ASSESSING BREEDING OWL SPECIES DISTRIBUTION WITHIN LOS ANGELES

Client: Friends of Griffith Park

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Abstract

For our Senior Practicum in the UCLA Institute of Environment and Sustainability (IoES) Environmental Science Program, we conducted research on breeding owl species for our client, the Los Angeles (LA) Raptor Study, a program of Friends of Griffith Park. The LA Raptor Study is a community science-based study of nesting raptors in the LA area. By documenting and tracking raptor nests across Los Angeles, the study aims to understand how ecological dynamics change from year to year in the natural and built areas of Los Angeles. The study, now in its eighth year, includes three species of owls that breed in the area, Great Horned Owl (*Bubo virginianus*; GHOW), Barn Owl (*Tyto alba*; BNOW), and Western Screech-Owl (*Megascops kennicottii*; WESO). Due to their nocturnal activity and more cryptic nest sites, data on these species have been more limited than the hawk species in the study. Our project focused on augmenting existing data on local breeding owl species to fill in knowledge gaps for the Los Angeles Raptor Study, through a combination of field surveys and species distribution modeling. Our project was built upon methods developed in a related Los Angeles area study. We utilized presence-only data to build our own model that predicts species distribution based on suitable habitat to analyze biodiversity variables and identify environmental factors that have strong correlations with the habitats of our studied owl species.

Introduction

Raptor Background

Raptors, or birds of prey, are hypercarnivorous bird species that actively hunt and feed on other vertebrates and insects. The term "raptor" traditionally refers to species of the order *Falconiformes* (eagles, falcons, hawks, etc.) and *Strigiformes* (owls) (Fuller & Mosher, 1981). More recently, the definition was expanded to include species within orders that evolved from raptorial land birds (*Telluraves*) that still maintain raptorial lifestyles (McClure et al., 2019). As top predators, they exert top-down control over the food chain, which means they play an important role in maintaining ecological balance by regulating prey populations such as pests and rodents. Thus, a decline in population or their disappearance from an ecosystem could lead to cascading effects. In addition, they are ecological indicators, meaning their health reflects their environment's health (Buechley et al., 2019). Furthermore, their long cultural relationship with humans, whether through spiritual significance in indigenous cultures (Negro, 2018), or utility such as pest control (Donázar et al., 2016) or educational purposes, has cemented these enigmatic creatures as an important symbol for Los Angeles.

Several species of raptors breed in and around urban Los Angeles, including several whose local ecology remains poorly known. We have focused our practicum work on two of these more poorly understudied species, the Barn Owl and Western Screech-Owl, and we have also included the better-known Great Horned Owl in our analysis as we studied the nesting owl community of Los Angeles.

Project Background

To preserve biodiversity in a time of urban expansion, it is key to prioritize understanding environmental variables that allow raptor species to thrive, tolerate, or merely survive. Our project aims to identify and address gaps in the Los Angeles Raptor Study, a community science program launched by Friends of Griffith Park in 2017. The LA Raptor Study is a community science-based study of nesting raptors, now in its 8th year, with over 200 volunteers this year alone. The purpose of the survey includes studying the urban adaptation of raptor species, developing baseline population estimates for nesting raptors, and assessing population trends. With this project, over 800 hawk and owl territories have been located and over 700 nests monitored across LA.

However, there are still significant gaps in data when it comes to the most understudied species in the area, including several owl species, which may hinder effective conservation efforts. Due to the need for more data on owls in the study area, we have focused on understanding the breeding owl species distribution within Los Angeles. Specifically, the focal species of our practicum are the Barn Owl and Western Screech-Owl species. Further, as the Great Horned Owl has a wide distribution across the LA Basin, and thus was present in many of the sites we visited, we included any sightings as part of the report.

Significance & Justification

In the Los Angeles area, the more cryptic raptor species include both the Barn Owl and Western Screech-Owl. Due to the lack of research on their habitat ranges in the LA area, many conservation efforts tend to fall short of protecting their habitats and therefore these raptors may be at higher risk for displacement. Over the years under the Los Angeles Raptor Study, there have been more than 80 Great Horned Owl nests found. By contrast, there have only been a couple of confirmed Barn Owl nests, and no confirmed Western Screech-Owl nests. By helping support efforts to locate these birds and their nesting sites, we can help bridge a gap in their species distribution and gain more knowledge of their nesting behavior.

Raptors have important ecological roles in their ecosystems, however, human development has changed their relationships within local ecosystems. Barn Owls and Western Screech-Owls are nocturnal species and secondary cavity nesters (nest in holes in trees), with limited nest data surrounding them in the current LA Raptor Study. Nocturnal surveys are harder to conduct and cavity nests are more difficult to locate. The long-term monitoring and tracking of these owls is thus imperative to increase our understanding of these populations and their nesting biologies. Additionally, furthering our understanding can help guide appropriate conservation efforts and enact measures such as local guidelines for tree trimming and habitat restoration. Interventions can be implemented to prevent their displacement and to protect priority habitats such as oak woodland, and key habitat features such as mature trees, snags (dead trees), palm skirts, etc.

Research Questions

We aim to address and increase our knowledge of these lesser-documented species in the Los Angeles Raptor Study by asking:

1. What is the population distribution of Barn Owls and Western Screech-Owls in Los Angeles?
2. What are the key environmental factors that correlate with the suitability of habitats for these cryptic LA raptor species?

Methods

Due to the significant gap in the less studied owl species in the Los Angeles Raptor Study, our project focuses on understanding the population and habitat of Barn Owls and Western Screech Owls. As a means to coordinate for effective results, our team split into two groups – a modeling team and a fieldwork team. As our team was made up of 8 students, each team consisted of 4 students. The modeling team utilized the programs MaxEnt and Random Forest to create habitat suitability models for each of the two focus species in our study area and then compared the two programs for accuracy. Alongside utilizing these predictive programs, the modeling team would inform the fieldwork team of potential presence and/or absence areas for each species. With this information, the fieldwork team surveyed multiple locations throughout the study area over the course of 10 weeks, playing species calls at each location to confirm presence and/or absence. Afterward, the fieldwork team would inform the modeling team of presence and/or absence so that they would have a better understanding of the model's accuracy. The fieldwork team was integral to ground-truthing the MaxEnt and Random Forest models, and ensuring that the models being created were useful. The fieldwork team further contributed to the LA Raptor Study as a whole by either discovering or monitoring a variety of nests within the study area. In addition to modeling and fieldwork, a revitalized map of the study area was created (Figure 2).

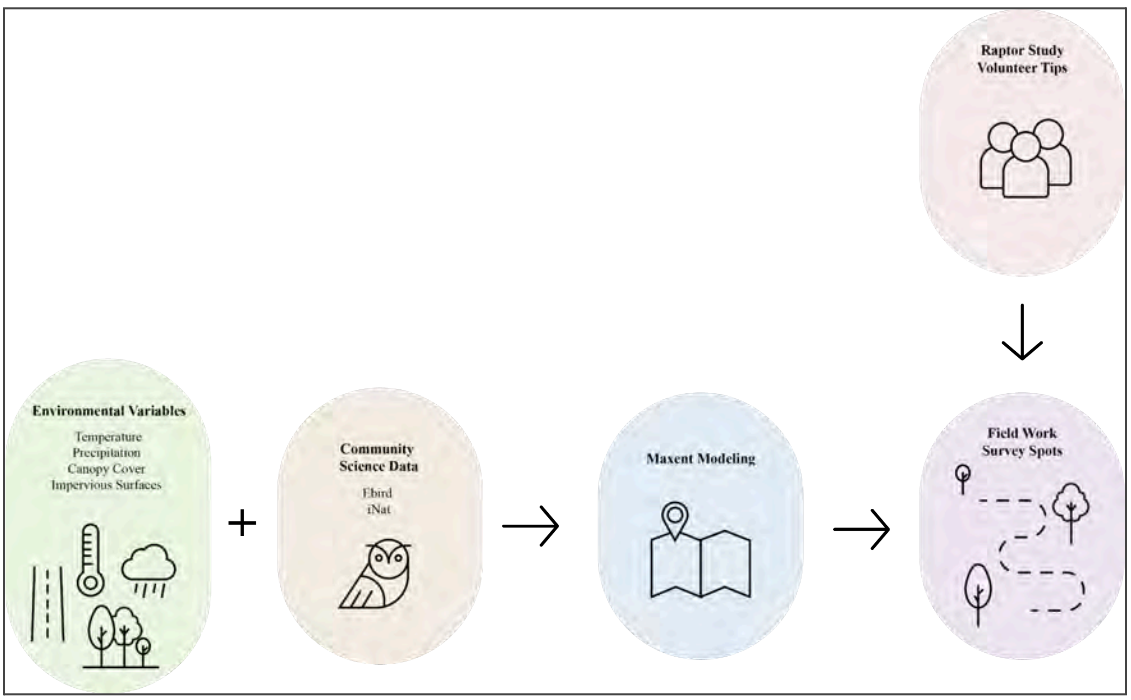

Figure 1. Provides an overview of the workflow of our project

Study Area

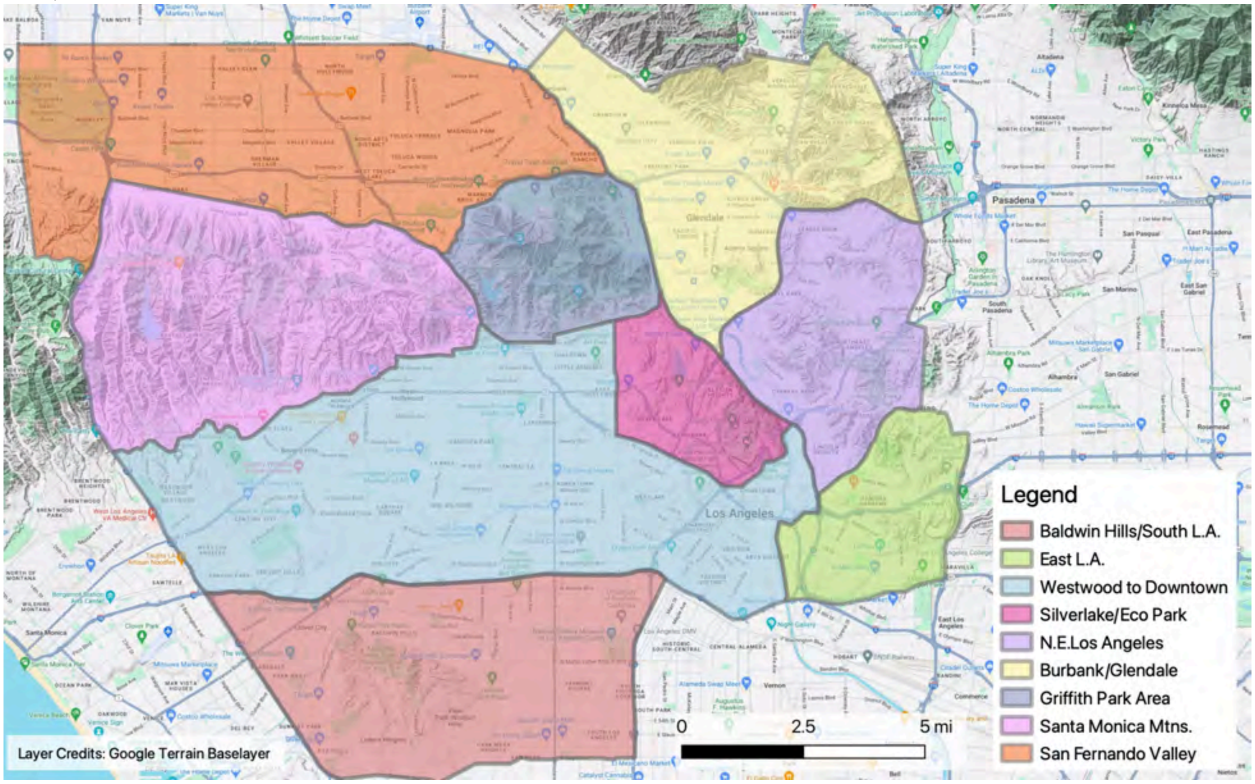

Figure 2. The LA Raptor Study Area

Previous to the formation of this research group, the LA Raptor Study determined and adopted a defined study area. Figure 2 displays the various neighborhoods in which nest monitoring for the LA Raptor Study occurs, and it is broken up into sections for better coordination. We utilized QGIS to create a proper map of the study area as a deliverable to our client. We not only created polygons for each section but also created shapefiles of the polygons merged together and added borders for the region. The digitization of the study area will further help the LA Raptor Study with the monitoring and reporting of their surveys and nest monitoring.

Modeling

<u>MaxEnt</u>

To predict suitable areas to conduct surveys for elusive owls like the Barn Owl and Western Screech-Owl, we used the program MaxEnt to create habitat suitability models to help predict where we could locate the owl species. MaxEnt is a program that utilizes presence-only data to create a model to predict a species distribution based on suitable habitat (Elith et al., 2010). Our models used the Greater Los Angeles (GLS) study area from the Beninde et al., (2023) study to analyze biodiversity variables and identify environmental factors that have strong correlations with the habitats of our studied owl species. Presence records between 2013-2023 were collected from Ebird and iNaturalist and environmental layers were derived from WorldClim files and published data from prior analyses (Beninde et al., 2015).

The environmental variables we used included climatic and geographic variables, such as temperature, precipitation, and canopy cover, and certain anthropogenic factors like population density and imperviousness (as an indicator for urban development). The maps showcased in Figure 3 are some bioclimatic variables mapped in the LA Raptor Study Area. These environmental variables came from two sources: bioclimatic variables from WorldClim, a set of global climate layers with a spatial resolution of 1km, and LA Biodiversity HSMs, variables developed to investigate native and non-native species in the Greater Los Angeles Area (all variables listed in Appendix C).

Different parameters and settings were tested on MaxEnt to better fit the data. The final maps (Figures 6 & 7) were run using a 5-fold cross-validate (CV) with a reduced number of variables. After the multiple habitat suitability models were processed and created, we overlaid the results utilizing QGIS to better identify the suitable regions within the study area. We also used QGIS to make the maps visually appealing by applying color gradients and smoothing out the more pixelated raster data from MaxEnt (the list of variables used in the final maps and detailed methods and modeling process are described in Appendix C).

