other flora and fauna endemic to the Maputaland biodiversity hotspot region (8). Like elephants and mangroves, this ecosystem is vulnerable to temperature and rainfall changes, both affected by climate change. Additionally, research in nearby South Africa has revealed linkages between rising atmospheric carbon dioxide levels and the growth of trees, shrubs, and bushes in Africa's grasslands (9). This conversion from a savannah into a wooded ecosystem threatens the area's iconic grasses, insect, and vertebrate animal species dependent on African grasslands' unique characteristics.

EXPOSURE OF TARGETS

The Maputo Special Reserve, like much of Southern Africa, is already undergoing climate change-driven shifts in rainfall, temperature, and extreme weather events. Mozambique has suffered major cyclones in each of the previous three years (2019, 2020, and 2021), destroying human and animal lives and battering the coast (10). Ongoing drought conditions are especially acute in the south, where the reserve is located (11). Over the last century, southern Mozambique has experienced a 1° C warming trend above the global average.

Temperatures in the greater Maputaland region are projected to climb by as must as 3° C by 2055 and 4.6° C by the end of the century (12), threatening many wildlife, plant species, and human settlements.

Elephants

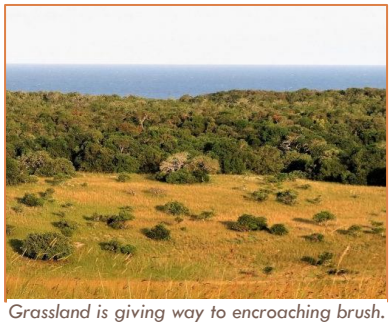
Elephants' immense water needs leave them vulnerable to drought conditions. The number of dehydration deaths within the reserve borders is unavailable, but nearby Zimbabwe and South Africa have reported hundreds of elephant deaths associated with the current drought (13). While rainfall projections for the country overall are flat through this century, the Maputo Special Reserve is forecast to receive between 24% to 31% less rainfall by 2100 (12), draining many small lakes and watering holes Maputo's elephants rely on. Unable to perspire and reliant on dwindling surface water to cool down, elephants in the reserve are vulnerable to extreme heat events, of which Southern Mozambique is projected to experience 17 more days per year by 2100 (14). Elephants in the Maputo Special Reserve should be considered highly vulnerable to the effects of climate change.

Mangroves

Cyclone Eloise impacting Mozambique.

Mangroves face climate change threats both above and below the waters of Maputo Bay. The heightened frequency of extreme weather events, such as large cyclones, physically damages these vulnerable trees while depleting the sediment mangroves require to survive and grow (15). Nevertheless, mangrove swamps along the reserve's northern shore have increased their cover by 13% since 1958 (16). This growth trend may not continue due to climate change. Mangroves cannot survive above 38° to 40° C (15), well below temperature projections for the region, leaving sea level rise as their greatest threat. Using scenarios predicting 47.5cm and 132cm of ocean level rise by 2100 (17), it is possible to map the areas of inundation in the reserve's mangrove forests (see the Appendix), demonstrating the wide degree of potential seawater flooding in this area.

> **"The water is eating the land - little by little, it's eating the land."**
>
> **-Lifelong area resident (18).**



Grassland is giving way to encroaching brush.

Grassland Ecosystem

Maputo Special Reserve's savannah area is host to over a dozen grass species endemic to the Maputaland-Pondoland-Albany biodiversity hotspot (19). These grasses depend on the region's distinct "moist savannah" biome, fed by the nearby Indian Ocean's warm Mozambique Current. As the reserve's weather increases by up to 4.6° C and rainfall drops by up to 31% by the year 2100, these biological conditions will no longer exist. Conditions are predicted to become "dry savannah" and semi-desert in nature, threatening endemic flora within the reserve. Rising atmospheric carbon levels have created a fertilizer effect across much of Southern Africa, fueling bushes and trees' growth within Maputo Special Reserve's grasslands, further threatening this ecosystem (9).

ADAPTIVE CAPACITY OF TARGETS

Elephants

Elephants' watering holes are drying out.

