Chun Hang  
Dr. Caglar Koylu  
Geospatial Programming

Final Project

Problem StatementThe reintroduction of endangered species, such as Chiricahua leopard frogs and Northern Mexican Garter Snakes, into their native habitat within Saguaro National Park poses a multifaceted challenge in the context of larger initiatives aimed at increasing biodiversity and restoring ecological balance in Southern Arizona. While recent developments have committed significant funding from the Interior Department (Davis, 2024) and defined a comprehensive conservation strategy, the successful implementation of this attempt is dependent on negotiating complicated spatial dynamics and meeting essential data requirements.

The significance of reintroducing Chiricahua leopard frogs and Northern Mexican & narrow-headed garter snakes into Saguaro National Park cannot be overstated. These species serve as vital components of the park's ecosystem, contributing to its ecological balance and resilience. The Chiricahua leopard frog contributes to the health of aquatic ecosystems by controlling insects and cycling nutrients. The structure of the park's food web is also influenced by the Northern Mexican and narrow-headed garter snakes, which are vital in managing amphibians and small animal populations. These native species also act as indicators of habitat quality, demonstrating the general well-being and integrity of the park's ecosystem. By restoring these endangered species, there is a hope to not only restore their numbers but also improve the park's biodiversity, creating a more resilient and sustainable natural environment for future generations to enjoy and appreciate.

However, one of the most difficult issues is undertaking detailed spatial analysis and habitat suitability modeling to determine appropriate release sites for these endangered species. This demands the integration of numerous datasets that include elevation differences, vegetation cover, land use patterns, topographic characteristics, and stream locations. Without reliable and thorough geographical data, it is difficult to assess habitat suitability and make informed decisions on species reintroduction.

Furthermore, the project must deal with connections between environmental conditions and species requirements. Chiricahua leopard frogs, for example, rely substantially on aquatic ecosystems with certain water quality parameters and habitat configurations suitable for mating and foraging. Similarly, Northern Mexican Garter snakes have distinct environmental preferences, favoring riparian corridors and regions with abundant prey.

Moreover, the success of the reintroduction effort is dependent not only on selecting appropriate release sites, but also on addressing possible challenges and limiting dangers to newly formed populations. Human activities like land development and infrastructure expansion continue to threaten habitat integrity and species viability. As a result, effective conservation efforts must include steps to protect habitats, reduce anthropogenic impacts, and encourage coexistence between wildlife and human communities.

WorkflowTo begin developing a strong suitability model adapted for the reintroduction of endangered species in Saguaro National Park's diverse ecology, a systematic approach is required. The first phase requires a detailed specification of criteria that define appropriate habitat conditions for the selected species. In this scenario, the primary determinants discovered are vegetation cover type, distance to water sources, and height gradients. These parameters serve as the foundational pillars upon which the suitability model is built, providing critical guidance in determining habitat appropriateness and finding viable release sites.

Following the establishment of criteria, the next step is data preparation and cleaning, which is important for ensuring the accuracy and dependability of the suitability model. This entails converting qualitative data into numerical representations, which is necessary for quantitative analysis. For example, raster datasets displaying elevation are normalized by assigning numerical values, with 1 indicating the presence of favorable elevations and 0 indicating their absence within the regions of interest. Similarly, buffer evaluations are carried out to identify the proximity of possible release locations to water bodies, allowing for a better understanding of hydrological connection and its impact on habitat appropriateness. Furthermore, using the ArcPy Search Cursor, relevant keywords are extracted from vegetative datasets to distinguish locations defined by suitable habitat conditions.

With an effectively curated dataset in hand, the third phase is overlaying all relevant layers and integrating varied spatial datasets to build a comprehensive habitat suitability map. This technique allows for the discovery of locations where many criteria overlap, indicating ideal habitats for species reintroduction attempts. By combining spatial data on vegetation cover, water accessibility, and elevation, the suitability model provides important visualization into habitat suitability across the park landscape, allowing conservationists and decision-makers to make informed decisions about species management and habitat restoration initiatives.

The fourth step of the workflow focuses on finding and designating prospective release sites within Saguaro National Park. Candidate sites are identified using advanced spatial analysis tools and techniques, such as site suitability evaluations and habitat connectivity assessments, based on their alignment with defined criteria and potential to support viable target species populations.