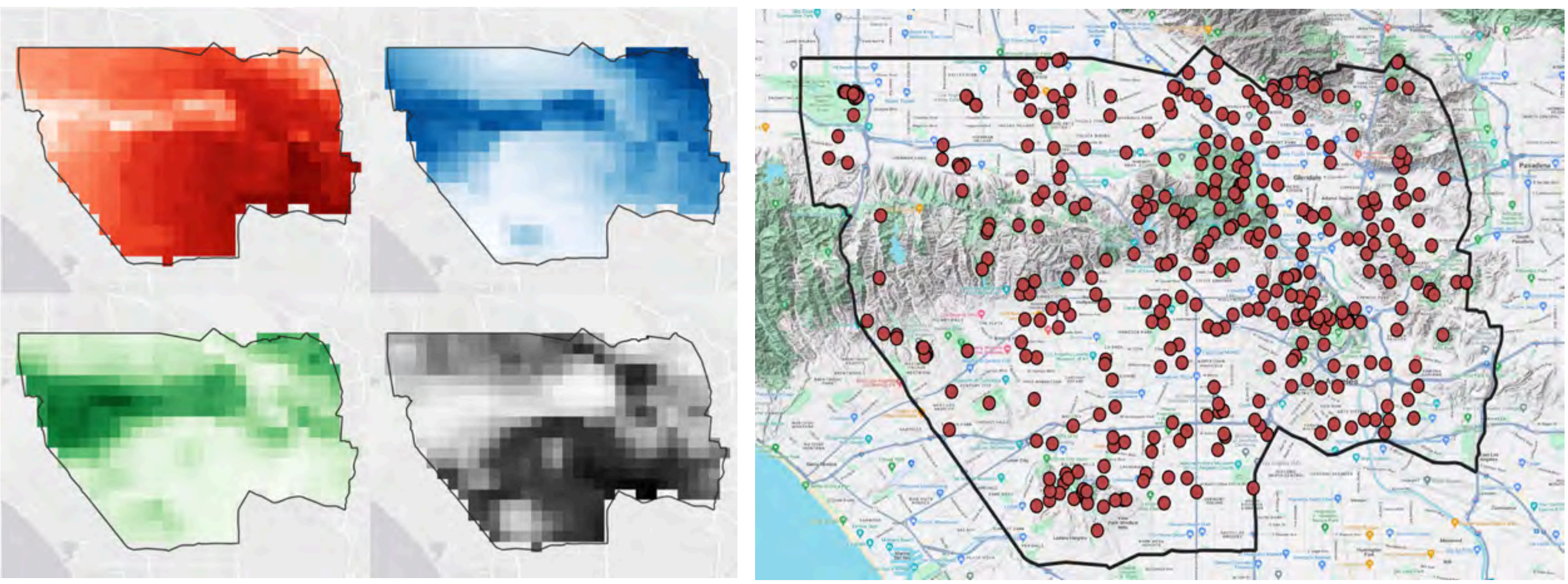

Figure 3. An example of the environmental layers used as inputs for MaxEnt habitat suitability modeling (left). From top right to top left clockwise: mean annual precipitation, impervious surface, canopy tree cover, and mean annual temperature (source: Dr. Ryan Harrigan). An example of presence-only data from iNaturalist and Ebird is shown on the right of the figure. Each point indicates the presence of a Great Horned Owl.

<u>Random Forest and Pearson's Correlation Coefficient</u>

We also utilized Random Forest modeling to identify habitat suitability. This method helps determine the environmental conditions that favor the presence of raptors by utilizing multiple decision trees that merge their results to improve accuracy. This method allows us to identify which environmental variables are most influential in determining the presence or absence of a certain species. Random Forest modeling requires both presence and absence observation data from raptor sightings and environmental variables for each point of observation data. We utilized QGIS to create random absence points and acquired our presence records from Ebird and iNaturalist. The environmental variables used were the same variables used for our MaxEnt Models.

For data preparation, which includes compiling the data into a structured format, we used QGIS functions such as the random points in layer bounds tool and point sampling plugin. Figure 4 indicates the structure used in the comma-separated values (CSV) files. We used BBedit software to clean the CSV files by handling missing values and ensuring data quality.

species	lat	lon	non_native_species	non_native_plant_sp	non_native_plant_sp	non_native_chordat	non_native_arthropo	native_species_706
1	34.010563	-118.053637	0.45661	0.43966	0.43966	0.46931	0.49353	0.30085
1	34.10674	-118.32126	0.4696	0.40727	0.40727	0.51992	0.65068	0.24426
1	34.083851	-117.798612	0.3222	0.33415	0.33415	0.39408	0.25207	0.37747
1	34.197225	-118.669744	0.15022	0.17903	0.17903	0.05762	0.1169	0.33216
1	34.195804	-118.669547	0.15022	0.17903	0.17903	0.05762	0.1169	0.33216
1	34.177605	-118.420708	0.47326	0.4296	0.4296	0.51442	0.59556	0.24542
1	34.179557	-118.479784	0.45152	0.46813	0.46813	0.49323	0.38839	0.43149
1	33.827667	-118.342984	0.46801	0.39631	0.39631	0.58904	0.61354	0.38825
1	34.104914	-118.06031	0.41084	0.36547	0.36547	0.44119	0.52529	0.19911
1	33.878395	-117.812664	0.43592	0.4794	0.4794	0.30477	0.36283	0.30366
1	33.878395	-117.812664	0.43592	0.4794	0.4794	0.30477	0.36283	0.30366
1	34.191179	-118.842236	0.3115	0.32839	0.32839	0.2135	0.31547	0.32142
1	34.190981	-118.107526	0.50308	0.51994	0.51994	0.3735	0.48863	0.61844
1	33.784518	-117.805675	0.40187	0.38321	0.38321	0.38042	0.46707	0.22104
1	34.179555	-118.480432	0.45152	0.46813	0.46813	0.49323	0.38839	0.43149
1	34.179591	-118.47902	0.45152	0.46813	0.46813	0.49323	0.38839	0.43149
1	34.090909	-118.591929	0.27428	0.33054	0.33054	0.12892	0.17837	0.463
1	34.065842	-118.260876	0.49319	0.44152	0.44152	0.59138	0.61146	0.25455
1	33.8037	-118.383338	0.53571	0.53687	0.53687	0.542	0.50956	0.49035

Figure 4. Great Horned Owl data (as a CSV file) for Random Forest. Data points include presence data with their corresponding latitude and longitude points and environmental values.

We also utilized Pearson's correlation coefficient, which evaluates the linear relationship between two variables. We created a graph and a plot that showcases the relationship between each pair of the 36 environmental variables we utilized (Figure 5). We picked our environmental variables according to uniqueness, meaning that we prioritized variables that had less overlap with others. For example, the aspect variable (aspect_1km) was chosen since its Pearson's Correlation Coefficient has a value of 0.25 or lower when compared to the other environmental variables (Figure 5a) and it has no overlap with any other variable in the point plot of Pearson's Correlation Coefficient (Figure 5b).

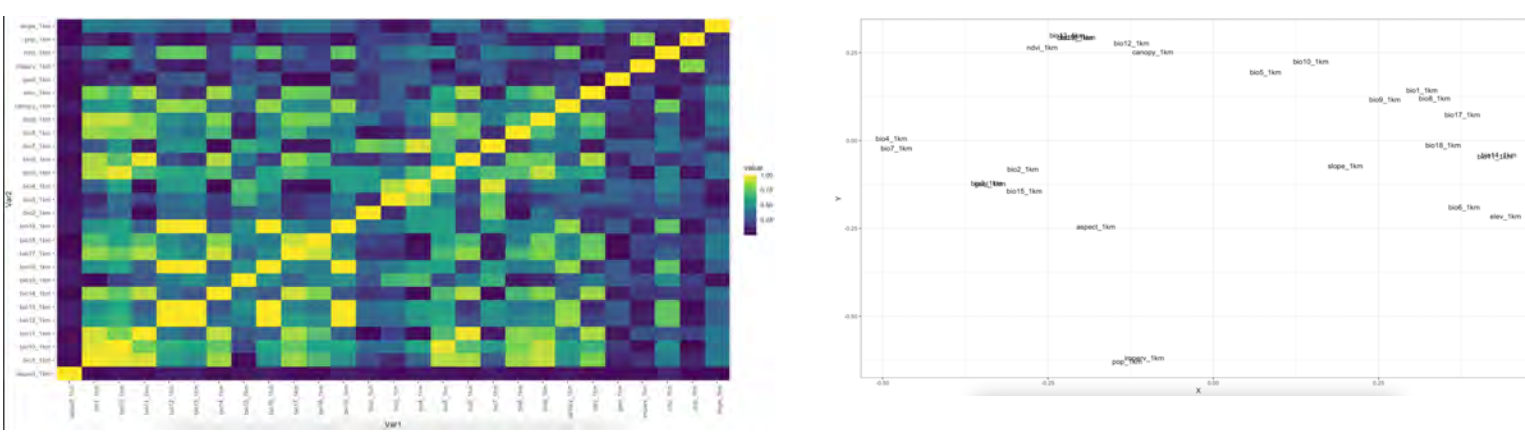

Figure 5. Example of a linear Pearson's Correlation coefficient graph for bioclimatic variables (Figure 5a-left) and a point plot of Pearson's Correlation Coefficient between variables (Figure 5b-right).

After reducing the number of environmental variables and creating a list of unique layers, we used RStudio to run lines of code to construct trees and bootstrap samples. Bootstrap sampling means that the model creates multiple samples of the dataset by randomly sampling with the replacement. Tree construction means that a decision tree is built for each sample, and each node is split based on the best set of environmental variables. The model is trained on the data presented, creating multiple decision trees and each tree associates specific conditions with the absence or presence of raptors. We also ran models that not only created a Random Forest but proceeded to predict at unknown locations as well (review Appendix C for further information).

Fieldwork

Using the methodologies of several owl-centric studies as a guide, we created our own survey protocol for fieldwork. Based on coordinates provided to us by our modeling team, owl sightings obtained through community science platforms – such as iNaturalist and eBird – or tips from LA Raptor Study volunteers, the fieldwork team found territories and nests to survey.

To establish/confirm owl territories, we developed a walking play-back survey method for each territory we visited. We started with a 2-minute silent listening period (passive listening) at the territory. Then in 2-minute intervals, we played the broadcast owl recordings for 30 seconds, followed by a 90-second listening period; this process was repeated 3 times for all 3 species – WESO, BNOW, and GHOW (Gula, 2022; Wingert & Benson, 2018). Next, we walked ~200 meters in one direction from the territory and repeated the previous procedures, then walked ~200 meters in the other direction and did the same (U.S. Fish & Wildlife Service, 2012). Each site/location was surveyed for approximately 10-15 minutes (Gula, 2022; Wingert & Benson, 2018; U.S. Fish & Wildlife Service, 2012). After we moved on to the next territory/site we had planned for the evening (about 3 per evening) We made sure to conduct these weekly surveys no more than an hour or half an hour before sunset and usually ended no later than around 10 PM (Bird Conservancy of the Rockies Citizen Science; U.S. Fish & Wildlife Service, 2012). We completed this process of surveying twice a week.

For confirming nest sites we followed a similar protocol but began with an environmental survey for owl presence indicators such as whitewash, suitable tree habitat, and prey species presence – including cottontail rabbits, mice, roaches, other large invertebrates, etc. (Leicestershire County Council Planning Ecology Service, 2021). After surveying the surrounding environment we began a longer listening period of about 10-15 minutes that also involved waiting for visual observations of owls around potential nesting sites (Gula, 2022; Wingert & Benson, 2018; U.S. Fish & Wildlife Service, 2012). Based on the amount of activity in the survey site, we would either extend the listening and visual observation period or begin to broadcast owl recordings for 30 seconds, followed by a 90-second listening period. This process was repeated for all potential nesting sites.

Results

Modeling

The predicted habitat suitability of Barn Owls in the LA Raptor Study Area is depicted in Figure 6. On the color bar, regions closer to a value of 1 (light yellow) represent areas with environmental or anthropogenic conditions that are more suitable for Barn Owls. On the other hand, regions closer to 0 (dark purple) represent areas in which Barn Owls are less likely to reside due to unfavorable habitats. Regions such as Baldwin Hills, West LA, Silverlake/Echo Park, and Northeast Los Angeles are illustrated as regions of high habitat suitability for Barn Owls within the study area, while regions such as the Santa Monica Mountains, Glendale, and East LA are shown to be less suitable (Figure 6). MaxEnt results of the BNOW model also demonstrate that the variable that had the greatest importance in determining habitat suitability was population at 16% percent contribution. Population was followed by precipitation of the driest month (11.2%), non-native species (9.9%), canopy coverage (9.2%), and aspect (6%). Although the standard deviation for the population variable was large, the overall pattern shows that as human population increases, the predicted probability of BNOW presence increases. Biases (described in limitations) could have impacted these results but knowing the effects of human population on the presence of BNOW can help us further understand their adaptations to urbanization. For the other top contributing variables, there is a mix between the variables having an overall positive or negative relationship with the probability of presence. For example, while keeping all other environmental variables at their average sample value, as canopy coverage increases, the predicted probability of BNOW presence decreases almost linearly. On the other hand, the probability of BNOW presence increases as aspect, which measures the compass direction or exposure of the habitat, increases.

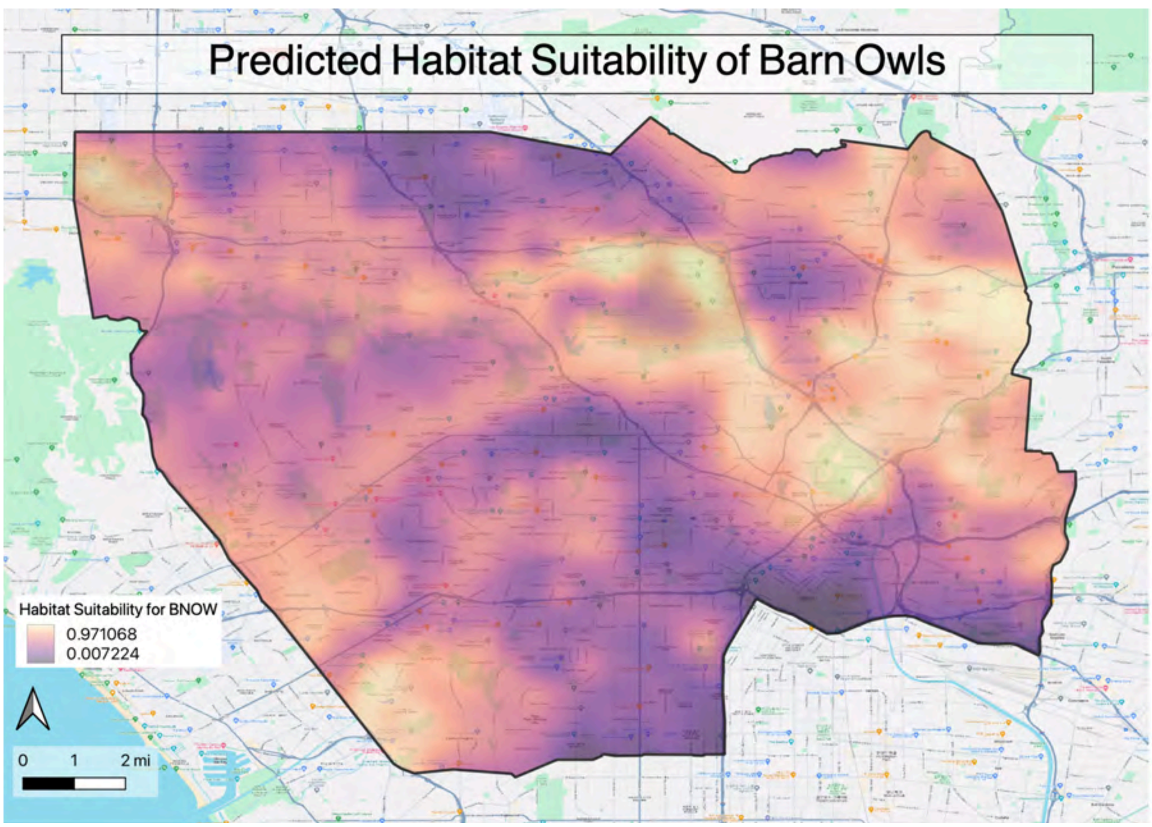

Figure 6. Habitat suitability model for the Barn Owl (BNOW) in the LA Raptor study area.

