Species occupancy, detection, and distribution using camera trap data on Brookhaven National Laboratory in preparation for the colonization of coyotes

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Abstract

Currently, Long Island is the last area in the continental United States to be colonized by coyotes *(Canis latrans)*. The colonization of coyotes can result in many ecological changes, not only to prey, but also to predators. Currently, Long Island has two fox species, the gray fox *(Urocyon cinereoargenteus)* and the red fox *(Vulpes vulpes)*. Their populations may be affected by the presence of coyotes due to similar diets, which could result in competition and altered resources for the fox species. This will then result in cascading effects to small mammals. The colonization can result in some positives as well. One major one being that currently white-tailed deer *(Odocoileus virginianus)* are overpopulated, which could be affected by the presence of coyotes. Yet, this alone would not be a major factor in reducing their populations, since coyotes primarily prey on fawns. In order to gauge how coyotes will impact the ecosystem of Long Island, one must first look at the current populations of the differing species. Camera traps were set up throughout Brookhaven National Laboratory, located in Long Island, New York. The cameras were set out and moved every two weeks to ensure that multiple areas were covered. The images were analyzed from those cameras and previous camera trap images by using Timelapse2 and R Studio, to estimate species occupancy, detection, and distribution at Brookhaven National Laboratory. These were then visually displayed using maps created in programs such as ArcGIS Pro and R Studio.

Introduction

Historically coyotes did not exist in New York, but in recent years they have colonized parts of New York and have been spotted in Queens, Nassau, and eastern Suffolk counties Long

Island (Green, personal communication). This colonization will influence both prey and predator species alike. Coyotes are opportunistic feeders and tend to eat what they can find, so in order to understand how the colonization will impact Long Island one must first investigate the current species abundance and distribution.

A study by Duncan et al. 2020 found that white-tailed deer were the most identified prey species in the coyote's diet. Yet, another study found that coyotes do not impact the overall population growth of white-tailed deer, except in small-scale studies of local deer populations (Bragina et al. 2019). This is due to how coyotes primarily prey on fawns and malnourished deer (Balluffi-Fry et al. 2020 & Murray et al. 2015), rather than hunting them. Despite the overall population of white-tailed deer being unaffected, it is still necessary to keep track of the current status of their population, and how it will change with the colonization of coyotes.

There are two main predators on Long Island, the red fox and the gray fox, which have very similar diets to the coyote, since they are also opportunistic feeders. Currently red foxes' population status in Brookhaven is at stable rates since they adapt well, but gray foxes' status has been declining and it is rarer to spot them in the lab. A study by Egan et al. 2021 found that gray fox populations have been declining due to interspecies interactions from coyotes in areas where they both exist, and also found that increased urbanization also caused declines since they are not as adaptable as their counterpart the red fox. The usage of similar resources will cause competition and potential cascading effects on prey species. This can result in both positives and negatives on the small mammal populations. For species that have lower abundances this may result in a significant drop in their populations that could cause them to be threatened. Yet, for the ones that have abundant populations, this could potentially have a massive effect on the spread of ticks, especially ones that carry diseases, such as the black-legged tick that carries

Lyme disease. This would be a very important positive for Long Island since if more prey species are around to consume smaller mammals, then there will be less species around to be hosts for ticks, resulting in a reduced spread of disease to humans (Hofmeister et al. 2017).

Conducting analyses of the current state of the wildlife species on Brookhaven National Laboratory will help us better understand how to prepare for the changes that the ecosystem will face. In order to do this, a process of reviewing literature was conducted to see which methods would be best suited for the camera trap data I collected. This resulted in a final decision of creating occupancy and detection estimates created using an occupancy model in R, and distribution estimates from ArcGIS Pro.

Methods

Study Area

This study was conducted throughout Brookhaven National Laboratory, located in Upton New York. The laboratory is a United States Department of Energy national laboratory that spans 5,265 acres. The laboratory is within the Central Pine Barrens of Long Island, with white pine, pitch pine, oak, and red maple being very common tree species found throughout the area. The landscape consists of grassland, shrubland, forested areas, and industrialized buildings.

