Estimating the number of bird species in INBio Park in the Central Valley of Costa Rica
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Introduction

As the environment burns around us, often literally, we can often find little pockets of nature that thrive anyway. As Dr. Ian Malcolm says in the popular film Jurassic Park, “Life finds a way.” Ironically, there are times when these pockets of freedom from human encroachment on wild habitats can be aided by human intervention.

Macarthur and Wilson proposed *The Theory of Island Biogeography* with their revolutionary 1967 book describing the theory. The absolute most basic form of the theory, to reduce it to its basic elements, is that greater species diversity is correlated with a larger island, and also proximity and connectedness to the mainland habitat (MacArthur and Wilson, 1967) though in the preface Wilson claims that even the entire book describes the theory with “oversimplification and incompleteness.” The theory in full is expansive, but can be examined at small scales.

One such island place is the Instituto Nacional de Biodiversidad, or the National Institute of Biodiversity, which was a private institution that had various goals. It was mainly focused on creating an inventory of the country’s natural biodiversity. This involved taking samples from the various environments around Costa Rica and preserving them in samples and exhibits in the park of 7.2 hectares, shown in a map in Figure 1, and maintaining a forest around the buildings of the exhibits as well.

Figure 1. This image shows INBio’s size and a view of it outlined in white. INBio Park, Canton Santo Domingo, Provincia Heredia, Costa Rica. 9°58'23.63"N, 84° 5'36.19"W. Accessed August 6, 2021. Maxar Technologies, Google Earth Pro.

Following the dissolution of the public access to the garden and of the National Institute of Biodiversity in about 2013 and the subsequent government management of INBio Park, the government kept up maintenance of the forests, trimming the undergrowth from the paths and using the buildings for government offices.

The forest island nature of INBio makes it possible for forest-dependent birds to potentially colonize the forest patch, depending on the quality of the forest based on the structural diversity of the forest. The structural diversity and quality of the forest can be estimated by basal area, which affects the potential biodiversity in the area (Lee and Carrol, 2018).

It's important to understand the bird diversity of forest patches like INBio because it helps to make clear the necessary size of a forest island to maintain certain levels of biodiversity. This allows us to better understand which sizes of forest patches and corridors are ideal to preserve and reinforce biodiversity, especially in areas of development where forests are disappearing.

Much like almost everywhere else in the world, Costa Rica's Central Valley has gone through rapid urbanization and loss of large tracts of premontane forest over the past few centuries. This has resulted in the disappearance of numerous species of forest-dependent birds from the region (Bilamonte et al. 2011). The term premontane includes the forests at an altitude just underneath montane forests in the mountains, so a moderate altitude. This is the altitude of INBio Park in the Central Valley.

The preservation of forest patches of sufficient size to maintain or at least temporarily support forest-dependent species seems to be a hopeful alternative to despairing over the disappearance of many more bird species from urbanizing and developing areas, especially if these forest patches are close enough to each other that these forest dependent species can to colonize and re-colonize each forest tract due to proximity. And the more sizable each forest island is, the less dependent each one will be on recolonization to sustain the species in each place. So, what INBio does is provide one such semi-isolated forest patch that possibly does exactly that, and potentially provides a place for forest-dependent species of birds native to the premontane forests of the Central Valley to colonize and remain.

To observe the birds, I walked along the paths of INBio and identified and recorded as many species of birds as possible to achieve the objective of my study: to estimate the total number of bird species living in the INBio forest patch.

Methods

I used Nikon Aculon A211 7x35 binoculars to observe birds in INBio Park one or two hours a day between 6 and 8 am three to four days per week for three and a half weeks. INBio Park is in Santo Domingo in Heredia Province, Costa Rica and its coordinates are 9 degrees 58 minutes 22 seconds North, and 84 degrees 5 minutes 31 seconds West. To identify the birds, I

used the field guide *A Guide to the Birds of Costa Rica* by Gary F. Stiles and Alexander F. Skutch (Stiles and Skutch, 1989).