The Western Screech-Owls' predicted habitat suitability within the study area is shown in Figure 7. The sequential color scheme represents suitable habitats with light yellow colors (values closer to 1) representing areas with a higher probability of finding these owls due to more favorable environmental conditions. Some of these regions are distributed along the northeast area of Burbank and Glendale (in the Verdugo Woodlands and Eagle Rock) extending down to Northeast Los Angeles. Another region of suitable habitat was generally predicted to occur across the Santa Monica Mountains, in Griffith Park Area, and in Silverlake/Echo Park. Dark purple (values closer to 0) represents habitats less suitable for Western Screech-Owls and a predicted low species distribution. Figure 7 shows that most of Baldwin Hills/South LA, East LA, and a good portion of the San Fernando Valley and Westwood to Downtown LA are predicted to be unsuitable habitats for the Western Screech-Owl. MaxEnt results also demonstrated that in the assessment of WESO models, the most important environmental variable that contributed to the habitat suitability map was canopy tree cover (29.1%), followed by precipitation of coldest quarter (15.8%), temperature annual range (8.2%), mean diurnal range (6.5%), and precipitation of warmest quarter (6.3%). The probability of a WESO presence increases as canopy coverage increases up until a certain threshold. The same positive relationship can be described for the other four variables where the probability of presence increases when the temperature or precipitation increases (excluding the extreme ends of their ranges). Understanding the environmental variables that contribute to the making of Figures 6 and 7 is crucial in recognizing the habitats and their environmental and anthropogenic conditions that are predicted to be the most suitable for WESO and BNOW.

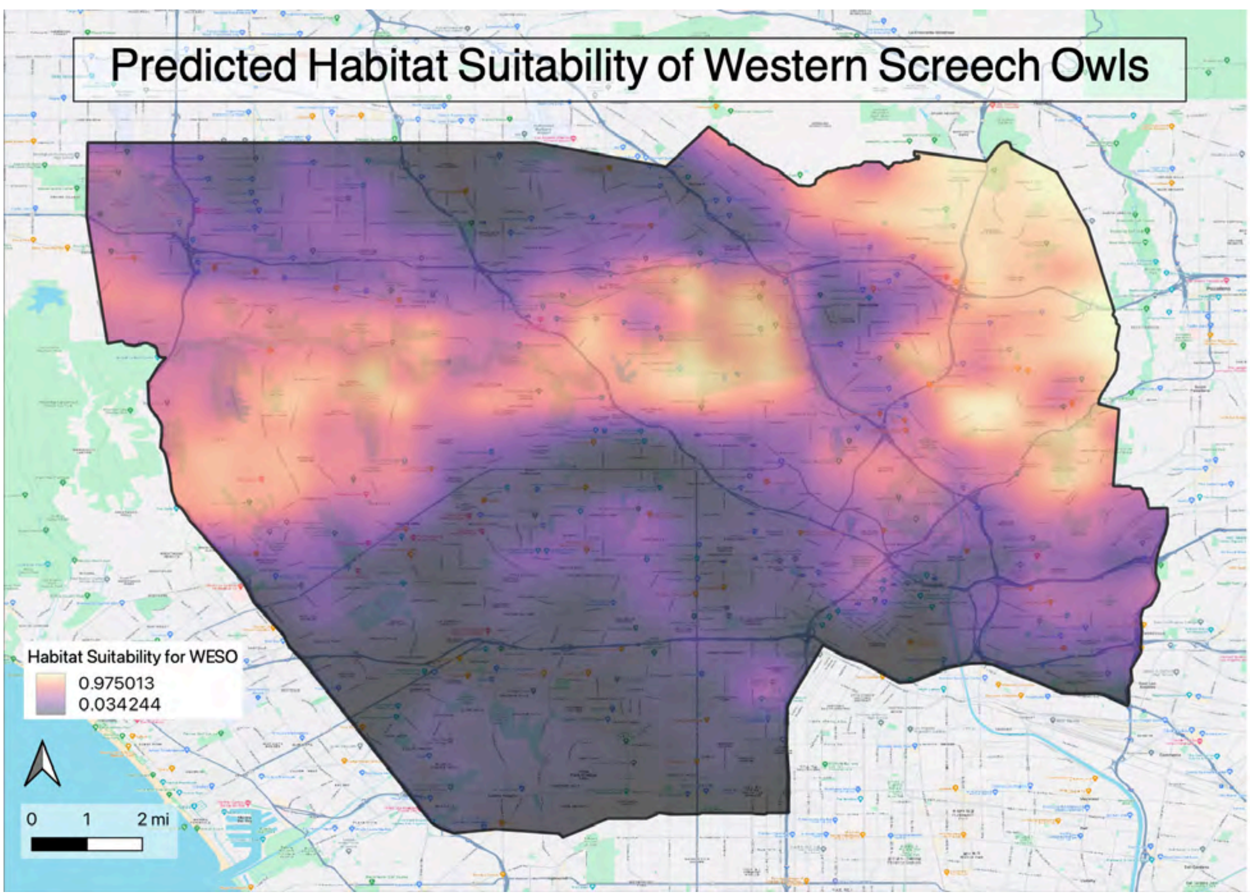

Figure 7. Habitat suitability model for the Western Screech-Owl (WESO) in the LA Raptor study area.

Fieldwork

The fieldwork team conducted extensive surveys to assess the distribution of breeding owl species in Los Angeles. Early in the planning stages, we decided that, given the wide distribution of Great Horned Owls (GHOW) in the study area, our efforts would be best directed toward studying two more cryptic species: the Barn Owl (BNOW) and the Western Screech Owl (WESO). By concentrating on these less conspicuous species, we aimed to gather more detailed and focused data, which would provide valuable insights and fill the existing data gap for these two species. This strategic decision allowed us to delve deeper into the behaviors and habitats of the Barn Owl and Western Screech Owl.

To finetune the scope of our field surveys to BNOW and WESO, the team used habitat suitability models to predict the likely distribution of these species in the study area. This allowed us to ground truth what was predicted by the models by actively seeking neighborhoods of high predictability, which was mostly within 6 neighborhoods across the LA Basin (Figure 8).

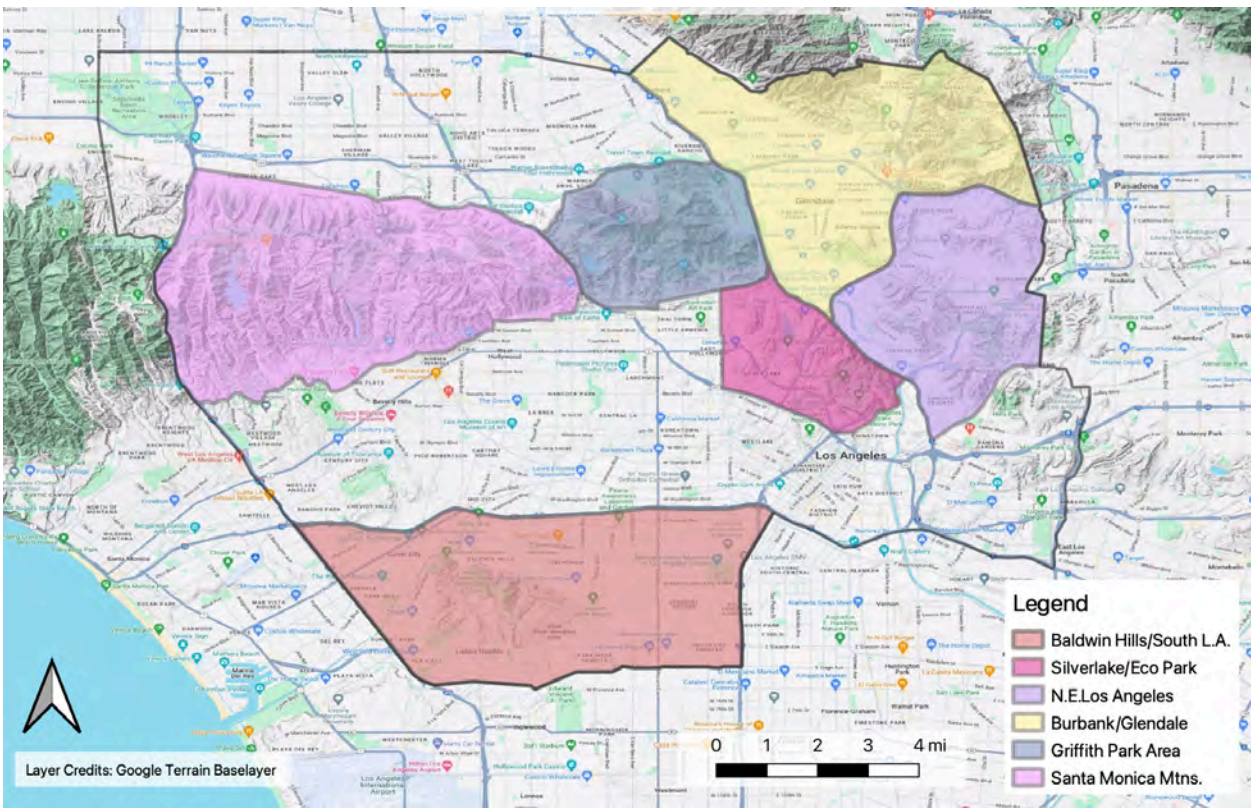

Figure 8. Surveyed neighborhoods within the LA Basin.

Overall, the field team visited 11 different locations, sometimes visiting the same place more than once, and conducted over 50 hours of surveying. As shown in Figure 9, red dots represent presence of these species and blue dots represent absence. Among the sites and coordinates visited, we detected the presence of owls either visibly or audibly about 28% of the time. Specifically, we confirmed the presence of WESO approximately 7% of the time and BNOW about 5% of the time. Although we did not focus on surveying the distribution of GHOW, it is important to note that GHOWs were observed at nearly every presence point shown in Figure 9. This observation reflects the wide distribution of GHOW, as seen in both the observational datasets and the habitat suitability models used in our study. The sections below describe the species presence or absence predicted by the habitat suitability models or local tips for the sites visited and the results from these field surveys.

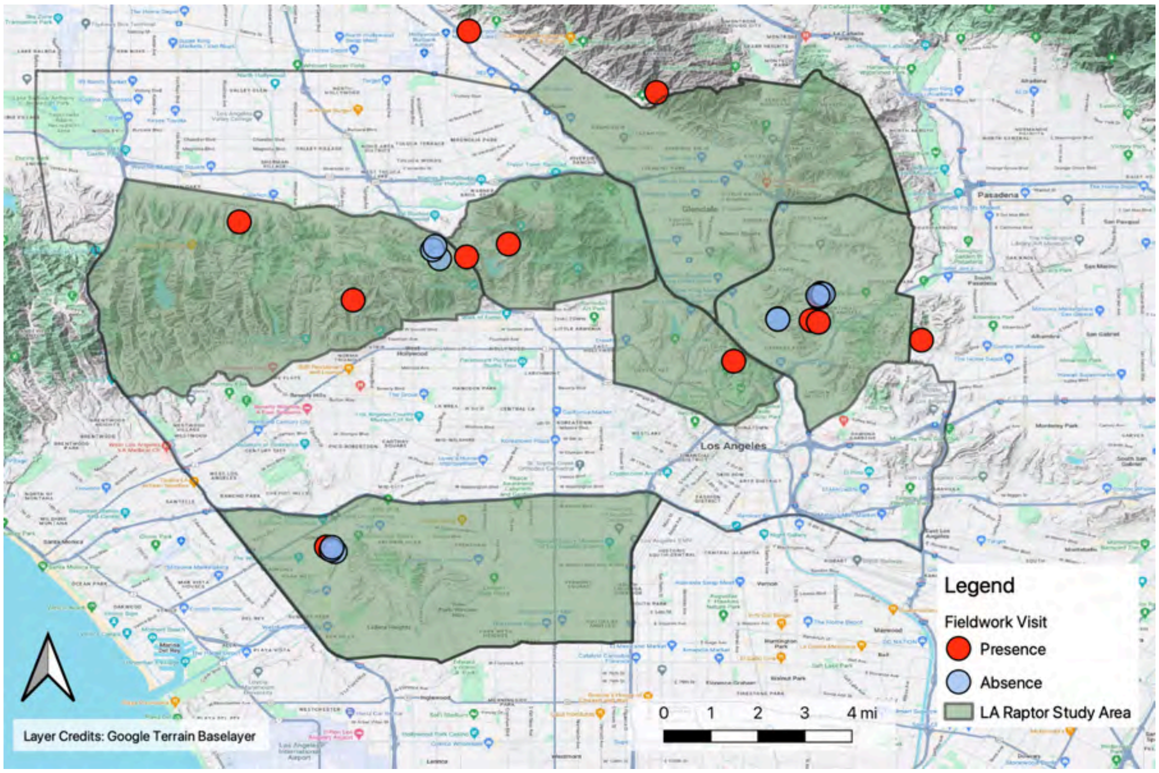

Figure 9. Presence and absence points for each coordinate visited.

Barn Owl (BNOW)

Based on predictions from habitat suitability models, our team conducted field surveys in Northeast Los Angeles, but this effort did not yield any presence data for Barn Owls. However, with tips from citizen scientists, we expanded our fieldwork to include Burbank and Culver City, where we successfully spotted Barn Owls in both locations. This collaboration with the local community proved invaluable, guiding us to active survey sites and enhancing our understanding of Barn Owl distribution in the region.

Visiting both the high-predictability areas and the areas with tips provided a lot of information regarding the commonalities in environments where BNOW nests can be supported. For example, in both locations where BNOW nesting pairs were observed, the environment was primarily urbanized. In the Burbank location, the nesting pair was observed in a palm tree on a highly-paved college campus. In Culver City, we saw a similar theme of highly paved roads in a neighborhood that was also highly urbanized but containing multiple untrimmed palm trees (*Washingtonia filifera*) that were being used as nesting sites for the observed nesting pair (Figure 10). In both presence locations, the Barn Owl pairs were observed entering the cavities between palm fronds, reinforcing their elusiveness.

Other factors that hinted at the presence of BNOW in these areas include things such as the presence of prey species- in particular, the presence of mice (*Mus*) and rats (*Ratta*). Another observable clue that owls were in the area was the presence of whitewash or owl pellets (Figure 11). Interestingly, we found that in implementing our survey protocol, the most effective recorded call for BNOW in particular was to play recordings of young/juvenile owls.