Brookhaven National Laboratory is host to many wildlife species, including large mammals such as fox and deer, smaller mammals such as shrews, mice, bats, woodchucks, raccoons, squirrels, and various species of reptiles, amphibians, birds, and invertebrates.

Camera Trap Set-up

18 Moultrie trail cameras were set up throughout Brookhaven National Laboratory by randomly selecting 18 sites out of 73 overall sites made on a grid of the laboratory. This process was repeated every two weeks to ensure that all 73 sites were eventually accounted for. Cameras were strapped on to a tree at each site and pointed primarily towards trails and roads since predators are known to use man-made routes to prey on species (Wysong et al. 2021). Approximately six feet away from the camera fatty-acid scent tablets were placed to attract animals to come into the view of the camera. Data for winter 2021 was collected by Jennifer Higbie, in which she followed the same process. Photos were then processed through an image processing program called Timelapse2 in order to create csv data files to work with in R and ArcGIS Pro (Greenberg 2019).

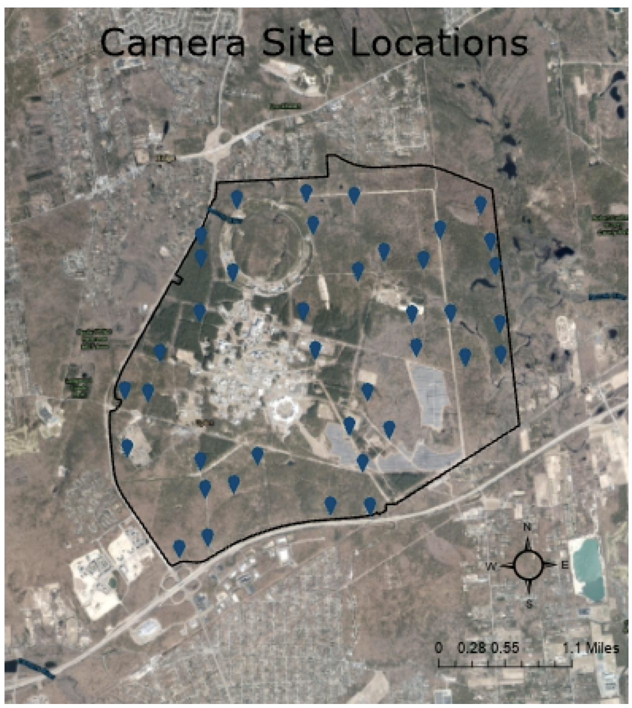


Figure 1. Map of Brookhaven National Laboratory with points indicating where camera traps were placed.

Statistical Analyses

Occupancy and distribution estimates were created using the package unmarked in R studio (Fiske & Chandler 2011). This package was made for data that includes repeat surveys of unmarked animal species. In order to fit camera trap data into surveys the data was split up by week of the year and counted each week as a survey per camera site location. Estimates were made for each species that was caught on camera. Repeat detections of the same animal triggering the camera multiple times were accounted for by running the raw data through a for loop code made in base R that counted multiple detections as one if the detection was the same species with the same species count, at the same camera site, within thirty minutes of the last image in the time series.

Creation of Maps

Maps to show species distribution were created in the program ArcGIS Pro using the sum counts of species per camera. Each circle size represents the species count per camera site. The same for loop code used for statistical analyses was used in creating the maps to account for the same species coming up on the camera repeatedly.

Results

Summary Statistics

Summary statistics were made for both study periods. Statistics include how many weeks were species detected out of the total time cameras were out, total detections, and total counts of species detected (Table 1 & 2). For example, in the summer of 2022, cameras were out for a total of eight weeks, and white-tailed deer were detected at least once every week. There was a total of 107 unique detections of white-tailed deer, which means the cameras picked up 107 images of them. There were then a total of 595 white-tailed deer in those images. Box plots for each camera were created to show species distribution through the camera trap sites (Figure 2). Species detected at the cameras included white-tailed deer *(Odocoileus virginianus)*, red fox (*Vulpes vulpes*), wild turkey (*Meleagris gallopavo*), raccoon (*Procyon lotor*), woodchuck (*Marmota monax*), gray squirrel (*Sciurus carolinensis*), feral cat (*Felis domesticus*), and various bird species.