My observation sessions consisted of fourteen mornings of one to two hours between 6 am and 8 am three to five days per week May 31 to June 30, 2021. My method of sampling was to walk slowly along the paved paths in the forest and record the species immediately after identification using the field guide (Stiles and Skutch, 1989). When I encountered birds that were immediately unidentifiable, I noted descriptions of them and spent more time identifying them later.

I estimated the basal area of vegetation using the dime method, a form of point sampling to estimate the tree biomass or wood volume; I took a dime and held it about 23 inches away from my eye, and in a 360 degree horizontal radius counted the number of individual trees and wooded plants that were thick enough to see on both sides of the dime, and averaged twenty three measurements, each approximately forty meters apart. This average, multiplied by ten, provides approximately the square feet per acre of wooded area in INBio Park and gives a perspective on the quality of forest there (Lee and Carrol, 2018).

To analyze the data into an estimate of total species, I took a semi-log extrapolation of the cumulative species identified and estimated the asymptote based on a range of time in which it would be reasonable to expect all of the species to have been identified. That asymptote is estimated based on fourteen to two hundred days; after a certain point, it is to be expected that all of the birds have been identified (Chao, 2005). Even two hundred days of extrapolation is excessive based on just two weeks, which is fourteen times a smaller unit of time, but is a sufficient time to expect to have identified most, if not all, of the species in the park. There has to be a time limit on the extrapolation because the equation theoretically keeps increasing (albeit at a smaller and smaller rate), and the number of species in INBio Park is not theoretically unlimited. Though it's true that if a long enough time passed new species would enter the park, that is not the purpose of my estimation, so I limited the timeline to find an approximate asymptote for my estimation (Chao, 2005).

Results and Discussion

For my basal area calculation, I took twenty-three measurements for the basal area calculation, which averaged out to 8.3 trees. That average says that there is approximately 83 square feet per acre (19.1 square meters per hectare) of tree cover in the park. This provides some perspective on the density of tree cover--it is moderately dense, though there are paths cleared through for walking.

In observation sessions at INBio, I was able to provide positive identifications for twenty-six separate species, listed below. For six identifications, identifications happened after the fact, identifying the bird after the observation session. This was the process for identifying the Squirrel Cuckoo, the Gray-Necked Wood Rail, the Eastern Kingbird, the Blue-Gray Tanager, the Ringed Kingfisher, and the Boat-Billed Heron. Of my 26 positive identifications, the six that I identified after the fact make up 23% of my identifications. For 4 species, about 15.4% of these identifications, I misidentified species and with my advisor's help corrected the identifications of

the Red-footed Plumeleteer to the Steely-vented Hummingbird, the Pheasant Cuckoo to the Squirrel Cuckoo, the Canebrake Wren to the Plain Wren, and the Costa Rican Warbler to the Rufous-capped Warbler.

I could not identify a large bird that was hidden in the branches that seemed white, and a few birds that looked like parakeets that flew too high to see properly against the glaring brightness of the sun. Based on my sightings, I estimate that there were three specific species of birds I saw but did not identify, about 11.5% of the observed species. I have not included those in my graphs, and these omissions might indicate that my estimates are low in relation to the real number of bird species present.

	Bird Observed	Scientific Name
1	Social Flycatcher	*Myiozetetes similis*
2	Clay-colored Robin	*Turdus grayi*
3	Steely-vented Hummingbird	*Amazilia saucerottei*
4	Rufous-capped Warbler	*Basileuterus rufifrons*
5	House Wren	*Troglodytes aedon*
6	Squirrel cuckoo	*Piaya cayana*
7	Hoffman's Woodpecker	*Melanerpes hoffmannii*
8	Blue-Crowned Motmot	*Momotus momota*
9	Crimson Fronted Parakeet	*Psittacara finschi*
10	Great-tailed Grackle	*Quiscalus mexicanus*
11	Plain Wren	*Cantorchilus modestus*
12	White-tipped Dove	*Leptotila verreauxi*
13	Grey-necked Wood Rail	*Aramides cajaneus*
14	White-eared Ground Sparrow	*Melozone leucotis*
15	White Winged Dove	*Zenaida asiatica*
16	Eastern Kingbird	*Tyrannus tyrannus*

