Habitat Suitability Modeling for Least Terns in Riley County

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Research Report

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Abstract

This report describes the process of modeling the Least Tern's, *Sternula antillarum,* habitat suitability map in Riley County, Kansas. Extensive literature reviews were conducted to determine the exact habitat preferences and requirements of the Least Tern regarding vegetation, hydrology, predation, habitat substrate, slope and human intervention. Data was found from a variety of sources that represented these factors. We then used the Multi Criteria Decision Analysis (MCDA) method to predict suitable habitat areas in Riley County (Kansas) of the Least Tern.

Further, we composed a weighted overlay analysis to predict suitability scores and generate a habitat suitability map of the Least Tern. After generating our model, we validated our model with the Kolmogorov Smirnov test, which is a Cumulative Distribution Function, followed by histograms of the bird's suitability scores. With the MCDA model, we found that a total of 9% of the area in Riley County is suitable for the Least Tern habitats, which are generally found near the streams and Tuttle Creek Lake.

Introduction

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"Habitat selection is the product of a complex suite of selective pressures and behavioral choices" (Catlin et al., 2019). Birds will look for a location that will protect them and their potential offspring (Catlin et al., 2019). There are many different factors that contribute to how a bird will select a habitat, and every species has different requirements and preferences. For Least Terns habitat selection, there were common factors found important throughout different research studies. These factors include vegetation cover, protection from predators, peak flows, water depth, sandbar characteristics, and availability of food.

Habitat Factors

Vegetation

The presence of vegetation plays a significant role in nesting selection for Least Terns. They prefer areas that have little vegetation (Catlin et al., 2019). Ideally, Least Terns prefer areas that have less than 20% vegetative cover (Noble, 1994). In addition to not liking the area where they have their nest to be heavily vegetated, they also prefer not to have any other tall shrubs or trees nearby. It has been found that Least Terns don't often nest within 150 meters of shrubs or trees over 2 meters in height (Lott et al., 2013). Least Terns prefer little vegetation to avoid predators that perch or live in vegetated areas like forests (Lott et al., 2013). Further effects of predation on Least Tern nest selection sites will be discussed in the following section.

Predation

Least Terns choose nesting areas that are farther from their predator's habitat (Catlin et al., 2019). Multiple studies have found that predation is the main cause of nest failure (Catlin et al., 2019). For Least Terns to have the highest chance of survival for its nest it is imperative that the nesting site is the farthest away from predation. To accomplish this, one thing they do is nest away from vegetation or trees that predators could live in or perch on, as discussed in the previous section (Lott et al., 2013). Additionally, the Terns tend to select sandbars that are islands instead of attached to the shore (Catlin et al., 2019). This helps reduce predators as some won't be able to access the islands by swimming or flying. So, Least Terns select nesting sites to reduce the risk of predators.

Recreation:

Distances from recreational sites affect Least Tern nest site selection, as well as the probability of nest survival or nest flushing. Both direct and indirect human contact can be detrimental to Least Tern nest survival overall, but direct human impact is the only measurable aspect we can account for in modeling.

When it comes to direct human interaction, the problem lies in that Least terns tend to nest in sandy, gravel, or shell-lined areas with little vegetation, and often beaches near water which unfortunately end up being near a lot of recreational foot traffic (Zuria, 2002). In many studies where human presence is measured on the impact it has on Least Tern nesting sites, it is found that many terns end up abandoning their nests due to the constant human presence, and many terns may even abandon their nests and move to a less favorable habitat to nest in order to avoid tourists camping, golfing, and letting their dogs run along the beach (Zuria, 2002). In another study where certain tern nests on a busy were protected by wire fences, while others weren't, 71% of nests were destroyed by people or predators as opposed to a 91% nest success rate when the nests were fenced off (Vaske, 1992). ORV usage and off-leash dogs in nesting sites represent an issue, but when humans themselves end up getting too close, this has been shown to result in the highest number of birds flushing from the nests, leaving eggs vulnerable, resulting in decreased productivity and species decline (Vaske, 2013).