Species	Weeks Detected	Total Detections	Total Counts
White-tailed Deer	8	107	595
Bird Species	8	41	99
Wild Turkey	7	24	55
Raccoon	7	22	45
Red Fox	7	12	19
Woodchuck	4	7	10
Gray Squirrel	5	7	8
Feral Cat	2	3	3

Table 1. Summary of wildlife species detections for summer 2022. The table includes the count of weeks that species were detected out of the 8 weeks of surveying, total unique detections, and total counts of species.

Species	Weeks Detected	Total Detections	Total Counts
White-tailed Deer	15	142	598
Bird Species	11	18	56
Wild Turkey	15	52	163
Raccoon	9	22	40
Red Fox	15	42	91
Gray Squirrel	2	2	3

Feral Cat	12	17	28

Table 2. Summary of wildlife species detections for winter 2021. The table includes the count of weeks that species were detected out of the 15 weeks of surveying, total unique detections, and total counts of species.

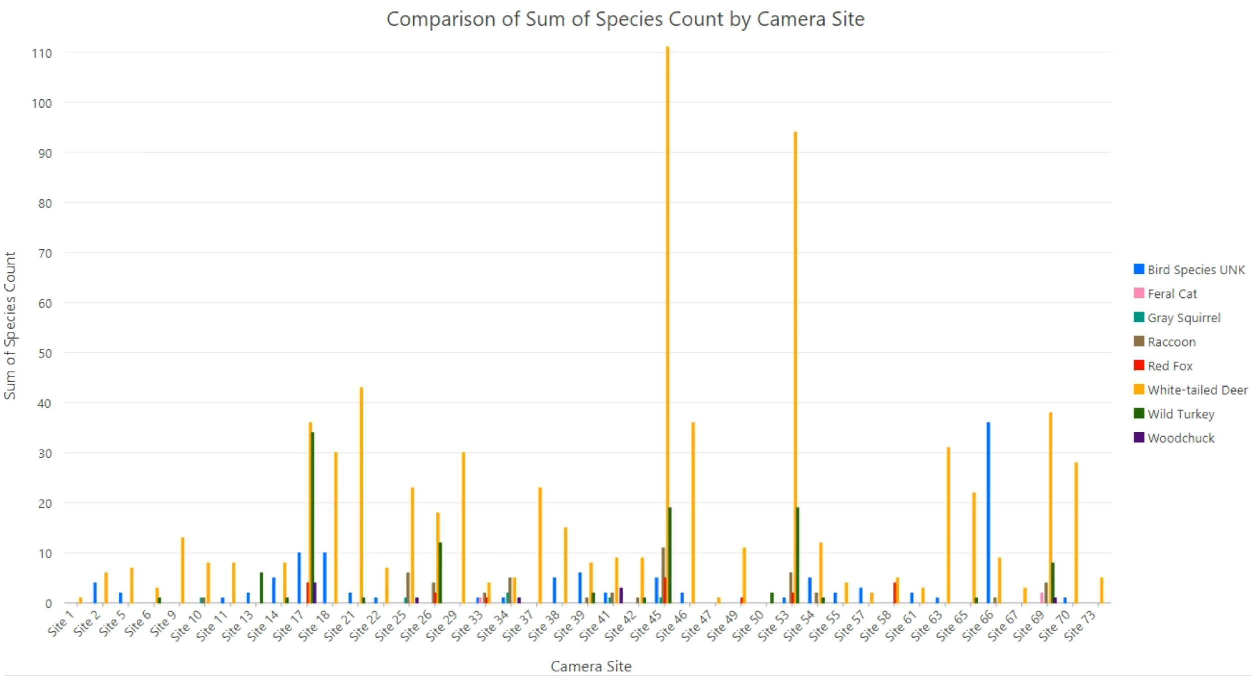


Figure 2. Box plots representing the sum of individual species counts for each camera site.