17	Montezuma Oropendola	*Psarocolius montezuma*
18	Greyish Saltator	*Saltator coerulescens*
19	Green Heron	*Butorides virescens*
20	Short-billed Pigeon	*Patagioenas nigrirostris*
21	Blue-gray Tanager	*Thraupis episcopus*
22	Boat-billed Heron	*Cochlearius cochlearius*
23	Ringed Kingfisher	*Megaceryle torquata*
24	Great Kiskadee	*Pitangus sulphuratus*
25	Rufous-collared Sparrow	*Zonotrichia capensis*
26	Inca Dove	*Columbina inca*

Table 1. Here is the list of bird identifications. The most common were the Clay-colored Robin, the Great-tailed Grackle, the Social Flycatcher, and the Hoffman's Woodpecker. The least common, only observed once each, were the Boat-billed Heron, the Squirrel Cuckoo, and the Ringed Kingfisher. Santo Domingo, Heredia, Costa Rica, May 31 to June 30, 2021.

Based on the number of new species identified per day I attempted to estimate the total number of species of birds INBio possibly holds by graphing the cumulative number of species I identified each day and using that graph to predict the quantity of bird species in the park (Chao, 2005). I plotted the data on a semi-log graph in excel as well as a decreasing log graph, and used these to approximately predict that the park holds over 26 species. According to one way of interpreting the data, there are about 26 and 35 species in the park, the remaining nine or so which would have been seen if the study had continued. According to

Theoretically, this equation just keeps increasing, but in extrapolations beyond the sampling effort, it is to be understood that after a particular number of efforts, practically speaking, there will be a complete census of the species present (Chao, 2005). Therefore, the practical asymptote of the estimation graph appears to be approximately fifty, as the extrapolation shows that the total number of species would approach forty-five over the next fourteen days and fifty over the next two hundred days. Two hundred days is fourteen times the initial sampling effort, so estimating any more than forty-five or fifty species to be present would require observation beyond the data compiled in this observation.