When it comes to a proper buffer zone for Least Tern nests from recreational areas, many of the restrictions vary. A report by the Atlantic Flyway Shorebird Initiative recommended a buffer distance of 100 m for terns (Mengak et al., 2019), A study done in Florida found a buffer distance of 180 m for terns to be ideal (Rodgers & Smith, 1995), and another study found the buffer to be around 140 m (Rodgers & Schwikert, 2002). Therefore, a buffer zone of around 140 meters (an average of the three buffer zones) from recreation zones was decided to be the ideal parameter for distance from recreation zones for modeling.

Hydrology

Various aspects of hydrology also affect the selection of Least Tern nest sites selection. Least Terns specifically nest near lakes and rivers that have a wide width, as well as rivers that have slower flow and occasional flooding. Therefore, human influences on natural river flow can also influence Tern's nest in the area.

Least Terns prefer wider rivers for their nests. The occurrence of nesting Terns, as well as stopover site usage, increases significantly with increasing width of channels (Brown, et al, 2012). This is related to avoiding predators, as wider rivers would allow for more islands and further distances from the shore to reduce access for predators. The most preferred width of river channels was at least 300 meters wide (Lott et al., 2013). Having a larger channel width also means the nests will be farther away from vegetation and trees on the river's banks. So, this helps satisfy the want of Terms to be away from vegetation. Terns have been found nesting on more narrow rivers if vegetation has been removed from the banks, for instance if there is farming on the bank that has removed trees to plant crops (Lott et al., 2013). This allows the Term to be away from vegetation to avoid predators. When examining where Terns nest, it has been observed that 150 meters wide is usually the minimum channel width where terns have been found nesting (Lott et al., 2013). Having wider channels is preferable for nest sites for Least Terns as it helps them avoid predation.

The flow and history of flooding will also be influential as Least Terns will nest on the river. This is because flooding gets rid of vegetation that may be growing on sandbars (Busby et al., 1997). And as discussed, Least Terns prefer to nest on sandbars that have limited vegetation growth. Terns are adapted to begin their process of nesting and hatching after peak flows have subsided and riparian areas are exposed in the Spring (Baasch, et al, 2016). However, as flooding decreases and vegetation grows, the habitat will become less desirable for nesting. This has happened with human influence and modification of rivers. Primarily through the construction of dams (Lott et al., 2013). Dam construction alters the natural flow of the river, which can also cause vegetation encroachment onto the sandbars used for nesting (Busby et al., 1997). So, human alternation of river flows and dam construction will affect the presence of Least Tern nests on that river as they may not nest due to the increase of vegetation downstream of the dam.

This can be seen in Figure 1. Images were taken of a section of The Missouri River downstream from the Gavins Point Dam at two separate times (Lott et al., 2013. Image A shows the location in 2005 with an absence of high flows (Lott et al., 2013.There had not been a high flow in 8 years, as the dam had not been released since 1997 (Lott et al., 2013. Image B shows the same area in 2001 after the dam upstream had been released earlier that year (Lott et al., 2013).

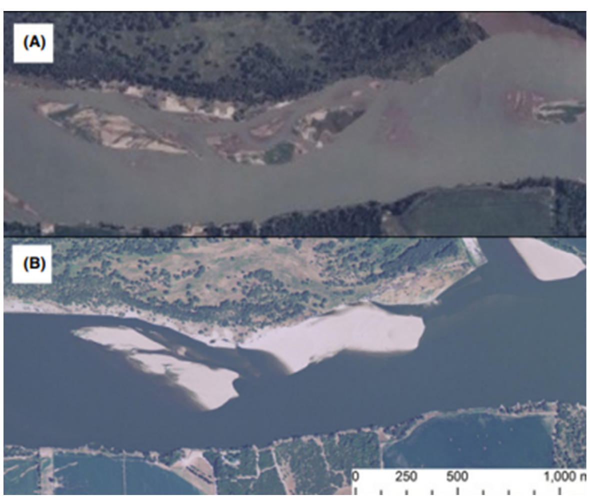

Figure 1. Showing vegetation encroachment from the absence of high river flow due to damming. (Lott et al., 2013)

The birds also prefer rivers with a higher flow and water level. This is because having a higher water level makes it harder for predators to reach their sandbar (Szell & Woodrey, 2003). This is because if the water was lower, a predator may be able to walk or wade through the water to reach the nest, but if the water level is higher, the predator will have to swim and fight a current or fly to reach the nest. So having a higher water level and flow will reduce the number of predators that can access the sandbar and nest.