Occupancy and Detection Estimates

For the summer data white-tailed deer had a 77% probability of being detected per week given they were present, (β = 0.771, SE = 0.0368, P-value = 5.46e-09). Bird species had a 37% probability of being detected per week given their presence, (β = 0.368, SE = 0.0648, P-value = 0.0522). White-tailed deer were found to occupy 93% of sites with detection accounted for, (β = 0.934, SE = 0.0400, P-value =4.28e-05). Red foxes were found to occupy 19% of sites with detection accounted for, (β = 0.194, SE = 0.0707, P-value = 0.00164). Woodchucks were found to occupy 16% of sites with detection accounted for, (β = 0.161, SE = 0.0707, P-value = 0.00622). Gray Squirrels were found to occupy 17% of sites with detection accounted for, (β =

0.173, SE = 0.0923, P-value =0.0153). Feral cats were found to occupy 6% of sites with detection accounted for, (β = 0.173, SE = 0.0646, P-value = 0.00196). Estimates that had P-values greater than the alpha value of 0.05, indicating a lack of significance, are listed in the tables below (Table 3 & 4).

Species	Detection Estimate	Standard Error	P-Value
White-tailed Deer	0.771	0.0368	5.46e-09
Bird Species	0.368	0.0648	0.0522
Wild Turkey	0.417	0.0866	0.349
Raccoon	0.431	0.0916	0.458
Red Fox	0.430	0.124	0.579
Woodchuck	0.316	0.159	0.296
Gray Squirrel	0.281	0.150	0.205
Feral Cat	0.317	0.232	0.474

Table 3. Back-transformed detection estimates per species for summer of 2022. Detection probability of species per week given their presence.

Species	Occupancy Estimate	Standard Error	P-Value
White-tailed Deer	0.934	0.0400	4.28e-05
Bird Species	0.760	0.111	0.0592
Wild Turkey	0.392	0.0924	0.258
Raccoon	0.357	0.0880	0.126
Red Fox	0.194	0.0707	0.00164
Woodchuck	0.161	0.0815	0.00622
Gray Squirrel	0.173	0.0923	0.0153
Feral Cat	0.0646	0.0522	0.00196

Table 4. Back-transformed occupancy estimates per species for summer of 2022. With detection accounted for, estimates represent the percentage of sites estimated to have species present.

For the winter data white-tailed deer had a 79% probability of being detected per week given they were present, (β = 0.785, SE = 0.0306, P-value = 8.83e-13). Bird species had a 27% probability of being detected per week given their presence, (β = 0.270, SE = 0.0663, P-value = 0.00310). Raccoons had a 22% probability of being detected per week given their presence, (β = 0.224, SE = 0.0552, P-value = 9.29e-05). Feral cats had a 30% probability of being detected per week given their presence, (β = 0.297, SE = 0.0728, P-value = 0.0134). Estimates that had P-values greater than the alpha value of 0.05, indicating a lack of significance, are listed in the tables below (Table 5 & 6).

Species	Detection Estimate	Standard Error	P-Value
White-tailed Deer	0.785	0.0306	8.83e-13
Bird Species	0.270	0.0663	0.00310
Wild Turkey	0.528	0.0995	0.978
Raccoon	0.224	0.0552	9.29e-05
Red Fox	0.561	0.0589	0.305
Feral Cat	0.297	0.0728	0.0134
Gray Squirrel	0.0117	0.0335	0.127

Table 5. Back-transformed detection estimates per species for winter of 2021. Detection probability of species per week given their presence.

Species	Occupancy Estimate	Standard Error	P-Value
White-tailed Deer	1.00	0.0017	0.905
Bird Species	0.387	0.110	0.320
Wild Turkey	0.499	0.0511	0.778

Raccoon	0.546	0.131	0.728
Red Fox	0.439	0.0957	0.527
Feral Cat	0.366	0.103	0.216
Gray Squirrel	0.949	2.55	0.956

Table 6. Back-transformed occupancy estimates per species for winter 2021. With detection accounted for, estimates represent the percentage of sites estimated to have species present.