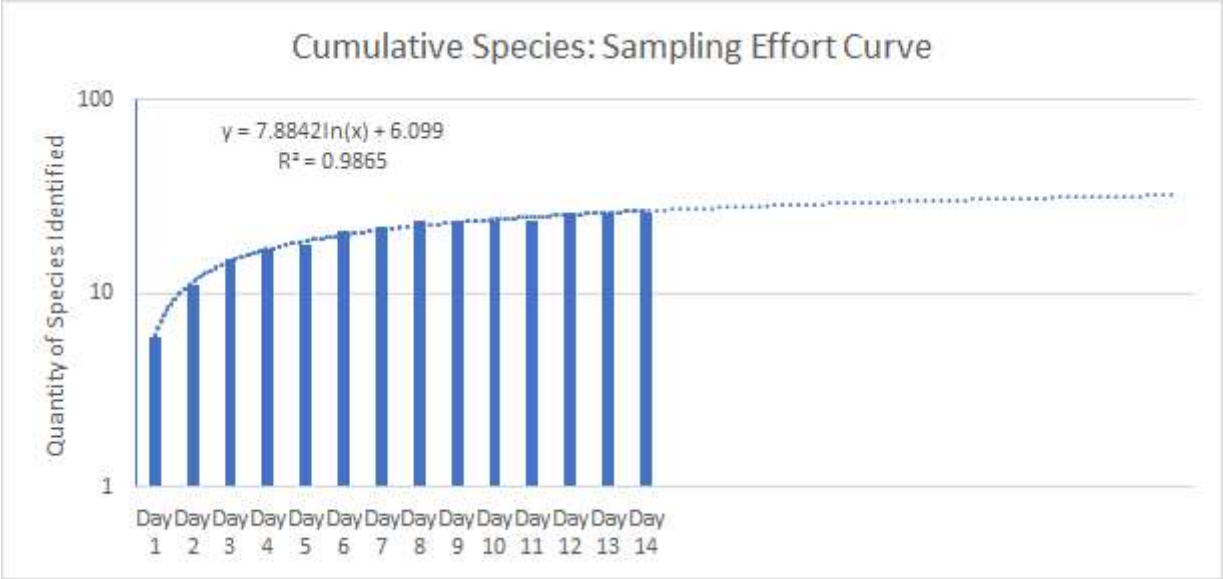

Figure 2. This graph shows that while the frequency of new species sightings was decreasing significantly by the last few days of the observations, there are probably a number of species in INBio that were not observed or identified.

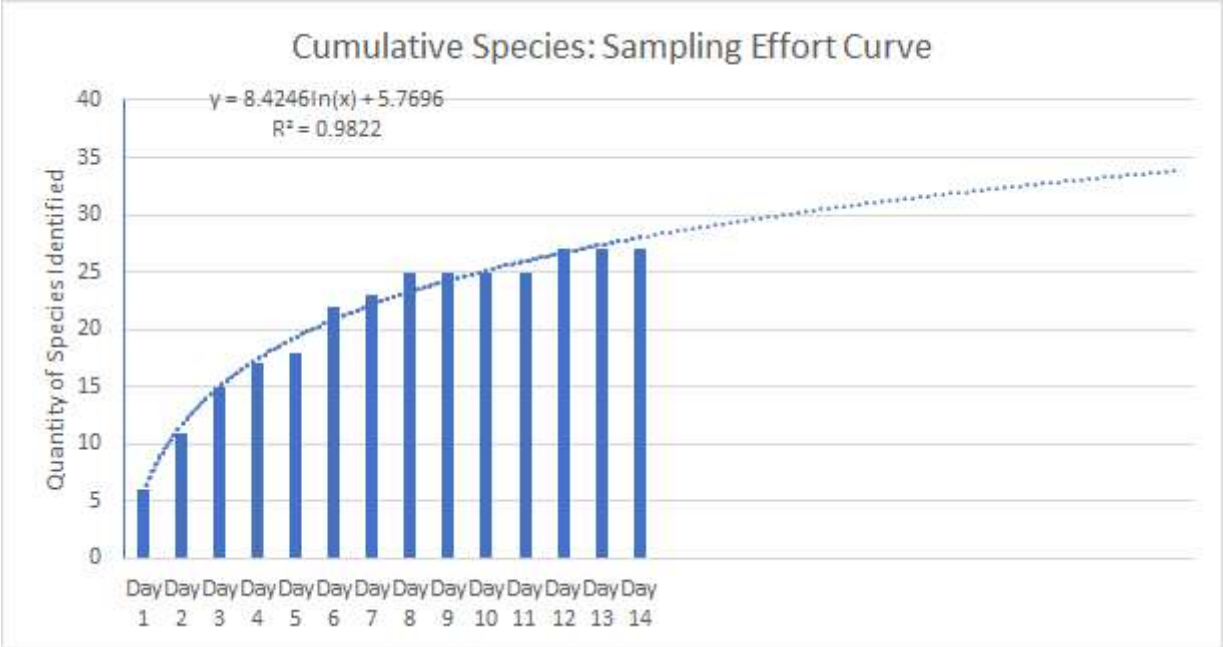

Figure 3. This graph presents the same information as figure 2, but after removing the log scale from the y axis to understand the data differently. I predict from this estimation that there are somewhere between 26 and 35 separate species of birds that appear in INBio Park.