Figure 10. Palm tree of nesting & Figure 11. Whitewash observed near nesting palm

Western Screech Owl (WESO)

Similarly to the BNOW approach, in conducting surveying for WESO we followed the guidance of both tips from community members and highly predicted areas from the models. The fieldwork team was able to locate Western Screech-Owl presence in two areas: Laurel Canyon and Mount Washington (North East Los Angeles). The Laurel Canyon presence point was identified through the tip of a local resident, while Mount Washington had two total presence points: one provided by a local resident and one that was provided by the highly predictable areas from the model. The point that was provided by the habitat suitability model was an effective way to ground truth the reliability of our models since we had a positive presence point in an area where observational data was limited.

While surveying Laurel Canyon, we noticed the environment contained eucalyptus trees and woodland shrubs as a large composition of the neighborhood's vegetation – but still remained to be an overall urbanized landscape. Following that theme, the areas in North East Los Angeles where WESOs were observed also had similar vegetation and level of urbanization, being that both areas were residential. Shaggy eucalyptus trees (*Eucalyptus globulus*) were observed as a perching spot for WESO, as these owls were observed flying in and out of these eucalyptus trees, and may be a potential nesting site for these owls (Figure 12). These eucalyptus trees often have enough shag to create a cavity for this small owl species. Similarly to the BNOW, we also observed the WESO come out of a palm tree cavity and could also be a potential nesting site.

Other observable factors also included the presence of prey species, such as large invertebrate species and mice (Figure 13). Another factor that we noted was the presence of GHOW close to all three presence points of the WESO but we did not observe any GHOW when the team found BNOW presence.

Figure 12. Shaggy eucalyptus tree with woodland shrubs & Figure 13. Potato bug (Leptinotarsa decemlineata)

Discussion

Challenges to Raptors

Our team is proud to have contributed even a small amount of knowledge to the L.A. Raptor Study and help demystify the ecology of these magnificent birds in our city. The modeling team provided the fieldwork team survey points to help confirm the accuracy of the models. The fieldwork team then informed the presence or absence of the species surveyed. Negative data in areas where species are predicted can help researchers infer if there are other factors outside the ones used in MaxEnt that may be influencing habitat suitability. The search for WESO in the last two surveys indicates this, as factors such as anthropogenic light and noise may have deterred this species from inhabiting the areas explored. It was noted during some of our surveys that there were many dogs barking in the area, as well as the sound of traffic from the 101 Freeway, which can be potentially disruptive to WESO. The high species presence of GHOW, however, may indicate that they are not as sensitive to these anthropogenic factors. Future directions could include measuring noise levels using autonomous recording units (ARUs) to understand at which volumes owls can tolerate. Noise pollution levels can be a potential variable to explore in future habitat suitability models.

As humans attempt to control more of the natural world by unnatural means, either through the use of anticoagulant rodenticides to control pests or palm trimming for aesthetic purposes, we may also unintentionally lose the beauty that comes with it. As more of these birds rely on imported plants such as palms and eucalyptus trees, we would like to advise urban planners and landscaping experts to consider the ecological repercussions of maintenance without disturbing its inhabitants. We were able to assist with preventing the removal of a palm tree as it was believed that there was BNOW presence. Through the help of a neighbor's tip, we were able to confirm a pair of BNOW nesting in the area. The discovery of a BNOW territory has helped fill in some of the knowledge gaps for the LA Raptor Study, as previously there had been no confirmed nests, and hopefully provides an opportunity to better understand their behaviors in human-dominated ecosystems. Future directions could also include a historical review of raptor presence in the Los Angeles area to see how the distribution of these birds has changed in conjunction with urbanization and climate change. Los Angeles is a landscape dominated by concrete, asphalt, and non-native vegetation such as eucalyptus trees and palms. The nesting preferences of these urban owls are also dependent on other birds such as Red-tailed Hawks and crows, so monitoring their distribution is an additional study opportunity. Canopy tree cover has been shown to be the most important factor in influencing WESO distribution, and thus, advocacy for protecting these trees should be prioritized. Additionally, green spaces and urban vegetation have been well documented in improving human health, such as accelerated recovery from stress and illness, increased physical activity, cognitive function, and emotional health (Pataki, 2015).

With the increased rate of urbanization, there is also a growing number of rodents and zoonotic diseases carried with them (Gratz, 1999). While an abundant prey population could be beneficial to certain predatory species, including the owls we have studied, their prevalence also leads to higher usage of rodenticides. There have been several efforts to curb anticoagulant rodenticide use, with the most recent being the California Ecosystems Protection Act of 2023, which extends the moratorium on a first-generation rodenticide alongside second-generation rodenticides (California AB1322, 2023). However, we believe that regulation and safeguarding measures can be and should be stronger, as secondary poisonings not only afflict owls, but other Californian wildlife species and children as well. By protecting our raptors from the unintended consequences of highly urbanized areas, we preserve not only the native biodiversity of California but also a healthier environment for humans to reside in.

Limitations and Future Research

There are limitations in our study, models, and fieldwork methods. MaxEnt is a program that allows you to predict the habitat suitability of a species using environmental variables and existing presence records from sources such as community science platforms. As model inputs, we specifically used presence records of Barn Owls and Western Screech-Owls from Ebird and iNaturalist. We want to acknowledge that there is bias associated with incorporating community science data in our models as observations are often spatially biased towards areas that are more accessible and with higher human population density. Therefore there is likely a disproportionate number of sightings and observations concentrated in locations such as parks, trails, and neighborhoods compared to natural areas where no one is documenting. Using citizen science data, which often underrepresents natural areas, can skew our data and the results of our models. It is thus imperative to be conscious about how we’re using this data and how we’re interpreting our MaxEnt models. To produce a more accurate habitat suitability model, future research should incorporate methods that account for the sampling bias from the presence-only data. For instance, a bias layer could be constructed and subsequently included in the MaxEnt models.

There are also limitations with our current suitability models as it relies on coarse scale data. The environment variables that we use are very general and broad and don't include microhabitats and therefore this limits our ability to specifically identify the best habitat suitable for these raptors. For example, one of the environmental layers is tree canopy, but the variable doesn't distinguish between different ecotypes and thus the model does not identify the preference of tree type. Fine scale variables and data are necessary to create more accurate predictive models and assess/understand the habitat preferences and nesting biology of raptors. Further research should focus on looking into and incorporating more specific biological and environmental variables.

Time was another constraint to our project as we were unable to finish running models using the Random Forest program. We were able to explore and use some basic and starter codes to get random forests to run on RStudio. We were able to open a script on RStudio that produced some regression trees and a forest. However, due to time limitations, we were unable to use Random Forest to build accurate predictive models of the Barn Owls and Western Screech-Owls species distribution and habitat suitability. The use of Random Forest, an additional machine learning algorithm, to further investigate and model the owls' distribution in relation to its habitat variables would be very beneficial to potentially reveal trends and associations. Comparisons and commonalities between MaxEnt and Random Forest could also be made.

In terms of limitations regarding our fieldwork, presence and absence of these birds may change from year to year. Owls (and other raptors generally) take over nests that may have been previously inhabited by a different species in the prior breeding season, inhabit nests that were previously abandoned, or abandon nests that were previously inhabited. Therefore, sites where we audibly or visibly confirmed the presence or absence of BNOW and WESO may remain the same or change in the following years. However, they will likely nest in habitats and areas similar to where they have nested previously. Under the generosity of the LA Raptor Study and Athlon Optics, the team was provided with high-quality binoculars to help aid in our field surveys. It would also be advisable to invest in better equipment such as digital cameras to capture nocturnal wildlife for better documentation purposes. We encourage future groups to establish a more streamlined fieldwork process early on, complete with a centralized spreadsheet and reporting system to better document every survey.

We are deeply grateful for the opportunity to garner enthusiasm about owls in neighborhoods all around Los Angeles. When asking people if they had heard any owls, their responses were eager and excited and they were curious about our project. The residents all around Los Angeles clearly demonstrated their care for their environment and have developed attachments to owls, affirming on multiple occasions that they pay attention to their calls. Further limitations in fieldwork include our restricted range, as we only conducted in areas where we would feel safe at night, and each field survey was usually quite labor intensive. The challenges of conducting urban ecology in general also lie in accessing privatized land, and there have been multiple times where we may have trespassed (and once where we had to be escorted out from our field site). Being able to establish a rapport with the community strengthens the LA Raptor Study by bringing more attention to this project and highlighting the importance of urban biodiversity in general. It is also practical to familiarize oneself with the inhabitants of an area, as one resident in Oakshire Canyon granted us access to privatized land for one of our surveys. Nonetheless, the field team would agree that each survey was treated as an adventure, and albeit tiring at times, obtaining a confirmation that an owl was in the area is an exhilarating experience. Of course, we would also like to acknowledge that it takes a certain type of privilege to be welcomed in certain spaces. We urge future groups to somehow utilize the full force of the L.A. Raptor Study's 200 volunteers, if possible since the fieldwork team was a relatively small group consisting of 4 students. Based on the habitat suitability models, we hope that they can provide adequate survey points for the study's volunteers to explore. As we continue to paint a better understanding of urban wildlife and their interactions in human-dominated environments, we must simultaneously do better in integrating Los Angeles' native biodiversity into our daily lives.

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Appendices

Appendix A. Species Accounts

Great Horned Owl

The habitat location of GHOW spans throughout the Americas. In addition to the urban area of Los Angeles County, these birds are naturally found in sycamore woodlands and ruderal grasslands. Along with its range of locations, this species has also shown a high ability to adapt in its natural regions and human-impacted habitats (Bennett & Bloom, 2005). Because GHOW is known for its adaptability across varying habitats, they are likely located in a broad range of sites within the county, including parks, residential areas, and severely developed locations. This impacts adult breeding birds, their stages in reproduction, and their nesting periods which threatens the stability of their population (Bennett & Bloom, 2005). The main factors causing the declining population have yet to be determined, but human impact has been found to be impacting the health and the geographical range of the GHOW.

Bennett & Bloom's research found that GHOW relies on "interactions of habitat use, prey selection, foraging behavior, energetics, and territoriality" for the survival and health of their populations and identified that all habitat types were impacted by human disturbances throughout the studied area (Bennett & Bloom, 2005). Published results show that in 2023 alone, 84 GHOW territories were identified, with an additional 13 territories from the previous year, and an overall increase in chicks hatched. However, a decline in the mean number of hatchlings from active nesting sites was detected in recent years compared to the years prior to 2019 (Cooper et al., 2023).

<u>Barn Owl</u>

BNOW is also a nocturnal raptor but is different in that it is medium in size, resides mostly in agricultural areas, and breeds within farms and barns (Séchaud et al., 2022). The breeding ecology of BNOW stands out from other raptors, for both males and females. This raptor species has a high reproductive potential, with some females able to bear three broods in just one year, and oftentimes with clutch sizes of 10 or more eggs (Béziers & Roulin, 2016). Clutch size for these birds of prey varies considerably compared to other owl and raptor species, with second clutches normally larger than the first (Roulin et al., 1999). Because female BNOWs have a higher probability than males to reproduce more than once in a single season, mothers are not necessary for the entire period following the brooding period (rearing); however, fathers are (Béziers & Roulin, 2016). Furthermore, females may abandon their first brood and renest with a different male who is not yet a father, as more single males are available in this species (Béziers & Roulin, 2016).

In an additional study that tested the effect of brood size manipulations (either making them larger or smaller) on both Barn Owl parents and offspring, Roulin et al. (1999) observed an effect only on the offspring. Offsprings had inflated mortality rates and the body masses of surviving offspring were lower in enlarged rather than reduced broods. In support of the above study, Roulin et al. (1999) concluded that even when broods require supplemental parental input, these parents do not compromise their future reproductive success, but brood reduction does occur.

Examining the effect of home range size and habitat quality on the breeding success of male BNOW, Séchaud et al. (2022) found that males who inhabited lower-quality environments covered larger ranges from their nests than males who lived in prey-rich areas. As a result, these male BNOW fed their brood less frequently, causing late-hatched nestlings to have a decreased rate of bodily growth as well as an overall decrease in the fledging success of juveniles (Séchaud et al., 2022). Further, all males were similar in their body masses and future reproductive success, which suggests that males that covered larger ranges (due to their habitats being less populated by prey) did not compromise their future reproductive success by investing more energy into going further out from their nests for resources (Séchaud et al., 2022). In regards to female Barn Owls, Séchaud et al. affirmed that they laid eggs every 2-3 days and incubated each one as soon as it was laid, causing asynchrony in the hatching of each nestling. On average, these birds laid 6 eggs, with only 4 reaching the fledging period (Séchaud et al., 2022).

A 14-year study that examined the relationship between habitat variables and various aspects of breeding and foraging performance for 257 BNOW breeding attempts involving both released and wild birds at 86 nest sites found that despite the size of the dataset, the number of significant correlations between habitat type and aspects of Barn Owl breeding success was similar to that expected by chance. Sites with more unimproved grassland within 1 km of the nest did not differ from those with less, except by a significant advancement of first‐egg date (Meek et al., 2009). Researchers concluded that BNOWs are fairly adaptable in habitat types and that they are not dependent on field vole habitats to the extent that was previously assumed (Meek et al., 2009).

Although there is a significant amount of literature on BNOWs that reveals information about the breeding ecology of BNOWs, there is less information and data about the Barn Owl within our study area, as there are fewer nests and territories on record in the Los Angeles Raptor Study. With that said, there are a decent number of records from community science platforms such as eBird and iNaturalist. This data can be downloaded from GBIF records and contribute to our data analysis.

Western Screech-Owl

WESO are small, nocturnal, non-migratory raptors that inhabit a large portion of western North America and Mexico (Hardy & Morrison, 2003). These owls can be identified by their grayish-brown color, protruding ear tufts, and yellow eyes. They are monogamous birds but may find another mate if one dies or leaves the habitat (McConkey & Chatwin, 2017).

WESO are secondary cavity nesters that can commonly be found nesting in tree cavities or other plant cavities, both natural and created by other birds, or in hollow tree trunks (McConkey & Chatwin, 2017). Their nest cavities are typically 25 cm or larger in diameter (Hausleitner, 2017) and can usually be found in regions abundant with black cottonwood (*Populus trichocarpa*), trembling aspen (*Populus tremuloides*), birch (*Betula*), and big-leaf maple (*Acer macrophyllum*) (McConkey & Chatwin, 2017). Moreover, their nesting areas were typically located in areas with low cover of perennial plants, saguaros, ironwood, and palo verde (Hardy & Morrison, 2003). They can also be found residing in nest boxes, but this is less likely as they mostly inhabit nest cavities not constructed by humans (McConkey & Chatwin, 2017). In a study that documented the nest site selection of interior WESO at the tree, patch, and stand scale for twelve nests, it was found that at the patch scale, these birds chose nests with a higher percentage of coniferous cover (33%) than at individual nest sites, and at the stand scale, they nested in medium-age forests surrounded by an agricultural region (Hausleitner, 2017).