Distribution Maps

Maps were created for each species that were detected on the cameras. Each dot is where the species of interest was detected with the size of the dot indicating the total count of that species appearing in the site. The most widely distributed species found throughout the laboratory were bird species and white-tailed deer.

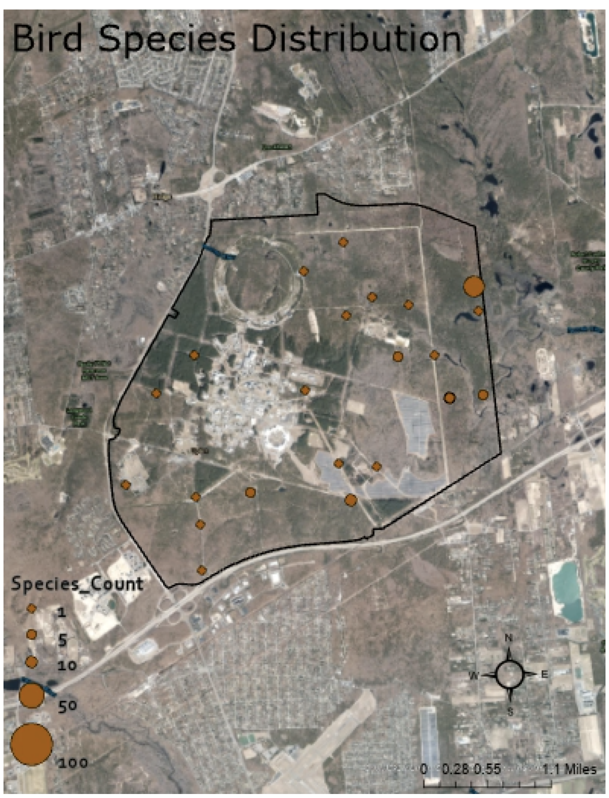
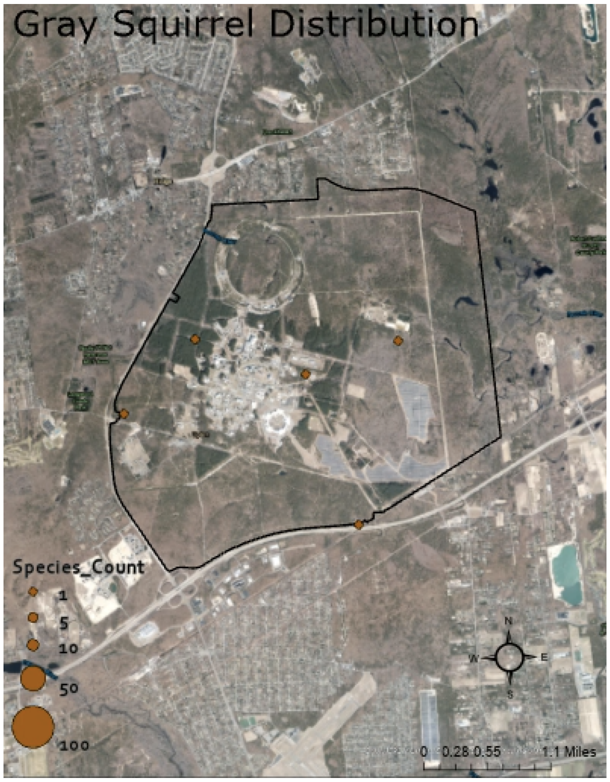


Figure 3. Bird species distributions.

Figure 4. Feral cat distributions.