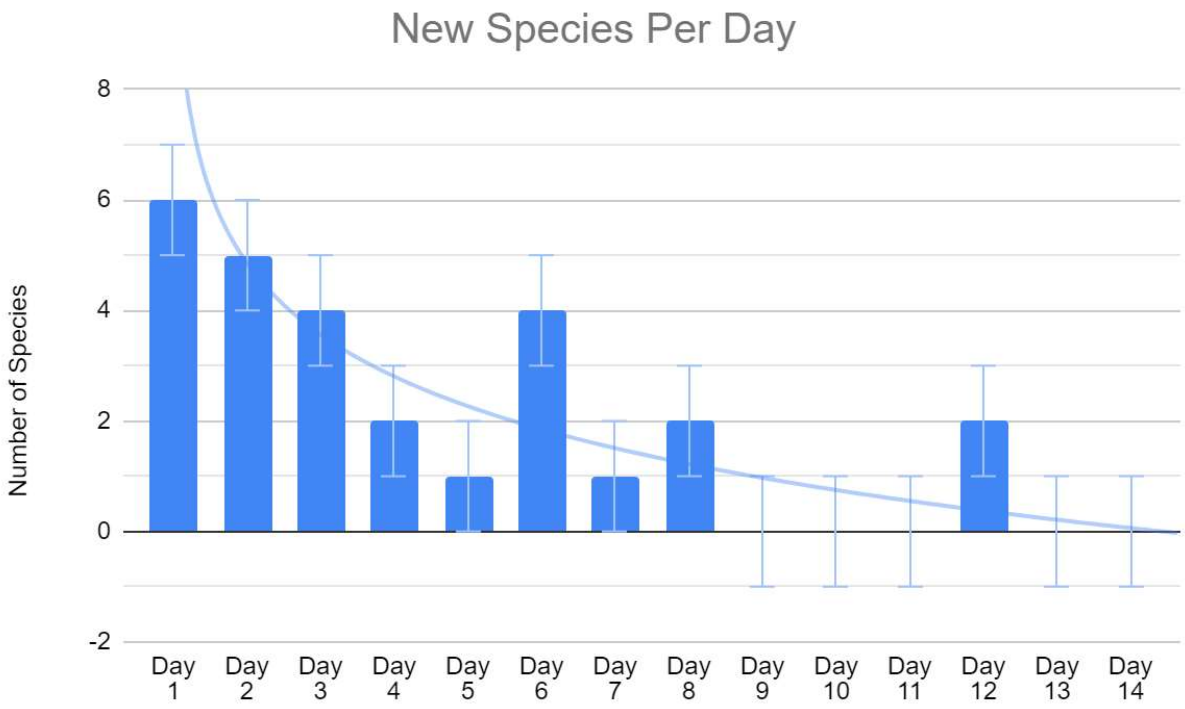

Figure 4. This graph was put together to identify the total estimation of bird species more accurately. This shows that according to the rate at which new birds were observed, there was a maximum of one to five more birds that remained unidentified in the park. According to this estimation, there are between 26 and 31 species that live in INBio Park.

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All of the birds I identified in INBio seem to have theoretical ranges that encompass Santo Domingo in Heredia (Stiles and Skutch, 1989) though they are not necessarily found everywhere throughout the Central Valley in cities or urban areas. Many of these birds are more dependent on places like INBio Park or more heavily wooded areas (Stiles, 1985). Even well landscaped and not undisturbed, INBio provides at least a patch of forest for species that depend more on forest cover, and the lake adds to the diversity that INBio is able to support.

In a comparable study, another student Katherine Germann also observed 26 bird species over a similar period of time over two separate areas of about 2,150 m^2 and 4,260 m^2 (Germann, 2018). Germann spent a similar amount of time, but split it over two observation areas that were respectively 2.5% and 5% of the size of INBio. There were species that I observed in INBio that Katherine did not observe, and vice versa. There was not a difference in species number, but there was a difference in specific species.