In addition to nesting habitat suitability, past literature also revealed findings about the breeding ecology of WESO. Their breeding process traditionally commences with a clear vocalization (so that they are not disturbed while breeding), bonding of a male and female, courtship (lasting from mid-March to early May), copulation, laying of eggs, and lastly, the act of nesting (usually occurring within the months April through June). A pair of WESOs typically incubate for around 30 days, and the nestling phase follows after hatching for 20-30 days. This phase is then followed by the fledging of younglings around late May to the middle of June. After fledging has occurred, these juvenile screech owls usually remain within 500 meters of the nest and continue to be in the care of their parents. In early July, these juveniles start to vocalize and develop their abilities for flight, allowing them to go out further from the nest. Lastly, around early August to September, these young WESO disperse themselves away from the original nest so that the breeding process may start anew (McConkey & Chatwin, 2017).

As our third focus species, the WESO is understudied in the LA urban area as there are almost no records of nests and territories in the Los Angeles Raptor Study. Similar to the BNOW, there are a handful of eBird and iNaturalist records, and past literature has shown that their habitat preference appears to be well-known. Utilizing known information and conducting direct surveys are therefore options to further our understanding of this species in our study area.

Appendix B. Raptor Threats

Essential resources for the conservation of raptors include nest trees and cavities – structural elements crucial for breeding. Further, all three owl species nest in natural cavities (e.g. in cliffs, banks, dead/hollow trees), and GHOW are known for utilizing nests made by other birds or mammals, and man-made structures (e.g. towers, windows, balconies, etc.) These human built structures can add value, especially in areas where natural nest sites are missing due to development, as raptors have a proclivity to these structures. Bohm (1977) and Steenhof et al. (1993) reveal the effectiveness of artificial structures in attracting nesting raptors, with the latter reporting a fast, quick settlement of towers by raptors and ravens. Artificial nests have the potential to expand the previous range of a species. They also have the potential to be placed in areas that are easy to study and observe. Ellis et al. (2009) provide insight into the diverse nesting materials and situations raptors use, including nests on the masts of boats, in attics, suspended automobiles, abandoned chimneys, and more. These studies collectively emphasize the adaptability of raptors in their nesting behaviors and the significance of man-made artificial structures.

Unfortunately, however, many human actions continue to have negative consequences for raptors. Human-induced disturbances within Los Angeles – including day-to-day human activity, removal of dead trees (or "snags"), tree trimming during nest season in and around nest trees, use of anticoagulant rodenticides, and extreme heat from climate change – pose significant threats to nesting raptor populations. Many raptors also die in building collisions as well as automobile collisions. Further, as high-trophic-level species, raptors have relatively low population densities, making them more sensitive and vulnerable to stresses and changing conditions. Out of ~557 raptor species, 18% (103 species) were recently classified as either vulnerable, endangered, or critically endangered, and another 13% (70 species) were categorized as near threatened in 2017 (McClure et al., 2018). Thus, given the nature of their higher vulnerability and the presence of anthropogenic threats, it is crucial to understand the threats that these birds face. The sections below further detail these threats.

<u>Human-wildlife conflicts</u>

Though many may not realize, even small-scale human activities can threaten the well-being of raptors. Anthropogenic disturbance, particularly from recreational activities, has been shown to impact the nesting behavior of particular raptors, leading to decreased nest attendance (Martínez-Abraín et al., 2010). Additionally, noise from human activity has the potential to influence nesting raptor distributions as well (e.g., the Cinereous vulture (*Aegypius monachus*) in Spain did not attempt to breed where road traffic noise levels were higher than 40 dB(A); Ortiz-Urbina, 2020). Further, auto-mobiles significantly threaten the survival of raptor species. In an extensive review of literature on the mortality of urban raptors within the U.S. and Canada, Hager (2009) discovered high instances of vehicle collisions: 73% (of 28 urban species) for Falconiformes and 63% (of 14 urban species) for Strigiformes.

For owls specifically, collision with motor vehicles is a major, if not leading, cause of death. In a study conducted in Charlotte, North Carolina which investigated the effects of road and surrounding environmental features on the likelihood of a Barred Owl (*Strix varia*)-vehicle collision, the following factors were found to have the largest respective effects: speed limit, road width, and habitat suitability within 825 meters of roads (Gagné et al., 2015). An owl-vehicle collision was more probable (> 0.5) on roads with posted speed limits above 53 km/h, a width smaller than 15 meters, and surrounded by 2.14 km^2 landscapes that maintained a habitat suitability value greater than 1.4 (Gagné et al., 2015). Thus, it is clear that all human actions, big or small, impact the security of raptors. As an example, in 2023, a GHOW was killed on Sunset Blvd. near UCLA (per conversation with our client).

<u>Removal of Snags</u>

Snags are dead trees containing cavities that provide nesting opportunities for many cavity-nesting species (e.g. raptors, other bird species, and mammals). Additionally, various cavity nesters use snags for purposes other than nesting, such as foraging and caching food (e.g. the American Kestrel (*Falco sparverius*) and various owl species use snags to cache their prey and other foods they may find; Brown, 1985). Therefore, removing snags may diminish or even eliminate these kinds of opportunities for these species, which are essential for their continued existence and well-being in these areas. In a study conducted in the Blue Mountains of Oregon and Washington, a strong positive correlation was discovered between the abundance of snags within a given territory and the abundance of cavity-nesting species (Thomas, 1979).

In an effort to provide and maintain more available snags in forest areas, Thomas (1979) lists a few methods: (1) long rotation of forest stands, (2) long rotations of a select group or individual snags, (3) intentional deterioration of trees to create snags, and (4) the preservation of snags in managed forest stands. In contrast, many snags are removed in favor of living trees to maintain a more attractive appearance in urban settings. Currently, there does not appear to be much research into how urban cities can better maintain snags, but it is crucial to establish their importance and maintenance strategies so that raptors may continue to thrive in urbanized areas.

Here in Orange County, CA, The Cavity Conservation Initiative – a 501 (C)(3) organization and a program of the Southern California Bluebird Club – encourages the secure retention of snags to both guarantee the future of cavity-nesting species and improve forest diversity. Their webpage includes multiple resources on the value of snags, wildlife that use snags, and how to safely retain snags. For example, there are many documents that provide guidance to the California tree care and landscape industry about the best management practices and how to minimize impacts and prevent harm to wildlife.

Anticoagulant Rodenticides

Anticoagulant rodenticides (ARs) maintain rodent populations in domestic, municipal, agricultural, and conservation settings. They are poisons that prevent blood clotting and also function as blood thinners (Fisher et al., 2019). Gomez et al. (2022) emphasize the global scale of this issue, with raptors in North America, Europe, Asia, and Australia all being exposed to ARs. They are mainly subjected to ARs through secondary exposure, which means through scavenging or preying on primary consumers of ARs.

There are two types of ARs: first-generation (FGARs) and second-generation (SGARs). The former breaks down quicker than the latter, and so there is a lower probability of non-target animals (e.g. raptors) being affected through secondary exposure to FGARs. Thus, SGARs are more dangerous and must not be placed in areas that raptors inhabit. Common FGARs include warfarin and diphacinone, whereas common SGARs include brodifacoum, bromadiolone, difethialone, and difenacoum. López-Perea et al. (2019) found that the presence of SGAR residues in multiple wildlife species – including raptors such as the Red Kite (*Milvus milvus*), Eurasian Eagle-Owl (*Bubo bubo*), and Eurasian Buzzard (*Buteo buteo*) – had a stronger correlation with their use as biocides in urban settings rather than as plant protection in agricultural areas. Overall, the use of ARs in urban landscapes seems to be standard and extensive (Riley et al., 2007; Morzillo and Schwartz, 2011; Bartos et al., 2012). Thus, this highlights how ARs are much more prevalent in urbanized areas.

For BNOW, brodifacoum has displayed stronger secondary toxicity than bromadiolone and difenacoum (Mendenhall & Pank, 1980; Newton et al., 1990). In a study conducted in Massachusetts over 4 years, 96% (of 94 raptors: Red-tailed Hawks [*Buteo jamaicensis*], Barred Owls, Eastern Screech-Owls [*Megascops asio*], and GHOW) tested positive for SGARs, and brodifacoum was found in 95% of these raptors (Murray, 2017). Further, only 16 were symptomatic for AR toxicosis, while the other 78 remained asymptomatic (Murray, 2017). These findings further support that ARs are a significant threat to raptors, and because raptors may not always display symptoms of toxicosis, we must be mindful of where we place ARs and how often these birds are being exposed to them.

Extreme Heat

As global temperatures continue to rise due to climate change from excessive greenhouse gas emissions, extreme heat events are occurring more regularly around the world. Tomback & Murphy (1981) found that a combination of a lack of nourishment during years of low prey abundance and vulnerability to heat stress during high temperatures increased nestling mortality for the Ferruginous Hawk (*Buteo regalis*). Catry et al. (2011) made a similar finding in relation to the Lesser Kestrel (*Falco naumanni*): nestling mortality increased significantly during extreme heat events. Moreover, extreme heat events as a result of climate change could reduce the Lesser Kestrel's population size by 7% each year moving forward (Catry et al., 2011).

Welch-Acosta et al. (2019) found that for Mississippi Kites (*Ictinia mississippiensis*), heat was correlated with low nesting productivity and success in both urban and exurban areas, but that urban areas provided more of a buffer to the effects of heat stress. Nonetheless, there has not been much research into the effects of extreme heat on raptors in the past few years, which is a necessary area of investigation due to the increased rate of warming in the past few decades. According to Valone (2021), observationally informed projections using climate science data predict a 5˚C to 6˚C rise in global temperature by the year 2100. Thus, this is a topic that needs to be further explored, especially in cities, where temperatures are usually hotter compared to their more rural counterparts.

Appendix C. Modeling Process

<u>MaxEnt</u>

The modeling process began with the exploration of MaxEnt as it was a new program that none of us had previously utilized. After a tutorial on the basic settings of MaxEnt by our advisor, Dr. Harrigan, each member of the modeling team was able to successfully download and open the application. Two sets of environmental layers were identified from two sources (Beninde et al., 2015 & WorldClim online database) to be good variables to use in our models to help us further understand the predicted species distribution and habitat suitability of the Barn Owl (BNOW) and Western Screech Owl (WESO) in Los Angeles. The WorldClim Layers consist of 27 layers that cover the entire state of California. The layers, as shown in Table 1, range from environmental variables, such as the average annual temperature and canopy coverage to anthropogenic variables, such as human population and impervious surfaces. The Biodiversity Layers (GLS) consist of 9 biological biodiversity variables, such as non-native species and native arthropod species within the Greater Los Angeles area (Table 2). Because these two sets of layers come from different sources, the geographical dimensions vary but in order for them to run on MaxEnt at the same time, their resolution and geographic extent have to be matched. Before our modeling team was able to successfully cut and resample the WorldClim Layers to match the GLS Layers, preliminary models were run using one set of layers and sample presence data from community science platforms.

Table 1: WorldClim layers

BIO1= Annual Mean Temperature	BIO10= Mean Temperature of Warmest Quarter	BIO19= Precipitation of Coldest Quarter
BIO2= Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO11= Mean Temperature of Coldest Quarter	Slope
BIO3= Isothermality (BIO2/BIO7) (×100)	BIO12= Annual Precipitation	Population
BIO4= Temperature Seasonality (standard deviation ×100)	BIO13= Precipitation of Wettest Month	Normalized difference vegetation index (NDVI)
BIO5= Max Temperature of	BIO14= Precipitation of	Impervious surface

Warmest Month	Driest Month	
BIO6= Min Temperature of Coldest Month	BIO15= Precipitation Seasonality (Coefficient of Variation)	Geo
BIO7= Temperature Annual Range (BIO5-BIO6)	BIO16= Precipitation of Wettest Quarter	Elevation
BIO8= Mean Temperature of Wettest Quarter	BIO17= Precipitation of Driest Quarter	Canopy
BIO9= Mean Temperature of Driest Quarter	BIO18= Precipitation of Warmest Quarter	Aspect

Table 2: Greater LA Biodiversity HSM layers (GLS) from Beninde et al. (2023)

Non-native chordate species	Native species	Native arthropod species
Native chordate species	Non-native species	Non-native arthropod species
All species	Native plant species	Non-native plant species

Aside from the environmental layers, MaxEnt uses presence-only data to make predictions of species distribution. The end goal was to use the Global Biodiversity Information Facility (GBIF) to download as many presence points as possible of our focalized owl species but to begin with data from iNaturalist or eBird individually were used to run a few test models. For a model to run, the format of the comma-separated value (CSV) file containing the presence points of each species has to be consistent with the scientific name of the species in the first column, the latitude in the second column, and the longitude in the column.

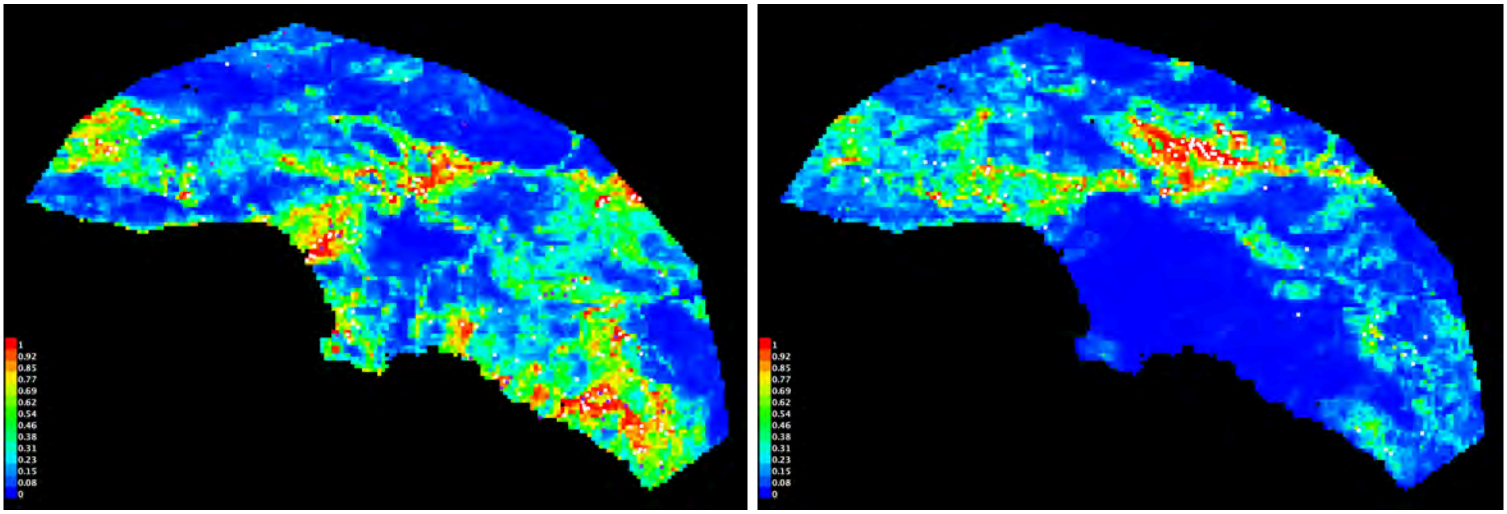


Figure 1 (left) & 2 (right). MaxEnt distribution models from the preliminary results of the Barn Owl (Figure 1) and the Western Screech Owl (Figure 2). Regions closer to the value 1 (red in the color bar) indicate areas with greater habitat suitability.