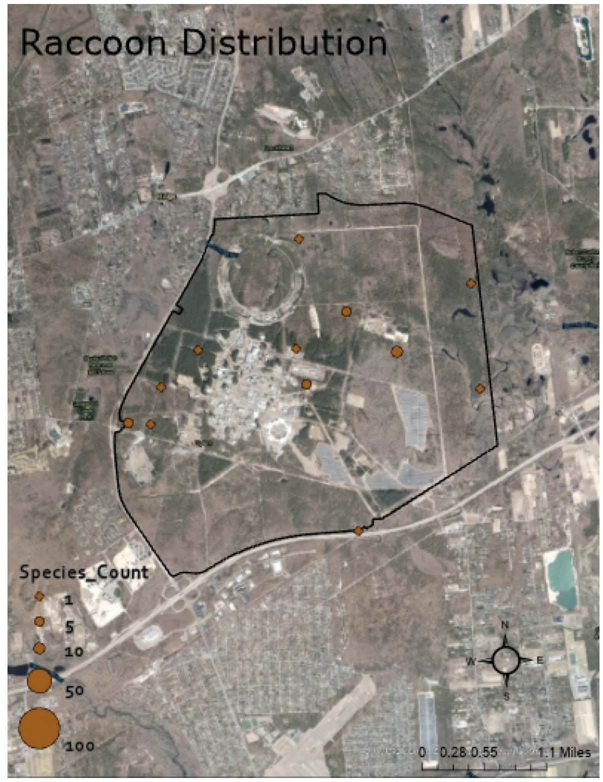
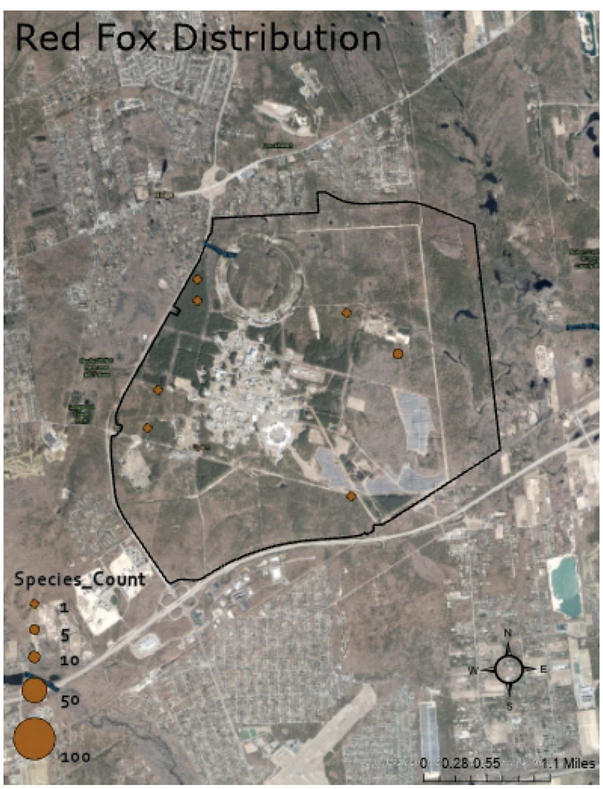


Figure 5. Gray squirrel distributions.

Figure 6. Raccoon distributions.



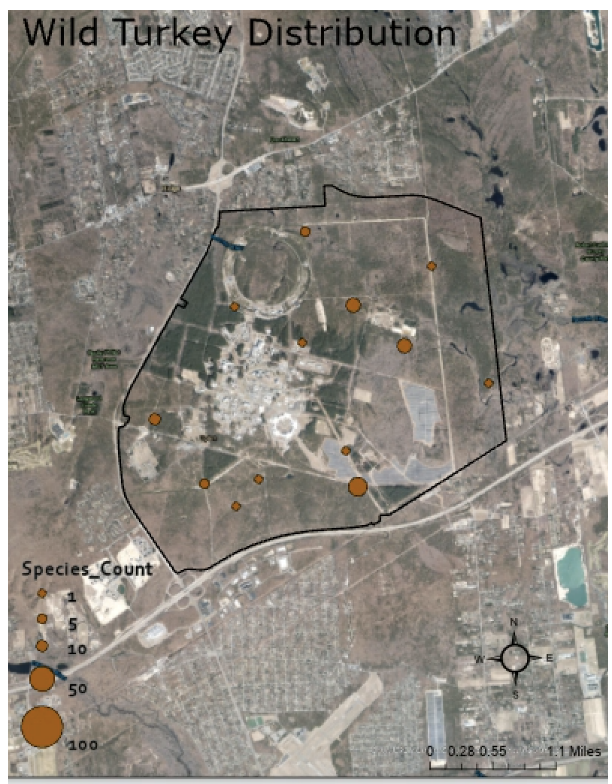


Figure 7. Red fox distributions. **Figure 8.** Wild turkey distributions.