African elephants are highly mobile, able to walk up to 195km per day (13). This ability allows them to adapt to changing sources and congregate around remaining water as rainfall decreases. The Maputo River, along with larger water bodies like Xinguti and Piti lakes, will likely see growing concentrations of elephants as herds are forced to abandon dried-up watering holes. This adaptability's effectiveness will depend on the long-term viability of the reserve's water (20). The creation of pumped watering holes has enabled elephants to remain viable in other parts of Southern Africa (21), and would likely strengthen the adaptive capacity of the herds in the Maputo Special Reserve. Elephants are acutely heat-sensitive, unable to sweat or shed heat efficiently (22). This heat-sensitivity leaves elephants with little capacity to weather high heat events.

Mangroves in the desert of Mexico

Mangroves

Mangroves exist across a wide range of latitudes and regions, leaving the saltwater-resistant tree well equipped to adapt to shifting temperatures and rainfall levels. If peak yearly temperatures rise from their current 27° C average high to 31.6° C by the year 2100 (a 4.6° C increase), the reserve's mangroves will remain within their maximum 40° C temperature range. In considering the adaptability of the mangals, sea-level rise must be taken into consideration. Mangroves can generally tolerate a 7mm sea-level increase per year through various natural adaptations (23). The world faces up to a 1.32-meter sea-level rise under the Representative Concentration Pathway 8.5 climate projections (17) by the year 2100, averaging out to 16.5mm per year. Mangroves face inundation throughout the reserve's brackish mangals under this worst-case scenario. Using the more optimistic RCP 2.6 projections of a 300 to 650mm rise in ocean levels, we can predict a yearly 4 to 8mm rise. Even under this more hopeful scenario, the Maputo Special Reserve mangroves may fail to adapt quickly enough. The impacts of climate change are not linear, and storm surges are expected to impact the accretion of silt necessary for mangroves to raise their height (16).

Grassland Ecosystem

Grasslands and coastal forests in the reserve.

Maputo Special Reserve's grasslands depend on the region's unique coastal biome. Along with the larger Maputaland-Pondoland-Albany ecoregion, these grasslands are home to many endemic animal and plant species (19). As temperatures rise, rainfall becomes less common, and extreme weather events impact the reserve, the grassland's key adaptation will consist of changes to the flora and fauna makeup. This shift has negative consequences for many of the endemic populations, which by definition have narrow habitat requirements. Additionally, there exists no effective adaptation to the

effects of atmospheric fertilization. Even under optimistic projections, anthropogenic carbon dioxide is projected to impact this region's grasslands. Bushes and small trees are expected to crowd out grasses and convert much of the reserve's iconic fields into brushland (9).

> **"The sea is rising; the waves are stronger and bigger. I watch how the temperature changes. It is not like it was before."**
>
> **-Daviz Simango, Government Official (24)**

OVERALL VULNERABILITY

Mozambique is considered one of Africa's most vulnerable countries to the effects of climate change (12). The El Niño Southern Oscillation is responsible for alternating drought and flood conditions, which are anticipated to become more intense due to climate change (25). Funding shortfalls hamper meteorological projections for the nation. This general lack of resources extends to the Maputo Special Reserve, limiting reserve managers' ability to conduct vulnerability adaption measures.

Elephants

Water and heat shifts pose the greatest threat to the reserve's pachyderm residents. Further on-the-ground assessment and projections of the area's water tables and sources are necessary to ensure enough water is present to sustain these sizable creatures. As the region becomes drier, elephants will have to travel further distances and congregate around the remaining water resources, introducing various other issues such as overcrowding, illegal poaching, food scarcity, and herd social disruptions (4). Even under optimistic RCP projections, extreme heat events will become more common in the Maputo Special Reserve by 2100. Already, elephants in neighboring Zimbabwe and Botswana have seen hundreds of confirmed heat deaths (one can assume many more have died unaccounted for) (13). Therefore, we must consider the reserve's elephants highly vulnerable to the effects of climate change and consider direct mitigations (such as pumped watering holes and man-made shaded areas) to ensure the preservation of the reserve's herds.