**Data**For this project, Digital Elevation Model (DEM) data was downloaded from the United States Geological Survey (USGS) at a resolution of 1 arc-second. The two products, namely USGS\_1\_n33w111\_20240401.tif.aux and USGS\_1\_n33w112\_20240401.tif.aux that make up this high-resolution elevation data were used to assess the topography changes in Saguaro National Park and identify appropriate elevation ranges for the target species. Furthermore, stream line data covering the HUC 4 subregion was obtained from the USGS National Hydrography Dataset. The distribution of water bodies in the park was revealed by this dataset, which made it easier to identify aquatic habitats and gauge how close they were to water sources—both of which are essential for conducting an analysis of habitat appropriateness.

The National Park Service's Vegetation Inventory and Map for Saguaro National Park provided the vegetation data. The target species' appropriate habitat types and plant communities can be identified with the help of this dataset, which provides comprehensive information on the types and distribution of vegetation cover across the park. Comprehensive spatial analysis and habitat suitability models were carried out to support conservation efforts and species reintroduction methods inside Saguaro National Park by utilizing these heterogeneous datasets, which included DEM, stream line, and vegetation data.

In addition to the datasets mentioned previously, the boundary data for Saguaro National Park was acquired from the National Park Service as well. This boundary dataset delineates the extent of the park's jurisdictional boundaries, providing a spatial framework for all subsequent analyses and modeling efforts. By incorporating the park boundary data into the project, I was able to confine habitat suitability assessments and species reintroduction strategies within the designated park area, ensuring alignment with conservation objectives and management priorities.

**Data Processing**

As represented in Figure 2, the initial procedure of merging the Digital Elevation Model (DEM) data into a single feature using the Mosaic to New Raster tool was essential in ensuring the spatial dataset's coherence and consistency. This step made it easier to integrate and analyze elevation data across Saguaro National Park by merging various derived rasters from the USGS DEM model. Given the park's boundary divide into main and west sectors, raster data consistency was crucial to accurately depicting topographical differences and elevation gradients across the region. This unified DEM file eased subsequent data processing stages while also providing a thorough and cohesive framework for habitat suitability modeling and conservation planning efforts in the park.

Next, the USGS stream line data was clipped to the park boundary and buffered by 60 feet to improve habitat compatibility for amphibians and reptiles like frogs and garter snakes, who favor habitats with plenty of water resources.

Additionally, the vegetation polygon dataset was clipped to the park boundary using ArcGIS’s Clip tool. Subsequently, two new fields, "Snake" and "Frog," were created using ArcPy Management tool, to indicate suitable habitat conditions for the New Mexican Garter Snake and Chiricahua Leopard Frog, respectively. Both fields were initiated to have a value of 0 using the calculate field function in ArcPy. Then, the ArcPy Search Cursor tool (Figure 1) was employed to identify keywords within the vegetation class. Northern Mexican Garter Snake is considered a riparian obligate and tends to habitat near broadleaf deciduous forest and streamside gallery forest (U.S. Fish & Wildlife Service, 2021). In addition, Chiricahua Leopard Frog are often found in areas that is close to water with grass and wood vegetation (Jeff M., 2018). Therefore, if the keywords "Flooded," "Riparian," or "Floodplain" were present within the vegetation class, the update cursor assigned a value of 1 to both the "Snake" and "Frog" fields. Moreover, if the keywords "Quercus" and "Forest" were both present, the update cursor assigned a value of 1 to the "Snake" field. Similarly, if the keywords "Quercus" and "Woodland" were both present, the update cursor assigned a value of 1 to the "Frog" field. This process delineated suitable habitat areas for the target species based on specific vegetation characteristics.  
A white screen with text

Description automatically generated

Figure 1

Returning to the merged DEM, the Con tool within ArcGIS was applied to assign a value of 1 to elevations conducive to the target species' habitat preferences. For instance, elevations ranging from 1000 to 2790 meters (Platz et al. 1979, p. 384) (Figure 3) were deemed suitable for frogs, while elevations between 40 to 2590 meters (Rossman et al. 1996, p. 172) (Figure 4) were considered favorable for snakes. The resulting conditioned rasters were converted into polygons for subsequent overlay analysis.

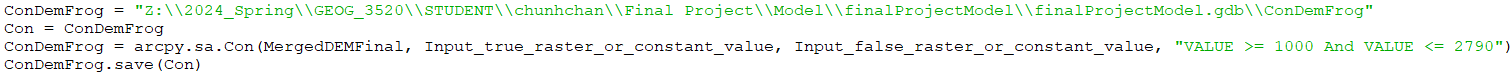


Figure 3

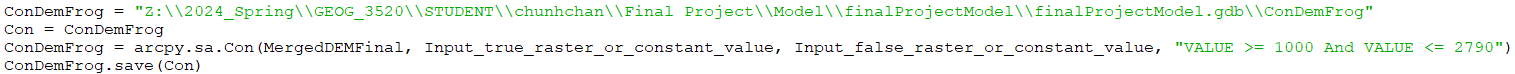


Figure 4

Lastly, all three layers—vegetation, stream lines, and conditioned DEMs—were overlayed using the intersect tool to find locations where both species' appropriate habitats intersected. The results, which identified possible habitat zones for the target species inside Saguaro National Park, were obtained by selecting areas with a value of 1 in the overlay analysis.**Results**