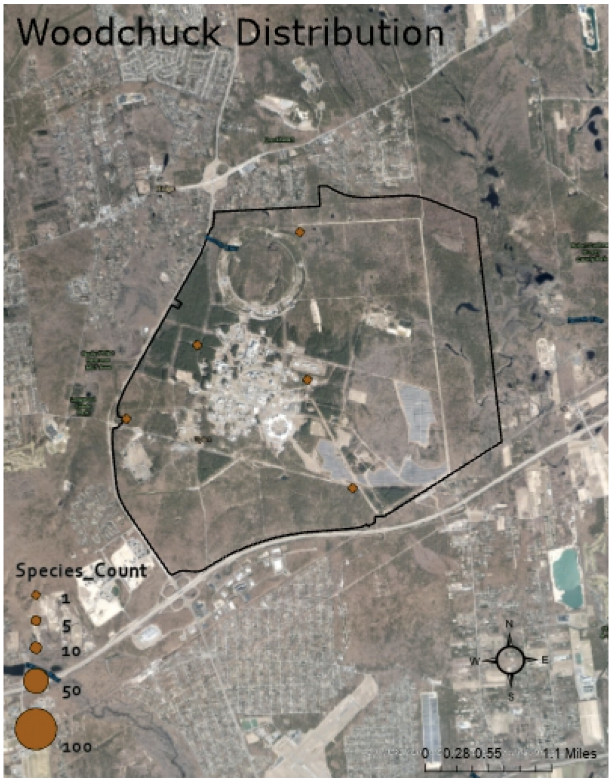


Figure 9. Woodchuck distributions.

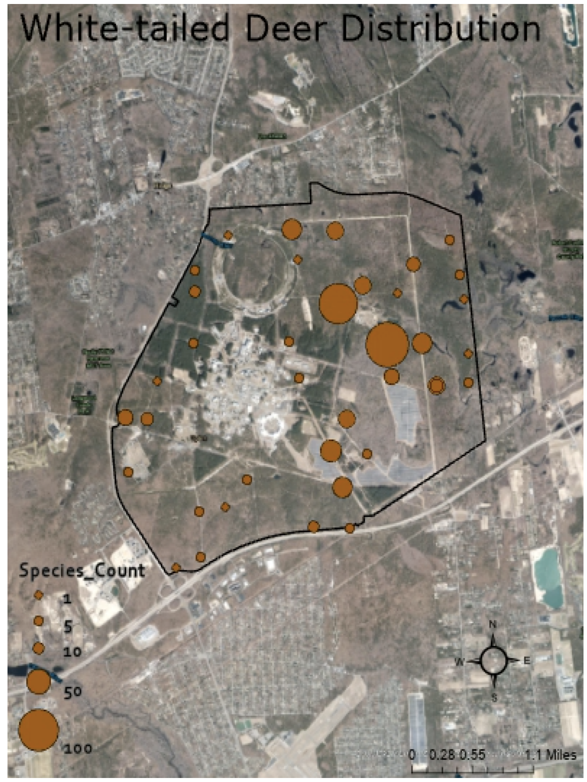


Figure 10. White-tailed deer distributions.