The twelve birds Germann saw that I did not see in INBio were the Red-billed Pigeon, the Rufous-tailed Hummingbird, the Masked Tityra, the Tropical Kingbird, the Eastern Wood Peewee, the Swainson's Thrush, the Yellow Warbler, the Baltimore Oriole, the Summer Tanager, the House Sparrow, the Melodious Blackbird, and the Rock Dove. The twelve birds I saw at INBio but Germann did not see were the Plain Wren, the Steely-vented Hummingbird, the Rufous Capped Warbler, the Squirrel Cuckoo, the White-tipped Dove, the Gray-necked Wood

Rail, the White-eared Ground Sparrow, the Eastern Kingbird, the Green Heron, the Short-billed Pigeon, the Boat-billed Heron, and the Ringed Kingfisher.

Conclusion

F. Gary Stiles, a prominent ornithologist and author of the field guide I used, classified birds into three categories of forest dependency in which category 1 birds require almost solid forest, category 2 need at least patchy forest, and category 3 does not need forest. Stiles classified the White-eared Ground Sparrow, the White-tipped Dove, the Squirrel Cuckoo, and the Montezuma Oropendola between 2 and 3, and the Rufous-capped Warbler at category 2 (Stiles, 1985).

INBio Park is a patch of forest that is landscaped by the government. Island Biogeography Theory definitely seems relevant, but the ease at which any of the birds could enter and leave the park makes it difficult to tell which birds do so often, and which species (if any) rely entirely on the INBio patch of forest for their entire population. However, the difference in birds observed within the park in this study when compared with a study of birds found outside the park (Germann, 2018) shows that there does appear to be a difference. INBio Park therefore seems to provide at least a patchy forest for birds that are slightly forest dependent, but does not seem to be enough to support species that are completely forest dependent.

Depending on whether I correctly identified certain morphospecies, such as the Rufous-capped Warbler in place of the Costa Rican Warbler, my estimation of INBio Park's ability to sustain forest-dependent birds could be slightly incorrect. However, the quantity of difference in birds within the park when compared with a study of birds nearby but outside of the park (Germann, 2018) shows that INBio seems to definitely house birds that are at least partially dependent on a forest.

Rather than simply observing inside the park, it would be interesting to observe the perimeter to gain an understanding of which birds regularly enter and leave in comparison with the specific species that remain inside the park. Additionally, it would be interesting to observe similar patches of forest at larger sizes and over longer periods of time.

Furthermore, there were species of other animals in INBio that I was unable to spend time identifying specifically that seemed to benefit from the park potentially even more than the birds. Green iguanas were among the most noticeable even though they are not native to the altitude, but also there were turtles that swam in the lake and appeared to be present in potentially large numbers.