A young mangrove taking root

Mangroves

Able to thrive at high temperatures, the mangrove swamps' vulnerability depends primarily on the sea level in Maputo Bay (23). By modeling different sea-level increases using an AI-enhanced digital elevation map, we can visualize various scenarios for the future of the reserve's mangals in the appendix images. Under the most optimistic greenhouse gas trajectory, Representative Concentration Pathway 2.6, mangroves in the bay should see minimal losses. If we utilize the more pessimistic RCP 8.5 trajectory (one in which little is done to curb human-caused climate change), over half of the reserve's mangroves stand to be inundated by rising ocean water faster than the species can adapt. Consequently, Maputo Special Reserve's mangals' vulnerability is highly dependent on global efforts to reduce climate change-associated emissions (16).

Grassland Ecosystem

Bushes are already appearing in grasslands.

The reserve serves as a critical protected region for endemic grasses and the multitude of species that depend on these ecosystems. Shifts in rainfall, temperature norms, and even atmospheric carbon concentrations can irreversibly wipe out flora and fauna dependent on the ecoregion's unique coastal wet savannah conditions. As Maputo Special Reserve becomes more desert-like and conditions become characterizable as "dry savannah," grasslands will transform, hosting different grass varieties resistant to drought along with an increase in bushes, which can crowd-out grasses. The future of grasslands within the reserve is fraught. There are no natural or economically feasible local means to ameliorate these compound threats, leaving the reserve's iconic grasslands highly vulnerable to the effects of human-caused climate change as we approach the next century.

LEVEL OF CONFIDENCE

In projecting close to eight decades of future climate change, nothing can be assured with complete certainty. The region's water table remains unexplored, leaving projections for the reserve's water future uncertain. This uncertainty complicates vulnerability assessment for local elephants. Grasslands will see climate change-driven disruption under almost all representative concentration pathways, allowing us to predict their collapse with a high level of confidence. Predictions are less sure for mangroves within Maputo Special Reserve, as they depend on future global human emissions and (challenging to model) ocean salinity shifts in the region. A survey of climate experts placed a central probability of 66% on sea level rises between 30cm and 65cm, which the author averaged into 47.5cm for the included maps.