The habitat suitability analysis reveals that approximately 7,632 acres of land are suitable for reintroducing the Chiricahua Leopard Frog, accounting for approximately 8.35% of the total area assessed (Figure 5). The majority of suitable habitat areas are concentrated in the eastern part of the main Saguaro National Park. In contrast, for the Northern Mexican Garter Snake, approximately 3,746 acres of land are deemed suitable, representing approximately 4% of the total area evaluated(Figure 6). These findings provide valuable insights into the distribution of suitable habitat for both species within the park, facilitating informed decision-making and targeted conservation efforts aimed at restoring and enhancing their populations.

**Discussion and Conclusion**

This analysis suggests that further refinement of the model is necessary to account for specific habitat preferences, such as the affinity of Northern Mexican Garter Snakes for deciduous forests. With only 4% of the total park area deemed suitable for the snakes, additional efforts are needed to introduce deciduous forest habitats near streamlines to expand suitable habitat availability. Furthermore, strategic planning is essential to ensure the success of species reintroduction efforts. Given the predator-prey relationship between Chiricahua Leopard Frogs and Northern Mexican Garter Snakes, it is imperative to prioritize frog reintroduction and establish stable populations before reintroducing snakes. By adopting a phased approach and addressing habitat needs comprehensively, we can maximize the effectiveness of conservation efforts and contribute to the restoration and preservation of biodiversity within Saguaro National Park.

Our comprehension of the temporal variations in habitat suitability across time can be greatly improved by adding climatic data to the habitat suitability model. The model can reflect the dynamic nature of ecosystems and how they may change in response to changing environmental conditions by taking into account variables like temperature, precipitation, and other climatic elements. In the context of climate change, when abrupt changes in climatic patterns can have significant effects on the appropriateness of habitat for target species, this temporal perspective is especially important. In addition to Chiricahua Leopard Frog’s habitat, further effort need to be made in controlling the population of chytrid fungus. Chytrid fungus is known to threaten it’s habitat (Ellis, R. 2004). The conversation also emphasizes how crucial it is to use current data on vegetation cover when assessing the viability of a given environment, particularly in light of the quick changes in vegetation brought on by climate change. Making sure timely and reliable data is available is crucial for keeping an eye on any significant developments.

**Reference**

Davis, Tony (2024) Ecological restoration projects announced for Saguaro Park, other Arizona sites, tucson.com. <https://tucson.com/news/local/environment/usinterior-federal-financing-ecological-restoration-saguaronational-park-arizona/article_7a7c84e8-d02b-11ee-a79d-233764a1672f.html>

Ellis, R. (2004). No Turning Back: The Life and Death of Animal Species. New York: Harper Perennial. p. 187. ISBN 978-0-06-055804-8.

Jeff M. & Ian W. (2018). Leopard Frog Monitoring Protocol, Pima County Ecological Monitoring Program. <https://content.civicplus.com/api/assets/33bdb184-4748-42a9-9fc5-0adfcc984931>

Phoenix Zoo marks restoration of 10,000th frog to the wild. National Geographic (September 1, 2010). [https://web.archive.org/web/20100904165126/http://blogs.nationalgeographic.com/blogs/news/chiefeditor/2010/09/phoeniz-zoo-marks-restoration.html](https://web.archive.org/web/20100904165126/http:/blogs.nationalgeographic.com/blogs/news/chiefeditor/2010/09/phoeniz-zoo-marks-restoration.html)

Platz, J. E., & Mecham, J. S. (1979). Rana chiricahuensis, a New Species of Leopard Frog (Rana pipiens Complex) from Arizona. *Copeia*, *1979*(3), 383–390. <https://doi.org/10.2307/1443211>

Rossman, Douglas A. and Burbrink, Frank T. (2005) Species limits within the Mexican garter snakes of the Thamnophis godmani complex, Occasional Papers of the Museum of Natural Science, Louisiana State University : Iss. 79 , Article 1. <https://repository.lsu.edu/opmns/vol1/iss79/1>

**A diagram of a company

Description automatically generated**

Figure 2 (Workflow/Model)

**A map of a forest

Description automatically generated with medium confidence**

Figure 5

**A map of a snake in saguaro national park

Description automatically generated**

Figure 6