Figures 1 and 2 are examples of the first models that were run on MaxEnt by the modeling team. Figure 1 only used the WorldClim Layers with 1009 presence data points of Barn Owls from iNaturalist. The settings used on the MaxEnt program were one replicate of bootstrap with a regularization multiplier of 1, a random test percentage of 20%, using 10,000 maximum number of background points, and allowing random seed. Results from this trial run showed that based on the inputted environmental layers and presence data, suitable habitats for BNOW in the Greater Los Angeles Area include West Los Angeles, Central Los Angeles near Griffith Park, and down in Orange County. An example of the first model that was run for the Western Screech Owl is shown in Figure 2. For this model, the WorldClim Layers, presence data points from iNaturalist, and the same MaxEnt parameters were used. Although the habitat suitability of WESO is a lot less distributed compared to BNOW, results from this run showed the species distribution of WESO was also higher likely to be located in the Griffith Park, Burbank/Glendale, and Echo Park regions.

To improve the validity and complexity of our models, the WorldClim Layers were cut and resampled on QGIS to fit the size of the GLS layers. This process included applying the following steps within QGIS: extracting the layer extent of a GLS layer, clipping the WorldClim Layers to the layer extent by utilizing “clip raster by extent”, and then using the SAGA resampling tool to resample the WorldClim Layers according to the dimensions of the GLS layers.

For the presence-only data, data for each species, including the Great Horned Owl (GHOW), was downloaded from GBIF using RStudio. The original code that was used to download the data did not directly include the geographical extent of the interested study area (longitude and latitude of Los Angeles County) and therefore with the limit of points imposed in the code (limit= 20000) for computational purposes, a smaller number of presence data for each owl species was captured after filtering the desired range of coordinates. On the other hand, for the final MaxEnt models, the code used to download the GBIF presence points directly included the geographical limits and so the computational limit of twenty thousand was above the number of presence data points available for each species within the study area. This means that all reported points in GBIF (from 2013 to 2023) for BNOW and WESO were captured in the downloaded data and used in the final MaxEnt model to predict the habitat suitability and species distribution of each species.

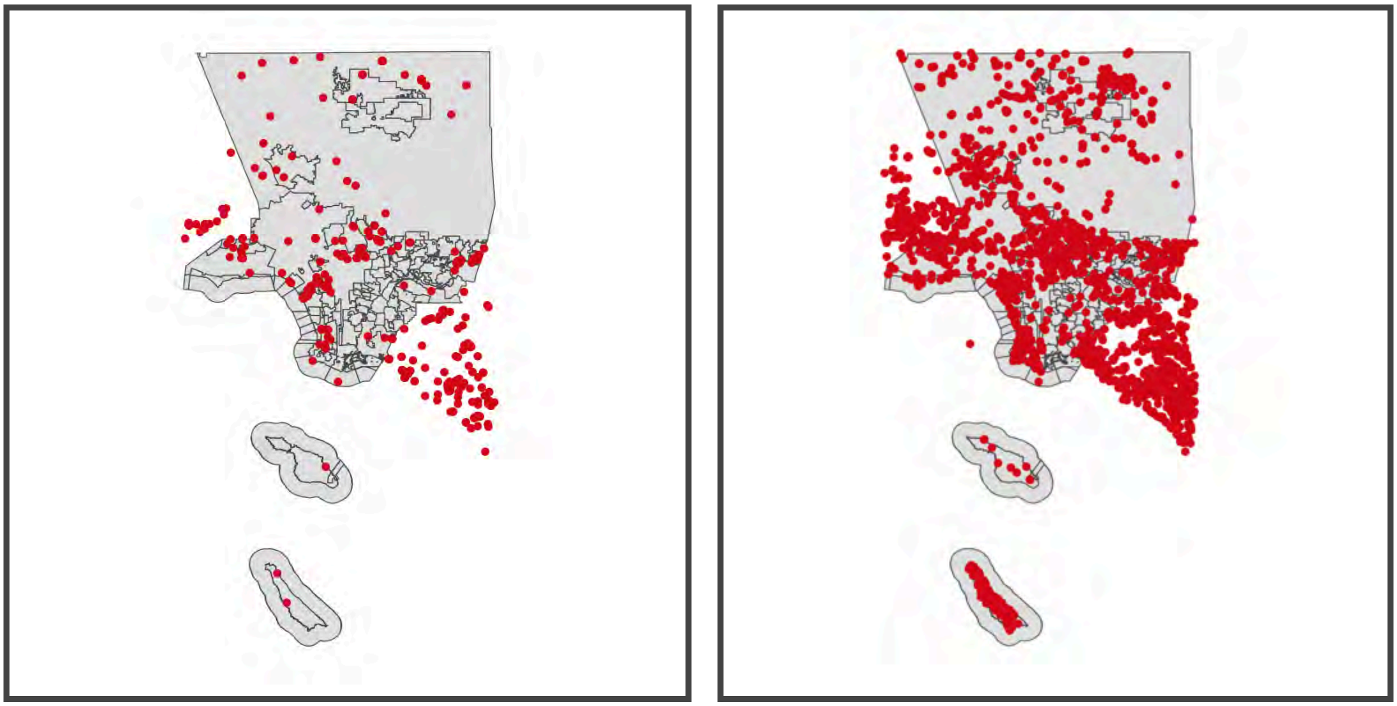


Figure 3. Presence data points downloaded from GBIF of the Barn Owl in Los Angeles County. The figure on the left (3a) shows the data points that were downloaded using the original GBIF code, while the figure on the right (3b) shows the data points from the final code that was used.

As demonstrated in Figures 3a and 3b, there is a large contrast between the number of data points for the Barn Owl within Los Angeles County. To be exact, there are 730 data points in Figure 3a while there are 12963 points in Figure 3b. This means that the models that were run using the presence-only points from Figure 3a had significantly less presence data which slightly affected the results and species distribution of BNOW within the Greater Los Angeles area. The same is applied to the Western Screech Owl where there were only 466 presence points downloaded in the original GBIF code but for the final models, 6687 data points were used. Aside from the final models shown in the report above, the rest of the MaxEnt models utilized the original GBIF records with fewer presence points.

The next steps involved a lot of playing around with different parameters and settings on the MaxEnt program and learning how to understand the results. Some of our trial runs included running all species (including the Great Horned Owl) in the same run, running replicates, increasing the regularization parameter, and observing the differences between bootstrap and cross-validation. Throughout this process, troubleshooting of the inputs was regularly done due to errors that popped up during the trial runs. For example, one of the errors that we ran into was written as “Fatal Error: java.lang.ArrayIndexOutOfBoundsException” for BIO8 and BIO10 of the WorldClim layers. After running a couple of models without those layers and looking into the geographical extent of the individual layers, we were able to resolve the problem by making a copy of each layer and not renaming those layers. Our conclusion for this error was either that the original layers became corrupted or that the MaxEnt program does not accept their original names as “bio8_1km.asc” and “bio10_1km.asc”.

Although our focused species are the Barn Owl and the Western Screech-Owl, we ran the same models for the Great Horned Owl (GHOW) to determine the validity of the MaxEnt results when compared to the GHOW nest sites and habitats that are being monitored in the LA Raptor Study. The GHOW are more commonly found in the region compared to our two cryptic species as demonstrated by the 80 nests that were found in the study and therefore we would be able to check and observe the areas in which the models were determining high species distribution. Some of the models that were run for all three species include a 5-fold bootstrap with a 20% random test percentage and 5-fold cross-validation, both with all layers. In the later weeks of the project, we decided to move forward with only running replicated models with cross-validation as both settings gave similar results in terms of the importance of the variables (environmental layers), and cross-validation was used in the Beninde et al. (2023) paper. In order to reduce computational needs and the hours required for each MaxEnt run, we also ran a couple of models with reduced environmental layers based on the results of variable importance (percent contribution) from previous models ran with all 36 layers. We accomplished this by eliminating all variables that did not make up the top 90% of variable importance for each species. The results for these trial runs were very similar in terms of the species distribution and the regions with higher habitat suitability.

Figures 4, 5, and 6 are MaxEnt results for the Great Horned Owl, Western Screech-Owl, and Barn Owl, respectively. The models were run on MaxEnt using a 5-fold cross-validation and later imported into QGIS to overlay the results on top of a Google Terrain layer. The overlay and choice of a new color ramp allowed for better observation and interpretation of the MaxEnt results. As previously mentioned, the LA Raptor Study has a lot more data on GHOW and therefore we were able to utilize our MaxEnt models to determine whether known nest sites or GHOW pairs were located in the areas the model depicts as higher habitat suitability. In the study area, GHOW are usually found nesting in eucalyptus trees, palm trees, and woodland vegetation. Figure 4 shows that there is high habitat suitability for the GHOW in a good portion of the study area, as shown by the orange-to-red pixels on the map. Some of these regions include the Verdugo Woodlands, East Los Angeles near Echo Park and Mt.Washington, Griffith Park, West Hollywood, and the Baldwin Hills. Due to the wide habitat distribution of GHOW as demonstrated by the LA Raptor Study but also our MaxEnt model results, we then heavily focused on applying this method to understand the suitable habitats of the BNOW and WESO.

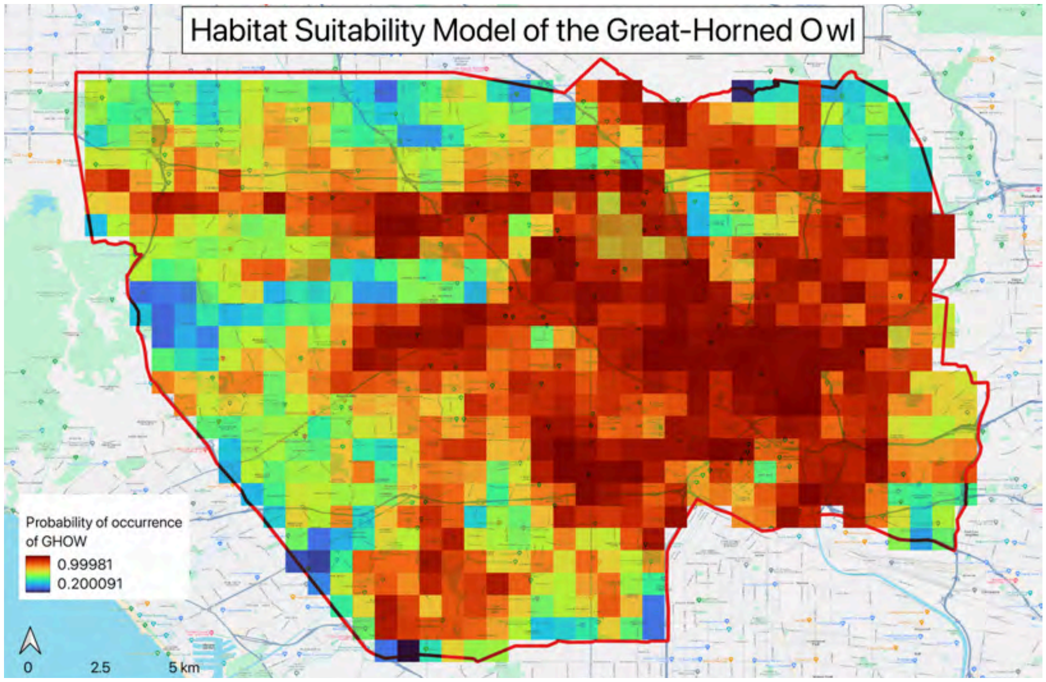


Figure 4. Habitat suitability model for the Great Horned Owl (GHOW) in the LA Raptor study area.

The predicted habitat suitability map of Western Screech Owls is shown in Figure 5. Values closer to 1 on the scale, which translates to pixels with a darker red color, represent habitats that are more suitable for WESO. Results from this map demonstrate that, within the study area, Northeast Los Angeles, Burbank/Glendale, the Santa Monica Mountains, and Griffith Park are regions with a higher species distribution of WESO. The MaxEnt results also indicated that the top five variables that contributed the greatest to the model are elevation (12.5%), precipitation of the wettest quarter (11.4%), slope (8%), canopy coverage (8%), and annual precipitation (6.2%). As canopy coverage increases (to a certain extent before leveling off), the probability of the presence of WESO increases. A similar pattern is also seen for the variable slope, as the slope of a habitat increases, the probability of presence increases linearly. These results were thoroughly discussed with our advisors and transferred to the fieldwork team for ground truthing.

For Barn Owls, our MaxEnt model determined a wider species distribution compared to WESO. In Figure 6, values closer to 1, and therefore pixels that are a darker shade of purple, represent regions that are more suitable for BNOW. Some of these areas include Northeast Los Angeles up into the Glendale/Burbank area, as well as Silverlake/Echo Park and from Westwood down into Baldwin Hills and South LA. The top five environmental variables that had the greatest contribution to this BNOW model are annual mean temperature (9.2%), aspect (7.8%), isothermality (7.5%), non-native chordate species (7.3%), and precipitation of the driest month (6.9%). When keeping all other environmental variables at their average sample value, the probability of BNOW presence increases linearly as the population of non-chordate species increases (to a certain threshold). On the other hand, MaxEnt results showed that as precipitation increases in the driest month, the probability of presence decreases linearly but at a slower rate. By analyzing the pattern of certain environmental variables and their effects on MaxEnt prediction, we can better understand the environmental variables that hold greater importance in determining the suitable habitats of BNOW and WESO. Just like for WESO, the MaxEnt results of BNOW were also conveyed to the fieldwork team.