Discussion

Coyotes have recently begun to colonize Long Island, but due to factors such as geography, their ability to adapt and their abundance, they are expected to arrive in the Central Pine Barrens and Brookhaven National Laboratory soon. They have recently begun to colonize western Long Island with several breeding pairs becoming established in Queens and western Nassau counties and a potential breeding pair in eastern Suffolk County (Green, personal communication). Once full colonization happens there will be significant changes to the local ecosystem. Due to the previous colonization of Eastern states that did not historically have coyotes, we can expect and prepare for this. This study will be further conducted in the future to create more robust estimates with greater sample sizes, including multi-seasonal data.

One takeaway from the analyses is that there are a lot of white-tailed deer that are also well distributed at the lab. As discussed earlier this could potentially be affected by the presence of coyotes. A study by Balluffi-Fry et al. 2020, found that in areas with highly dense ungulate populations, coyotes were more likely to prey almost solely on ungulates. Another takeaway from the results is the reduction in red fox detections. There are multiple factors that could be causing this decline. The first one being that there may have been a seasonal correlation with red foxes hunting habits. Another potential cause of this could be due to mange. Mange is a skin disease caused by the *Sarcoptes scabiei* mite. A study found that survival could be as low as 41% for adult foxes with mange (Willebrand et al. 2022). Most images of foxes from the summer of 2022 had mage visibly on them.

Camera trap data has become more popular in recent years due to the fact that it is a low effort survey method that also creates little to no disturbance to wildlife and large sample sizes (Silveira et al. 2003 & Roberts et al. 2016). It is especially helpful for tracking prey species, such as coyotes or foxes, since no contact is necessary. Various estimates can be conducted using camera trap data as well, such as occupancy, abundance, and species richness. Occupancy estimates were chosen due to the strength of the model with that data collected. Abundance estimates were attempted using an N-mixture model in the unmarked package in R, but the models were very weak due to low sample sizes and lack of covariates, so they were omitted from the study (Fiske & Chandler 2011). For future studies on this project, I highly suggest collecting area data and environmental covariates so that a more robust model can be created using the spaceNtime package in R (Moeller & Lukacs 2021). A species accumulation curve with the data collected in summer 2022 revealed that one would need about 600 detections at each camera site in order to detect all 8 species detected over the summer (Figure 11). This information can be used for future reference when planning out the study for the next few seasons.

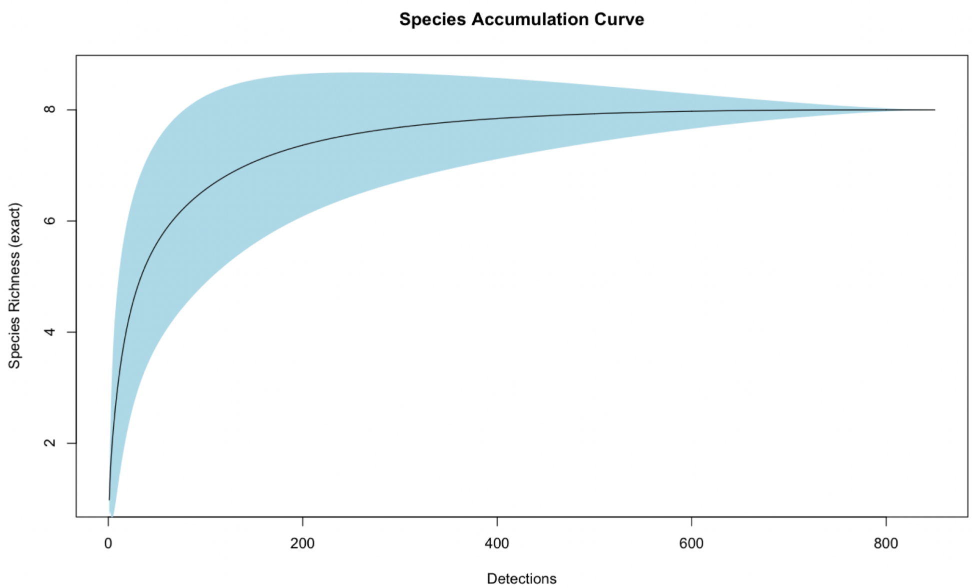


Figure 11. Species accumulation curve of summer 2022 data revealing how many detections needed to detect all species in the study area.

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