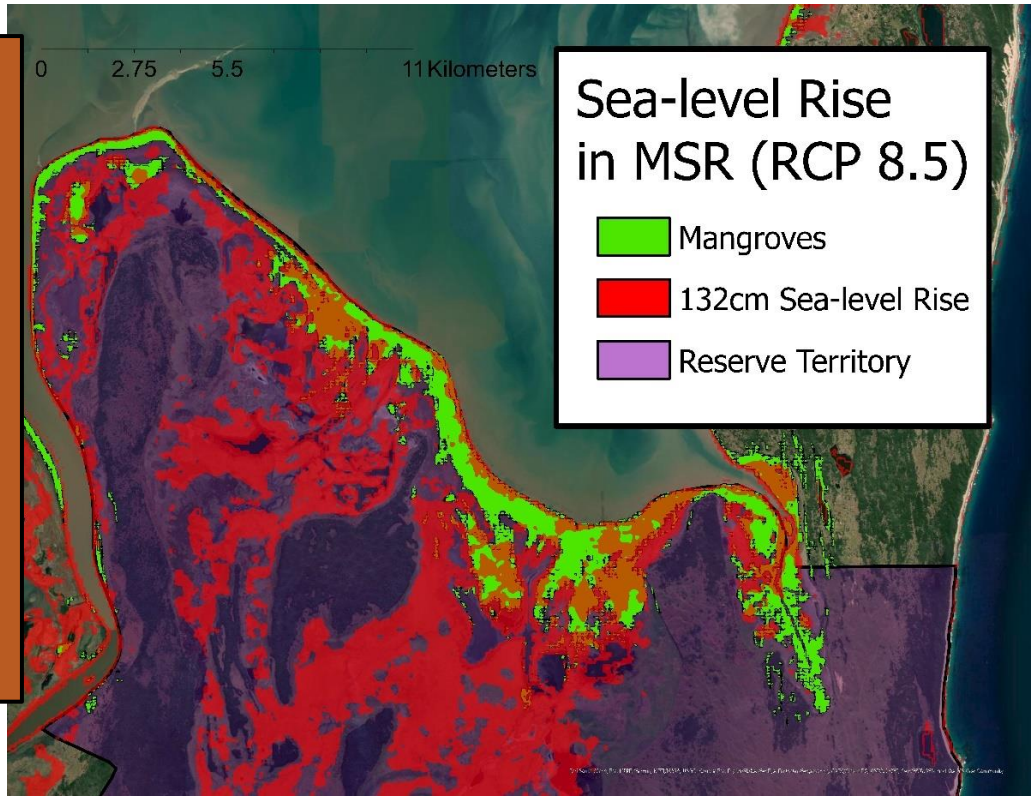
CONCLUSION

Maputo Special Reserve encompasses a wholly unique parcel of protected land. From the bay to its beaches along the Indian Ocean, to the newly dedicated elephant corridor linking the reserve's pachyderms with South Africa, this area has attracted conservation efforts from local, national, and international groups. While mangroves and elephants face uncertain futures, the reserve's grasslands are sure to confront significant disruption. Despite these climate change-induced challenges, interest in Maputo Special Reserve remains high. Ecotourism, native species repopulation, and agreements with international organizations such as Peace Parks Foundation demonstrate the high energy and investment levels this reserve is receiving. The effects of climate change will hamper these efforts' sustainability in Maputo Special Reserve as we approach the next century. By participating in mitigations and adaptations, current and future caretakers can better manage the reserve for generations to come while protecting a vital biodiversity hotspot. The rest is up to the global community.

APPENDIX

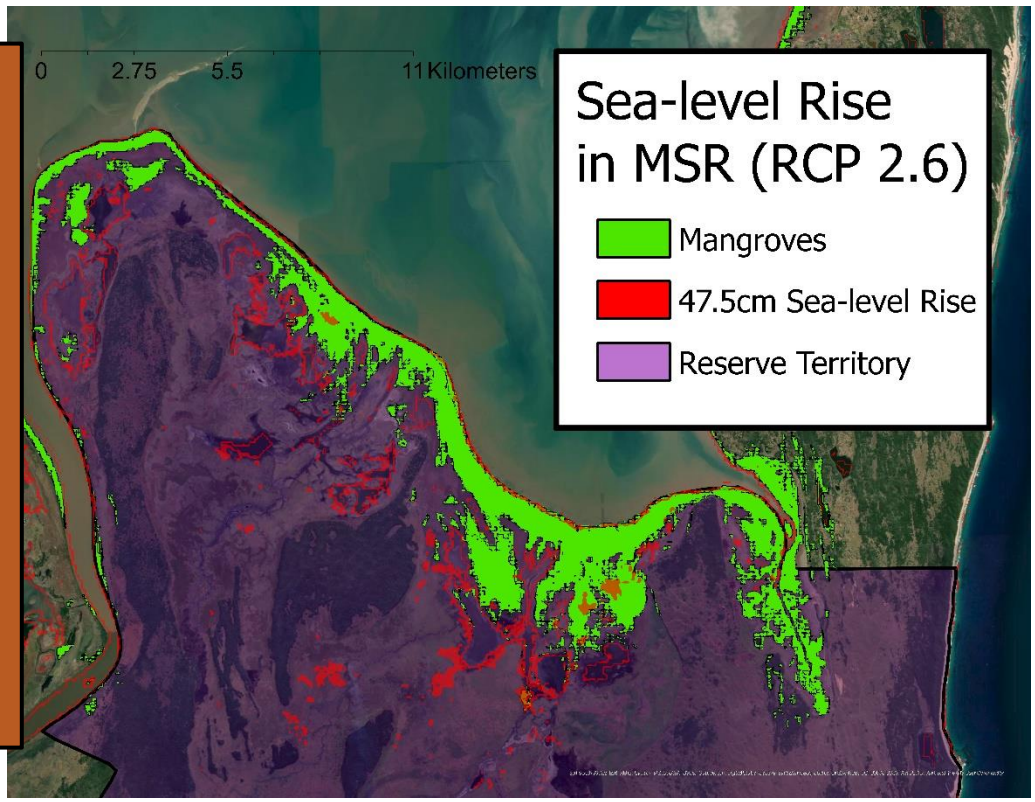
Worst Case Scenario

Mangroves near the bay face sea water inundation faster than they can adapt, wiping out much of the mangals.



Most Likely Scenario

Climate change driven sea level rise affects a select few mangroves stands while leaving the majority of the mangals intact.



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