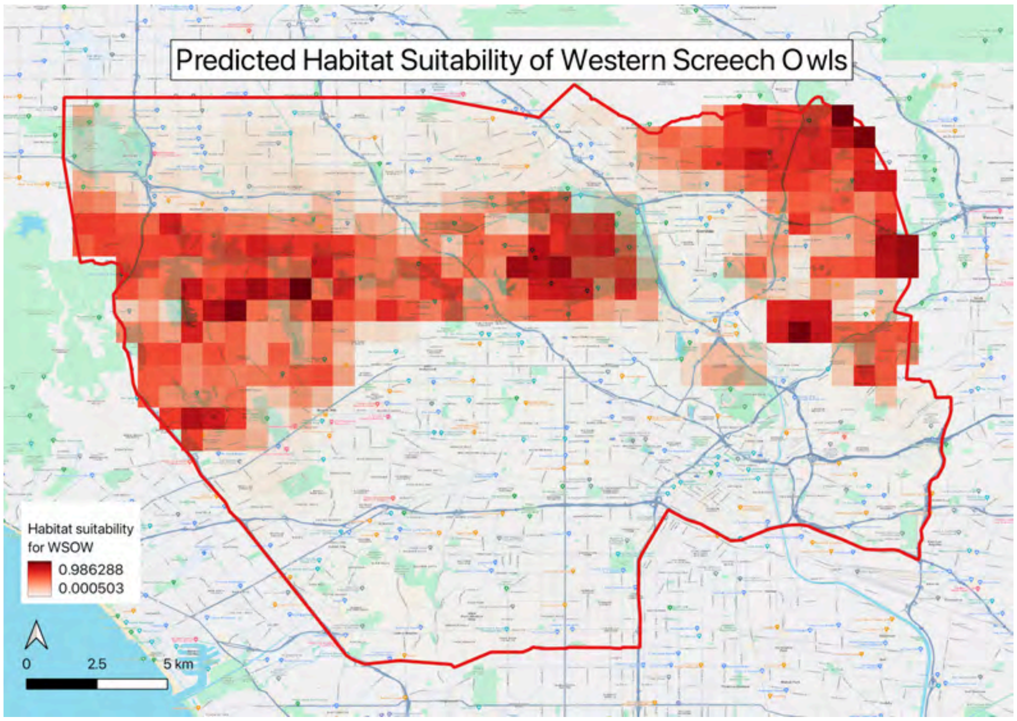


Figure 5. Habitat suitability model for the Western Screech Owl (WESO) in the LA Raptor study area.

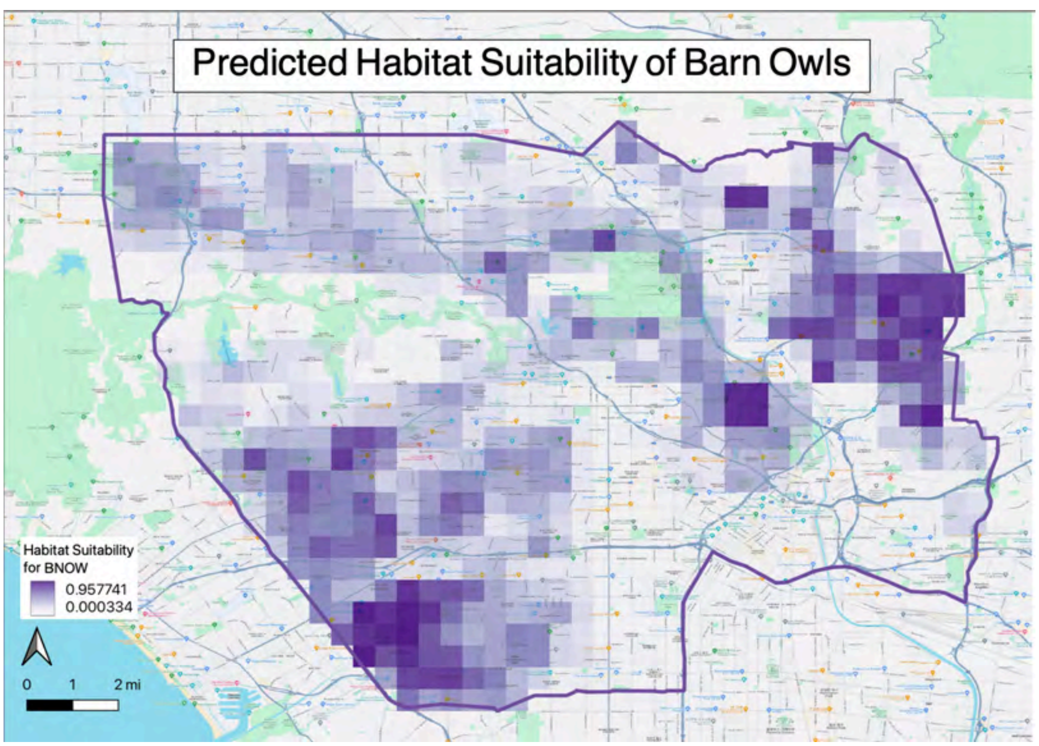


Figure 6. Habitat suitability model for the Barn Owl (BNOW) in the LA Raptor study area.

While Figures 5 and 6 provide an understanding of the species distribution of the two elusive owls within the study area, the map is difficult to interpret and isn't visually appealing. As a result, for our final maps shown in the report, we determined that it would be best to smooth the raster data by utilizing QGIS to create maps that are evener and easier to understand. This process required downloading the SAGA Next Gen plugin, which has a raster filter tool called "Gaussian filter." By using this tool, we were able to decrease the noise of the map and essentially smooth out the pixelation present in our initial maps (as illustrated in Figure 7). After increasing the resolution of the raster data by exporting the layer with a higher resolution (we increased the resolution by an order of magnitude), we applied the Gaussian filter tool. The tool required decreasing the standard deviation to get more discrete colors. For our purposes, we applied a standard deviation of 20 and a radius of 20 (meaning the tool used the 20 adjacent pixels). Initially, we had smoothed each raster file but there was still slight pixelation (Figure 8). We were able to determine the issue had stemmed from the raster file being incorrectly converted to a higher resolution. After smoothing the map, we used the tool "Clip Raster by Mask Layer" to fit it to the region of the LA Raptor Study. We ensured that we picked a color ramp that would emphasize the data and properly communicate the areas of high habitat suitability.

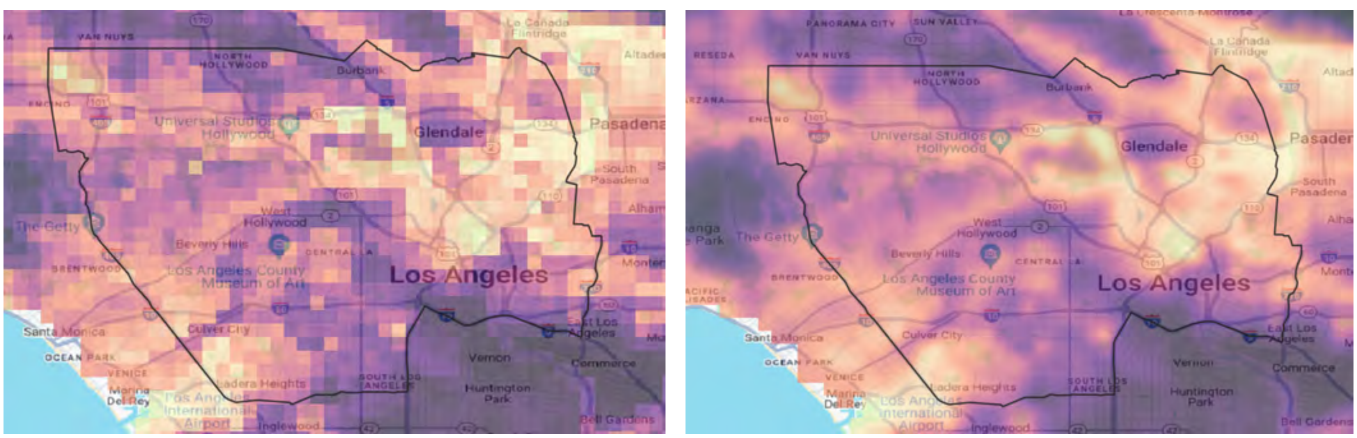


Figure 7. Habitat suitability model for the Barn Owl (BNOW) in the LA Raptor study area without Gaussian Filter (left) and with Gaussian Filter (right).

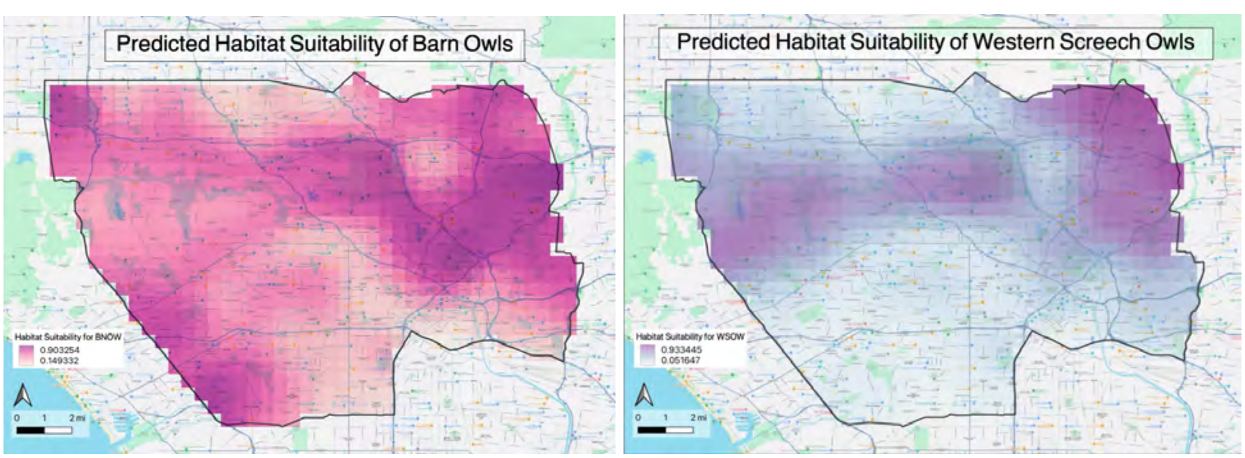


Figure 8. Habitat suitability model for the Barn Owl (BNOW) in the LA Raptor study area (left) and Western Screech Owl (WESO) (right) without proper resolution.

As described in the methods section of our report, we reduced the number of environmental variables inputted in our final MaxEnt models through Pearson's Coefficient. This is an unbiased method for reducing the 36 total predictors by eliminating variables that are highly correlated with each other. For our purpose, we used a threshold of a Pearson's Coefficient of 0.7, meaning that we retained variables with prediction correlation greater than -0.7 or less than 0.7. After our initial run, we eliminated 14 variables which lead us to a total of 22 environmental variables. Although we were planning on running another Pearson's Correlation Coefficient to further reduce the predictors for our MaxEnt models, unfortunately time was limited and therefore the final 22 environmental variables used in the final BNOW and WESO habitat suitability maps are shown in Table 3.

Table 3: Environmental Variables determined utilizing Pearson's Coefficient

Slope	Population	Non-native arthropod species
Normalized difference vegetation index (NDVI)	Native species	Native plant species
Geo	Canopy	BIO19= Precipitation of Coldest Quarter
BIO18= Precipitation of Warmest Quarter	BIO17= Precipitation of Driest Quarter	BIO15= Precipitation Seasonality (Coefficient of Variation)
BIO14= Precipitation of Driest Month	BIO9= Mean Temperature of Driest Quarter	BIO7= Temperature Annual Range (BIO5-BIO6)
BIO6= Min Temperature of Coldest Month	BIO5= Max Temperature of Warmest Month	BIO3= Isothermality (BIO2/BIO7) (×100)
BIO2= Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO1= Annual Mean Temperature	Aspect
	All species	

Random Forest

Despite narrowing down unique environment variables to utilize using Pearson's Correlation Coefficient, we were limited by time and therefore unable to produce an accurately completed Random Forest habitat suitability map. However, we did undergo the process of using the Random Forest algorithm in RStudio to create a map that predicts where an owl may be based on unknown locations. This process involved preparing all environmental variable layers and then extracting the values of environmental variables at the locations of presence and absence points. After training the Random Forest model, a grid is created that covers the study area where one wants to predict owl presence. Then, the predicted probability of owl presence is predicted within each cell of the grid. Figure 9 illustrates the spatial prediction map we were able to run, with the map being created by multiple points filling up the entire study area of the LA Raptor Study. Unfortunately, the map created is clearly incorrect as the distribution of Barn Owls is not linear and confined. This issue is most likely a result of the input data being incorrectly formatted.

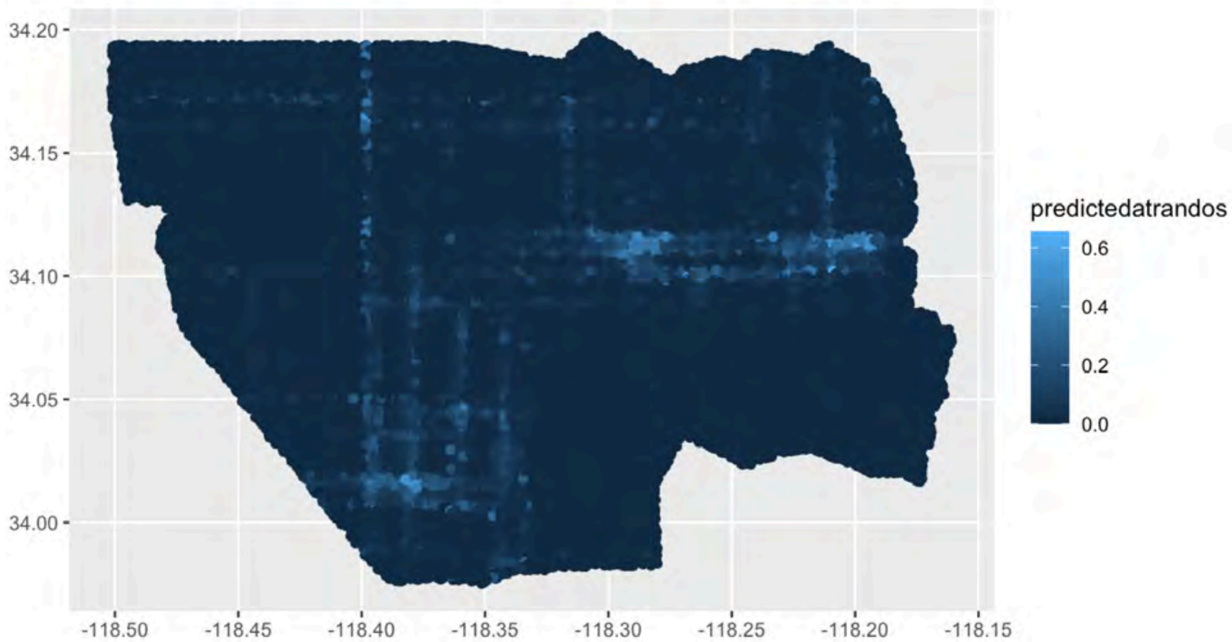


Figure 9. Random Forest model for the Barn Owl (BNOW) in the LA Raptor study area.

Appendix D. Field Reports

Date: 3/14/2024, Report by Nikole Liang

Start: 7:35

The field team (Andrew, Jocelyn, Nikole) arrived at Basil Lane (exact coordinates unavailable) on an extremely windy day to look for owls in the nearby palm trees. We played calls about 5 times but did not hear any presence. The strong winds also made things incredibly difficult to hear.

End: 8:00

Date: 4/23/2024, Report by Nikole Liang

Start: 7:35

The field team (Andrew, Beatrice, Jocelyn, Nikole) arrived at Brand Park at around 7:35 PM. From the parking lot, we made our way up the trail into the mountains and turned left at our first fork. We played our first BNOW call by the stream at 7:47 PM. At 7:51, we tried playing WESO calls and followed up 2 other times in the same location. Neither species were seen or heard.