Sandbars

While flooding can be beneficial to Least Terns to remove vegetation from sandbars, having a nest flood is detrimental to the nest's success. So, Least Terns will pick sandbars that minimize the chance of their nest being flooded. To do this, Least Terns will select sandbars composed of more dry, than wet sand (Catlin et al., 2019). The birds do not want to nest on wet sand as that can ruin their nests and means it could be breached by the river and flood their nest. Additionally, Least Tern nests are typically found at least 200 meters from the water (Conway et al., 2003). This gives the nest a better chance of survival if the river floods. Further, Least Terns prefer sand bars composed of sand and gravel (Conway et al., 2003). The sand substrate is used to create the scrape nest type of the Least Terns (Conway et al., 2003). As found in a study of Least Terns nesting on the Prairie Dog Town fork of the Red River in Childress County Texas by Conway et al. (2003), all the Least Tern Nests that were found in the area were on sand or gravel. The majority were on sand (Conway et al., 2003). So, the birds are less likely to nest on an island or bank if it is not composed of sand.

Nesting parameters	Least tern nests
Total number of nests (n)	20
Successful nests (n)	13
Abandoned nests (n)	2
Nests with unknown status (n)	5
Raw nest success (%)	65
Mayfield estimate (%)	70.7
Clutch ($\bar{x}$)	2.25
Range	1–3
Nests located on gravel substrate (n)	5
Nests located on sand substrate (n)	15
Nest dimensions (north to south) (cm) ($\bar{x}$)	9.7
Nest dimensions (east to west) (cm) ($\bar{x}$)	10.2
Nest depth (from nest rim to nest bowl bottom) (cm) ($\bar{x}$)	1.9

Figure 2. Showing different nesting parameters of Least Tern nests, including the substrate the nests were found on (Conway et al., 2003).

And as previously discussed, they prefer sandbars with little to no vegetation, wide or high enough to allow the nest to be away from water and on a river or body of water with a high-water level.

Methods

Data Collection

For this project, we gathered data from various sources and then used MCDA to create habitat suitability map. Sources for this data include the U.S. Geological Survey for the tree canopy cover and land use and land change data. The soil data was collected from the U.S. Department of Agriculture's Gridded Soil Survey Geographic (gSSURGO) Database. The stream data and slope data were from the Kansas Applied Remote Sensing Program (KARS). The recreation, waterbody, and Riley Country boundary data were from the Riley County Geography Information System office.

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Data Preparation

For this project, data was projected into NAD 1983 UTM Zone 14N. Data was also masked or clipped by a shapefile of our study area, Riley County. Reclassification and weighted overlay analysis was done to create the habitat suitability model. A one-to-five system was used, with one being the least suitable and five being the most suitable.

Hydrology

First, both stream shape files were projected into NAD 1983 UTM Zone 14N. Then we merged both files, one being stream orders one and two and the other three through nine to have one file with all the streams. This file was then clipped to our study area. Then, the Euclidean distance tool was used to create a file representing distances away from the streams. After, we used the reclassify tool to assign values of one to five to the distances from the stream. This was done using data collected in our literature about the preferences of Least Terns with water. The birds need to be close enough to water to have a forage source but also need to be far enough away not to have their nest flooded.

A shapefile containing all other water bodies in Kansas like lakes and ponds, was used to include all hydrology features in our analysis. This file was also projected and clipped. Then the Euclidean distance tool was again used to find the distance away from these water features. Then, the file was reclassified with the same parameters as streams.