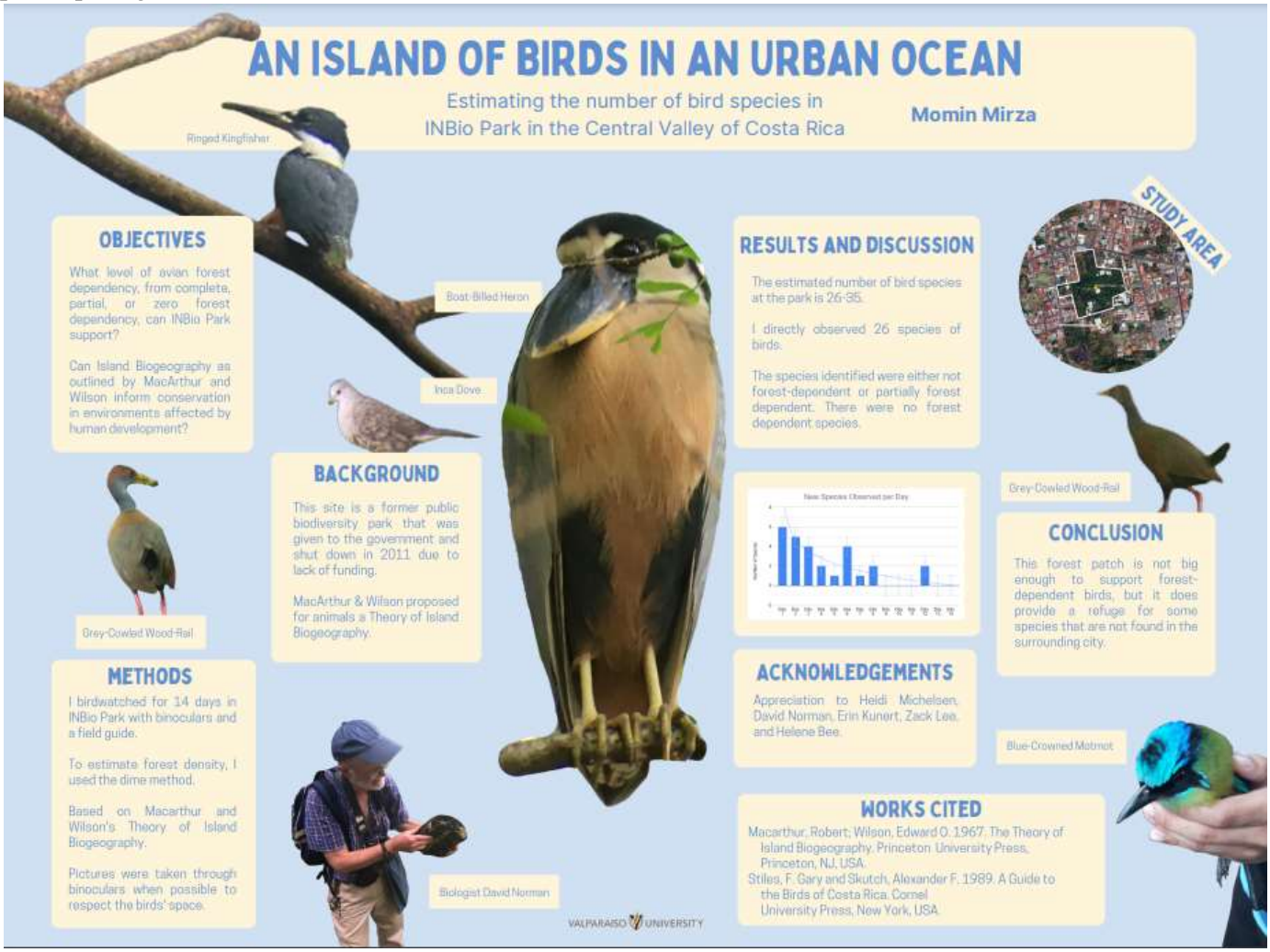
In conclusion, INBio Park is a place where there is undoubtedly a small reprieve for the indigenous animals of the region from the large-scale human development around it. However, it likely supports just 26-35 species of birds whereas there are hundreds native to Central America. INBio Park is an example of a forest patch that provides a space for a small number of slightly forest dependent birds to live, but is not large enough to house birds that are completely forest dependent.

Acknowledgements

Science does not take place in a vacuum; ecologists and ornithologists cannot always just wander into government restricted places and start taking pictures and looking at things. For this reason, I must thank Dr. Heidi Michelsen for finding a way for me to access INBio Park, which had been closed for a decade by the time this study took place. At a similar level of assistance was Professor David Norman, a biologist who works closely with the birds of Costa Rica. He helped me learn how to identify birds, and showed me several other methods that I used in this study, such as the legendary "dime method" of forest quality assessment. He helped me learn how to start identifying birds and assisted when I had trouble identifying several birds.

On the analysis side of things, I must thank my roommate Zack Lee and fellow student Helene Bee. Zack Lee deserves gratitude for demonstrating a better way to display the projected total species of birds. His contributions helped to more accurately display my conclusions and discuss the implications of this study to a greater extent. Helene Bee helped with the poster design in preparation of presenting this research.

To even get to Costa Rica, I went through the Study Abroad office at Valparaiso University. This would not have been possible without the help of Erin Kunert, who helped me to organize a class schedule and put the funds together so that I could study in San Jose while participating in this research.



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