At 8:03, we continued climbing uphill where the rocky terrain was more abundant in sage brush with no large trees. Frogs, crickets and mourning doves could all be heard and there were bats that flitted through the air. WESO and BNOW calls were both played from the higher elevation but presence was not detected. After 8:11, we decided to leave the area and head towards the center route of the fork. We hiked uphill towards an open area that had many 4 - 5 palm trees and at least one eucalyptus tree. We played the WESO call at 8:28 and 8:31 and only heard very loud cricket, plane noises, and other bird chirping. Continuing for another ½ mile, we heard a GHOW call at 8:44 and a second could eventually be heard. One was located on the right upper side of the mountains and the other one was farther in and in the canyon. We decided to keep walking but eventually heard coyote calls in the distance and called it a day.

End: 9:30

Date: 5/16/24, Report by Dan Cooper

Start: 7:00

The field team (Andrew, Nikole, and Jocelyn) met at 7:00 PM at "Lake Hollywood Park" along Canyon View Dr. northeast of Lake Hollywood. However, there was a massive film shoot setting up, plus the usual crowds to see the "Hollywood sign", so we made our way west to scout areas to survey along the northern edge of the lake.

I'd seen an adult RTHA cruise low from the slope below the Hollywood sign over Lake Hollywood Park. This would presumably be from RTHA-045, which has not been found this year. Shortly thereafter we observed a subadult RTHA (much white flecking on back, pale eye) "tee'd up" on a pine near the dam of the forebay at the NW end of the reservoir (south of RTHA-008). That pair was incubating in mid-March, so it's possible this was a fledgling from that nest this year.

We continued onto Wonderview Dr. southwest toward Cahuenga Pass, investigating potential cavities in black walnut trees in the small woodland there. Traffic noise was high, so we had our doubts we'd hear much. We observed a potential GHOW nest in a shamel ash high up a slope to the north (stick nest with some "fluff" in the cup).

Continuing west over 101, we wound along Woodrow Wilson Dr. toward the Adina nest (GHOW-LA-272/RTHA-LA-272). We observed copious whitewash on the ground below the nest (it's a RTHA this year). An adult RTHA cruised low overhead to the west and a mockingbird was actively harassing something (a fledgling?) high in the nest tree.

As dusk settled we played WESO calls three times (2 min. between broadcasts), and heard a distant counter-singing pair of GHOW to the south (presumably the GHOW-272 pair). No WESO.

We continued along Passmore to the MWD gate at the "Oakshire open space", a semi-permanent drainage emerging from 122 acres of chaparral and oak-walnut woodland. We serendipitously ran into the owner of a house ("George") at the gate who had a gate key and offered to let us through to explore (his property extended to include a part of the habitat). He reported seeing and hearing GHOW "every night", and described them counter-singing and flying from a large sycamore behind his house to other trees. He also said that this was the area the local Native Americans hid out in during the Battle of Campo de Cahuenga (!), owing to its reliable water and food. And, when I described screech-owls' call, he said that yes, he's heard that at night.

While we had no response from WESO in the canyon (we played the call c. 3 times in various spots up to 200 m back from the gate), we heard an occasional soft begging call from an unidentified sp. that sounded possibly like a GHOW fledgling. We also played BNOW once, with no response. As we were leaving, an apparent GHOW fledgling flew a short distance out of the same sycamore George pointed out (didn't appear to have ear tufts, labored flight). While he reported two pairs here, one near his house and another down-canyon (i.e., toward Adina), we couldn't confirm there were two. *We could report this as a successful fledging by GHOW-272.

We continued east along Passmore back to Woodrow Wilson, playing the WESO call a few more times at 2-3 more stops with oaks, blue gum and sycamores, without response. The area was fairly loud with traffic, barking dogs, etc.

We then crossed the 101 Fwy and stopped at the walnuts along Wonderview, where we inadvertently flushed a GHOW off the roadbed where it had been pursuing a mouse (which scampered away). The owl perched on a fence, then a snag near the road, affording excellent views.

Continuing up Wonderview, we played the WESO call up near the top of the walnut woodland, where we flushed yet another GHOW, an adult, which was c. 200 m from the hunting bird. It flew out of a deodar near the crest east to perch above a house on the ridgetop. *Presumably this is a new pair.

We then played the WESO call near the trailhead around Lake Hollywood, and heard a distant GHOW calling far to the southwest (we were standing at the old nest site of GHOW-024, which hasn't been found in many years). *Note on spreadsheet. We also heard at least 3 Common Poorwills here (which we hadn't heard at any stop prior, or after).

We passed the Tahoe Dr. RTHA territory (RTHA-045) since the volunteers have heard GHOW here this season, and there was considerable noise/light from the film shoot here. We ended up at the Innsdale Trail north of Lake Hollywood Park, and walked about 1/2 across to Deronda Dr., where we heard and saw a begging GHOW fledgling about 100 m north of the trail, perched on a low snag. *This could also be a new pair, which could be called GHOW-045 to "match" the RTHA); or, we could just call it GHOW-106, a very old territory, was reportedly south of here, along the perimeter trail around Lake Hollywood, until we work out the actual number of territories here. We played WESO twice, and didn't hear anything respond, but the entire area was illuminated by lights from the film shoot.

End: c. 10:00 PM

Date: 5/21/24, Report by Andrew Briones

Start: 8:00 PM

The field team (myself, Jocelyn, and B) met at the entrance to Deervale Trail on Crisp Canyon Rd. in Sherman Oaks. The entrance was located in a residential area, between two houses. Here, we noted the presence of many woodland shrubs, dry grass, open patches in the ground (possibly holes from prey species), and a pretty open patch. We played WESO two times (with our usual 2 minutes between calls) and BNOW once. We heard neither WESO nor BNOW.

We moved on to the next location, Camino De La Cumbre. We stopped along the middle of this road (34.13999° N, 118.44502° W) and played WESO twice and BNOW once. We also looked for any whitewash on the road, but did not see any. Again, we heard neither WESO nor BNOW.

Next, we hit what we assumed to be the south end of Davana Rd (34.14052° N, 118.43414° W). This was another residential street. We noted the presence of palm trees which appeared to be recently trimmed. Again, we played WESO twice and BNOW once. A helicopter interrupted our broadcasting for about 30 seconds. We also looked for the presence of whitewash on the road, but did not see any. Unfortunately, we did not hear WESO nor BNOW.

Our last stop was Dixie Canyon Ave., following the coordinates Dan provided us. We noted the presence of some woodland shrubs here as well, and saw what looked to be a mouse scurry across the road (indicating the presence of prey species). We played WESO twice and BNOW once, as well as looked for whitewash. Neither were heard and no whitewash was seen. We also heard movement in a nearby tree between our calls. We stopped to listen for a moment, and then resumed our calls, but heard nothing after.

End: ~9:30 PM

Date: 5/30/24, Report by Jocelyn Nuño

The field team (Jocelyn and Andrew) arrived at Van's Mount Washington home (4921 Aldama Street) at 7:15PM. Van and his friend, Kelsey, led the team to the first area of interest at the intersection of Terrace 49 and Aldama Street (34.1106700, -118.2097900). At the first location, a red tailed hawk was seen at the top of a palm tree. The hawk seemed to be chased out of the palm by two mockingbirds. When the hawk flew out of the palm, it was also observed to have a mouse in its beak.

Next, the team was led up a trail along Mount Washington and screech owl calls were played at the peak of the trail (34.1104957, -118.2113846) around 7:40PM. The calls were for about 60 seconds and followed by a ~10 minute listening period. At the peak we were also able to see the eucalyptus tree where Van had believed screech owls may be nesting, but we were not able to see a nest. After getting no response from the calls played, the team began to make our way down out of the trail.

On our way back down from the trail we began to hear screech owls begin to call, around 8:10PM. At the base of the trail the calls were clear and we observed a screech owl fly into a eucalyptus tree (34.1099644, -118.2111190). The screech owl stayed in the eucalyptus and a second owl began to respond from the adjacent street. After the first owl flew out of the eucalyptus and toward the mountain, the team began to call to the second owl (34.1100110, -118.2106999). After playing recorded calls and listening for about 5 minutes, the second owl swooped down toward the team and flew into the mountain as well.

After this encounter, Van led us to an area where he had heard great horned owls (34.1113921, -118.2102634). We played GHOW calls twice in this area around 8:40PM with no response. We also called GHOW in Van's backyard (34.1110934, -118.2093722) with no response as well. We ended our surveying with Van around 9:15PM.

The fieldwork team then headed back to W Ave. 45, where the team had their first screech owl finding (34.100666, -118.211170). We arrived at the location and played a screech owl call around 9:25PM. The screech owl almost immediately flew out of the palm we suspected a nest could be, and landed in the shrub in front of us (see attached photo). The owl began calling in response and did not stop for about 15 minutes. The owl also followed us further down the street as we left the initial call location.

We decided to try to call in one more area to try and find a new screech owl observation. We decided to head over to Elyria Park since there were two records of screech owls in the area. We drove to (34.1017205, -118.2247554) and played screech owl calls twice at around 10:20PM. There was no response within the total 10 minute listening period. We ended the night around 10:45PM.

Date: 6/6/24, Report by Nikole Liang

For our last field survey, we (Andrew, Beatrice, Jocelyn, and Nikole) followed a neighbor's tip who heard potential owl noises sent by Nurit in Culver City. We arrived at 8:13 PM at 4231 Madison Avenue and noticed that there were many palms lining the streets of the neighborhood. We walked to a large tree towards the intersection to investigate evidence of white wash and pellets. To begin, we spent some time listening first to our surroundings and did not hear anything. At the end of the street, towards the dead end side, we played the BNOW at 8:34 and 8:36. This was at the base of a tall rough eucalyptus tree that seemed promising.

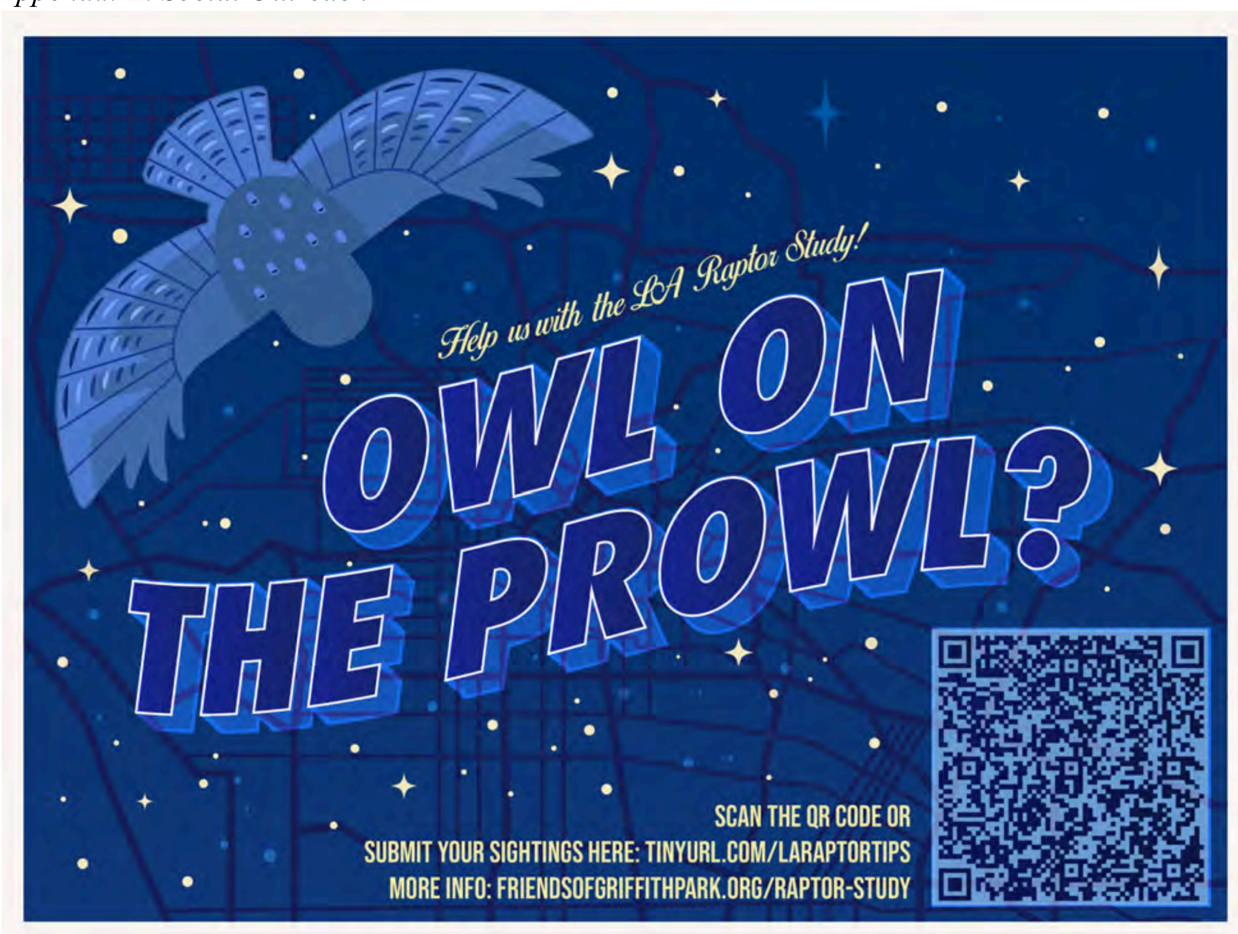
Moving towards the middle of the street, we played the call closer to the neighbor who reported the tip. At that moment, there was still no owl presence.

At 8:58, the call was played again, and we saw a barn owl swoop from behind us to the front of us. It circled the intersection briefly as we made our way towards its direction and it flew into a palm at the corner of Madison and Farragut. We staked out this palm for a while to see if it would fly to another location, however, it appeared to stay in that palm for as long as we were observing it.

Later, a neighbor relayed another tip that there was owl presence down at 4160 Madison Avenue at 9:24 (34.01761º N, 118.39379º W). We played the call of juvenile BNOW calls again and the BNOW was spotted at 9:27 PM and it flew into one of the palms in front of 4160 Madison Avenue. A presumed second owl flew from the houses into the other palm and then moved into an adjacent tree at 9:40. We spent some time observing the owl in the tree.

Ended field work at 9:50 PM.

Appendix E. Social Outreach



Above is a social outreach graphic designed by Nikole Liang. It was designed with the intention for people to scan the QR code to submit their owl sightings, or any other raptor sightings, to the LA Raptor Study Google form.

Appendix F. Author's Contribution

Modeling Team: The modeling team consists of Stephanie Choi, Karine Leclercq, Mélia Leclercq, and Ahalya Sabaratnam. Questions regarding the methods or results of MaxEnt models should be referred to Karine or Mélia. Questions or comments regarding QGIS work or Random Forest should be directed to Ahalya or Stephanie.

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