Recreation Areas

The golf course and park shape files were merged, projected, and clipped. The Euclidean distance tool was used to find the distance away from these recreation areas. Then the distances from these recreation areas were reclassified. Zero to 50 meters away were assigned a value of one. 50 to 80 meters was two, 80 to 120 was three, 120 to 140 was four, and greater than 140 was five.

The other recreation data, disc golf courses and recreation facilities were merged, projected, clipped, processed with the Euclidean distance tool, and reclassified in the same manner as the golf courses and parks. The same reclassification scheme was used as golf courses and parks. The trail data was also projected, clipped, ran through the Euclidean distance tool and then reclassified. It was also reclassified using the same parameters as the other recreation features.

All the recreation features could not be merged into one file because they were different geometry types. The golf courses and parks were both polygon feature classes, the disc golf and recreation facilities data were point feature classes, and the trails was a line feature class.

Sand and Gravel

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The sand and gravel datasets were extracted by mask to Riley County as raster files. Once the files were in the raster format, they were reclassified to fit the data values found in our literature. The data was then processed to obtain only the gravel and sand areas in Riley County that were 75% sand and 25% gravel. Any soil that fits 80 to 95 percent sand was assigned a 5; soil that was composed of 60 to 80 percent sand was given a 4; soils that fit 40 to 60 percent were given a 3; soils from 20 to 40 received a 2, and lastly, 0-20 was assigned a 1.

Slope

The slope dataset was extracted by mask of Riley County and then projected to change the dataset from degrees to meters. Once the DEM dataset was calculated in meters, it was reclassified in categories of 1-5. Any data point that was classified as a change from 0-10 meters was labeled as a 5; for a change of 10-20 meters, it was labeled as a 4; a change from 20-30 was labeled as a 3, for a change from 30-40 meters the data was classified as a 2, and for any change that was 40-100 it was labeled as a 1.

Vegetation

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The select layer by attribute tool was used to select certain land use/cover types that were categorized as vegetation. The categories deciduous forest, evergreen forest, mixed forest, woody wetlands, emergent herbaceous wetlands, and shrub/scrub herbaceous were selected from the land use data for our vegetation data. Additional classes were added for each category with the "or" Boolean operator. The data was then clipped to our study, reprojected, and reclassified. Zero to one meter from vegetation was classified as one, one to 50 was two, 100 to 150 was four, and greater than 150 meters was five.

Weighted Overlay

Finally, we used the weighted overlay tool, where different weights were assigned to each of the variables based on the findings from our literature review. Distances from recreation areas were weighted at 15 percent, vegetation was weighted at 16 percent, and the distance from the water was weighted at 17 percent; slope was given a weight of 16 percent, the substrate, which included sand and gravel, was given a weight of 36 percent. The results from weighted overlay analysis created a layer that was then masked with unsuitable land, which included urban areas and water bodies, to increase the accuracy of the final map.

Results and Discussion

Based on our model, the most suitable habitat for Least Terns, is by Tuttle Creek Lake and along the Kansas River. This is to be expected, as this area has the proper amounts and depths of water, as well as having the correct substrate for nesting and stopover locations. The map of Riley County broken down into the habitat suitability for Least Terns, can be seen in Figure 3. This map was then analyzed further to find the percentage and area of Riley County that fit into each suitable ranking one to five. This is shown in Figures 4 and 5. For class five, the most suitable class, there are 300.42 hectares in Riley County. For class four there is 13,738.85 hectares; three has the highest amount of area with 127,150 hectares. Classes one and two have relatively insignificant areas comprised of 0.24 and 2842 hectares. The suitability scores 4 and 5 highlight the areas that are moderate to highly suitable for Least Tern habitats, and scores from 1 to 3 are the areas less suitable for habitat. We found that 9% of the total area of Riley County is moderate to highly suitable for Least Tern nesting sites (Fig 4 and 5).

The majority of Riley County is classified as less suitable for Least Terns. This is unsurprising as there is not an overwhelming amount of water bodies in this area. However, in the areas surrounding Tuttle Creek and the Kansas River, there are portions of land that are suitable and should therefore be protected. These areas could provide critical habitat and stopover sites for this species, protection and conservation of these lands will be discussed in greater detail below.

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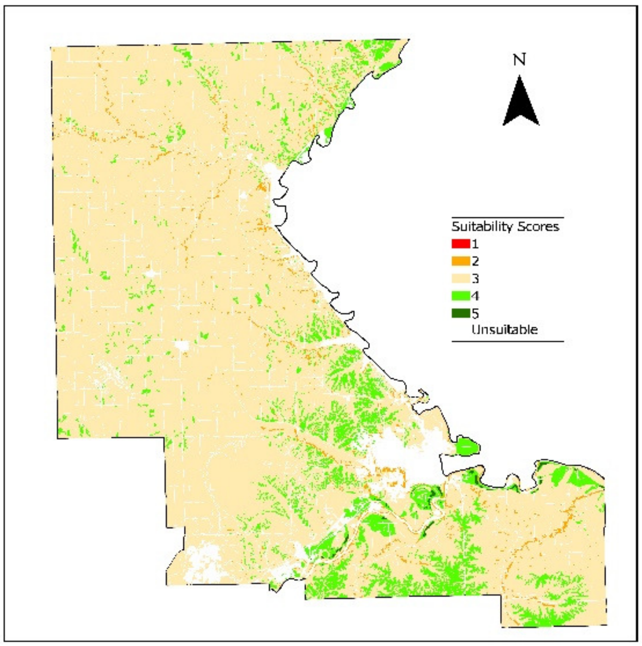
Habitat Suitability Map of Least Tern



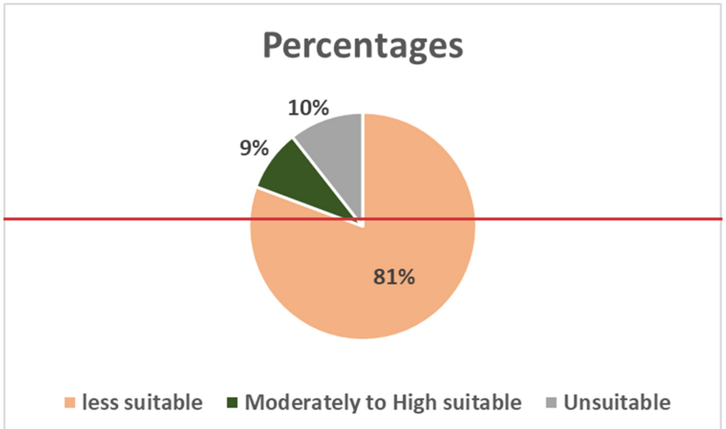


Figure 3. Final habitat suitability map of Least Terns

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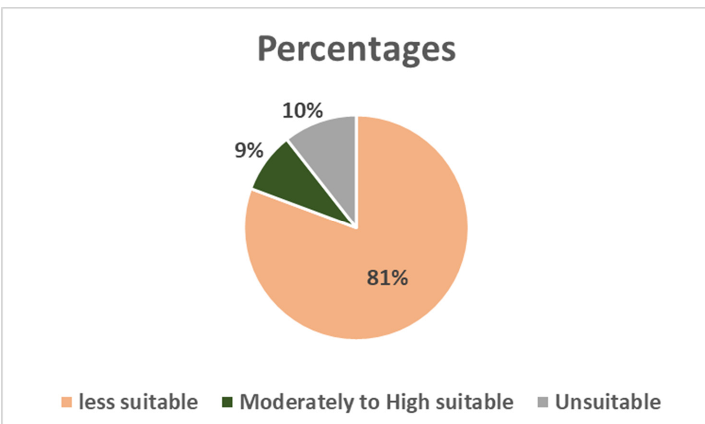

Figure 4. Percentage of suitability classes

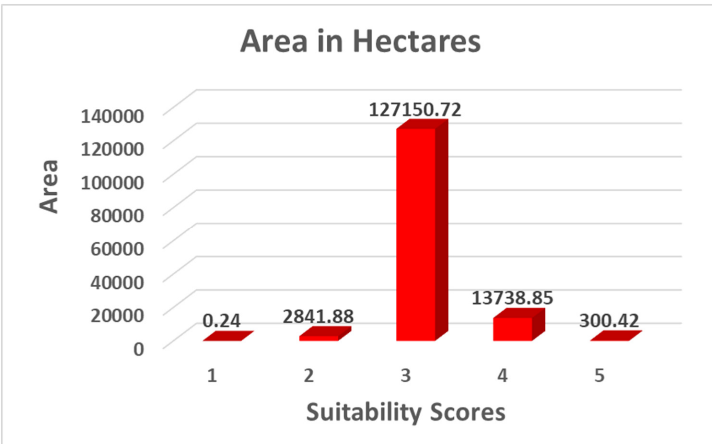

Figure 5. The area of each suitability score from the final habitat suitability map in Riley County.

Accuracy

The first test that was run to determine the accuracy of this model was the Kolmogorov-Smirnov (KS) test. In a KS test, our null hypothesis was that the bird's suitability scores distribution is the same as suitability scores for random distribution, and the alternative hypothesis is that these two distributions are different. To test our hypothesis, we performed the KS test. In our model, we found that our p-value is 2.2e -16, which is less than our level of significance, which is 0.05. So, we reject the null hypothesis and conclude that the distribution formed from the suitability scores of the bird data is significantly different from the distribution formed from the suitability scores of the random data. Further, we ran the cumulative distribution function to create a graph for our birds and random data points (Fig. 6). The cumulative distribution function (CDF) is a function that examines the probability of an x-given value randomly being less than or equal to a given value.

Our CDF graph explains initially how the cumulative frequency of the suitability scores of bird data is less than the cumulative frequency of the suitability scores of random points, and finally, the cumulative frequency in the case of the bird data was higher than random points. This comparison validates our model in terms of higher accuracy. Finally, we compare the histograms of the suitability scores of the birds' points with the random data. In the histogram, we found that higher observations of our birds' points were found in higher scores, which further validates our model in terms of higher accuracy (Fig 6 and 7).

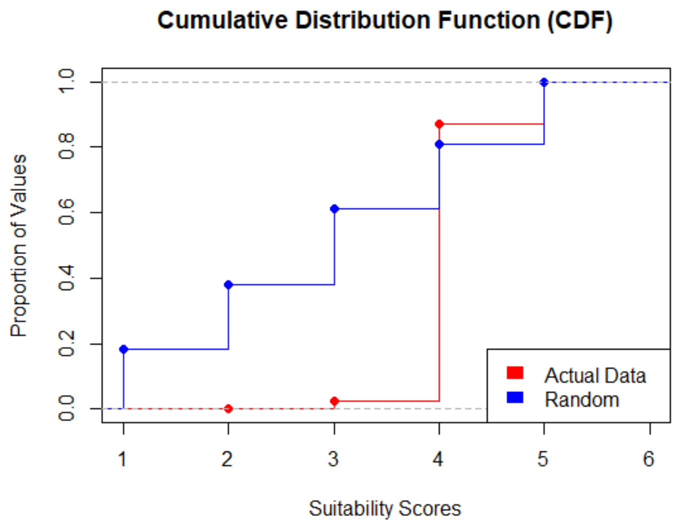

Figure 6: The Cumulative Distribution Function (CDF) graphing suitability scores to proportion of value.

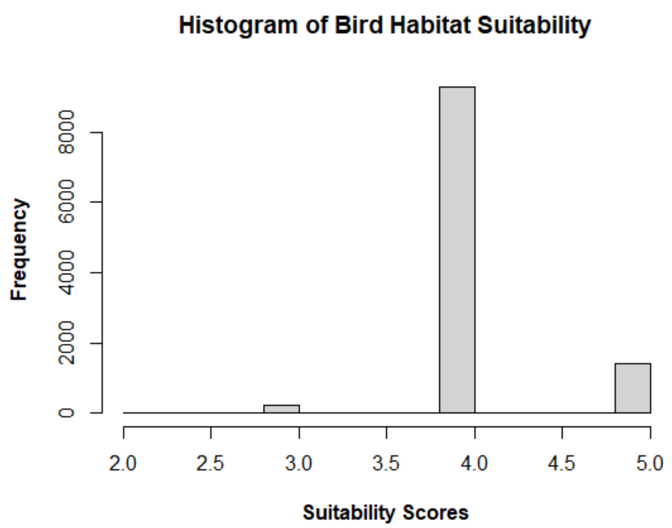

Figure 6: The histogram of bird habitat suitability graphing suitability against frequency.

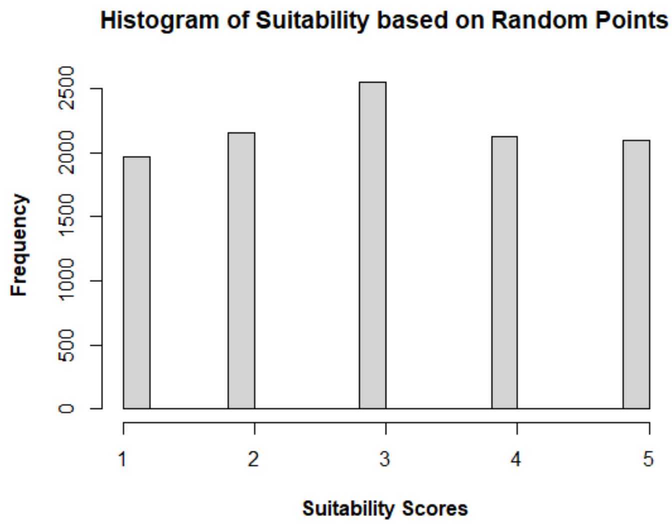

Figure 7: Histogram of random generated points with suitability against frequency.

Conclusion

Limitations

One limitation of this study is that the only bird data available was bird observation locations from eBird. There was not a comprehensive collection of Least Tern nest sites in Riley County that would have been more accurate for our purposes. Due to when this study was conducted, in the fall, it was also not possible to go into the field and locate nests when the birds are nesting in the early summer. In future studies, therefore, it would be beneficial to collect field data of nest locations in the county to increase the accuracy of our model.

Accuracy could also be improved with further research done on the preferences of the birds. There was not a clear threshold of when the birds were disturbed by different kinds of recreation. The preference that the birds want to be away from recreation could be improved with more research into different types of recreation activities. The map could then be improved by classifying the recreation areas into the different recreation activities and the corresponding distances used.

Conservation

It is important to consider nesting habitat when working on the conservation of species. Because without an adequate habit to nest, there will not be an increase in the number of the species. Conserving prime habitat for nesting will increase the likelihood of nest success and an increase of individuals in the population.

For Least Terns, human modification of nesting habitat is the greatest threat to their stability and future success (Schulenberg & Ptacek, 1984). This comes from constructing dams and other methods of altering river flow and flood prevention, and the extensive use of water that drains rivers and lowers the water table (Schulenberg & Ptacek, 1984). As discussed, the birds need flooding and prefer highwater levels around their nesting site. So, with these factors, the nest sites will become less preferable and easier to access by predators, consequently increasing predation. Additionally, increased anthropogenic climate change will decrease Least Terns habitat range as forested areas become more pervasive and bodies of water decrease. (Dobson, 2007).

To preserve the preferred nesting habits, river flow should be restored, and invasive woody vegetation should be removed in riparian habitats (Conway et al., 2003). Partnerships between Wildlife and Parks and the U.S. Army Corps of Engineers should be encouraged to facilitate timely flow releases from large water impoundments. The control of invasive woody vegetation will reduce the cover and perching options for predators, again satisfying the preference of the bird to nest away from vegetation and reducing the risk of predation.

Overall, understanding what a species wants in its breeding habitat and how the habitat is selected is significant in species conservation (Catlin et al., 2019). A greater understanding will allow for the preferred habitat to be conserved to offer the highest possibility of reproductive success. If we had a wider understanding of exactly where Least Terns preferred to nest this could be factored into all dam, housing, and energy development considerations and greatly increase their rates of conservation.

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