Analysis of the correlations between land use and avian biodiversity in Belize

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Introduction

An international bird conservation organization wants to purchase some land in Belize to protect local bird populations. The purpose of this analysis is to assist the organization in determining the best land to purchase between four available parcels given their priorities. Biodiversity plays a key role in maintaining natural balance, ecosystem services, and genetic resilience. When it comes to protecting our planet, protecting biodiversity hotspots is a vitally important investment in our future survival as a species, and determining the best sites for conservation often includes an analysis of the local biodiversity.

One of the biggest threats to biodiversity is habitat loss due to anthropogenic land uses. Rurangwa et al. (2021) found that Rwandan forest species tend to be highly sensitive to even small habitat changes, and primary vegetation played a role in maintaining distinct bird communities. Different land uses may favor different species and produce differing amounts of biodiversity. Mahiga et al. (2019) determined that forest-associated birds were more negatively affected by the agricultural conversion of previously forested lands than non-forest birds, and they determined that plantation forests support fewer species of birds relative to indigenous cultivated forests due to the monoculture nature of plantation forests. This analysis will look at how anthropogenic land use differences correlate to bird biodiversity using species richness, relative species abundance, and alpha diversity indices.

Understanding how land use and biodiversity interact in the region could help the conservation organization make more informed decisions on which parcel they choose. However, the final choice may ultimately depend on their goals, like whether they are aiming to protect existing biodiversity or restore habitats with the goal of increasing biodiversity.

Methods

For this analysis, McKinnon's list methodology was used to survey the bird populations of four different specific sites being considered for acquisition in Belize: Belmopan, Cockscomb Basin, Gallon Jug, and Punta Gorda, and point counts were used to survey bird populations in the wider region (15 miles diameter circle) that each site resides within. All regions and sites are at elevations at or below about 500 m. (See Figure 1.) Additionally, the land use area of each site and each region was estimated using GIS analysis and graphed in pie charts. Land uses included agricultural uses, lowland broadleaf forests, lowland pine forests, mangrove and littoral forests, lowland savanna, water, wetlands, and urban.

McKinnon lists and point counts are both useful tools for the rapid assessment of tropical bird communities, and they are especially useful in areas where traditional assessment methods may not be possible due to rough terrain and/or dense vegetation (O'Dea et al., 2004). McKinnon lists were used to record birds opportunistically over a longer period, and they were generated by listing birds as they were seen in consecutive lists of ten birds each (O'Dea et al., 2004). Point counts were used to record birds at specific locations for each region separated by a defined distance (O'Dea et al., 2004).

To determine whether each site had been adequately sampled, the number of accumulated unique species was calculated for each successive list and graphed, with the list order number on the x-axis and the number of accumulated species on the y-axis. Finally, adequate sampling was determined by looking for the point when the mean accumulated species value stabilizes to a continuous number, indicated by the asymptote in this graph (O'Dea et al., 2004).

Species richness was calculated from the McKinnon list data using the Chao 2 formula:

$$S_{Chao} = S_{obs} + \frac{\left(F_1\right)^2}{2(F_2)}$$

Where S_{obs} is the number of species observed, F_1 is the number of species with exactly one individual, and F_2 is the number of species with exactly two individuals (O'Dea et al., 2004). Relative species abundance was assessed by comparing the top ten ranked species counts for each region. Alpha diversity indices were calculated using the software PAST.

Figure 1:

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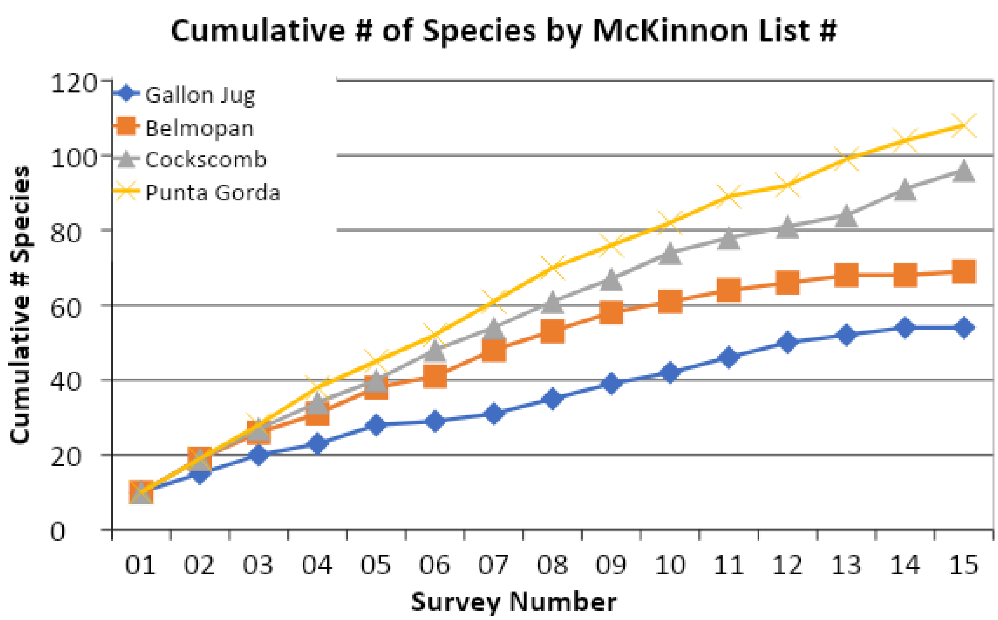
Results:

Figure 2:

- The following graph uses the McKinnon list data on the specific parcels being considered for possible conservation acquisition within each region.



In the graph above, the cumulative number of bird species for both the Gallon Jug and Belmopan sites began to level out at around 14-15 McKinnon lists, indicating sufficient sampling effort was likely completed at those sites. Cockscomb Basin and Punta Gorda on the other hand were both still accumulating new species at this point in the list collection, indicating that more sampling might be needed to understand the full extent of the diversity at these sites. Generally, the Cockscomb Basin and Punta Gorda sites had the highest total number of bird species identified, with 96 and 108 species identified respectively.

Figure 3: Diversity Indices

- based on single-day bird surveys in four regions (15 mi. diameter circles) of Belize

	Punta Gorda	**Cockscomb Basin**	**Belmopan**	**Gallon Jug**
Taxa (S)	240	240	97	96
Individuals	1855	3080	1802	1740
Dominance (D)	0.00443	0.05034	0.01101	0.1069
Shannon (H)	5.446	4.411	4.535	3.008
Equitability (J)	0.9936	0.8049	0.9913	0.6591

In the table above describing the overall 15 mi. diameter regions that each site is located within, the number of species counted was highest at Punta Gorda and Cockscomb Basin, with both having a count of 240, but the number of actual birds counted was much higher at Cockscomb Basin than any other region, with 3080 birds observed. The Dominance is highest in Gallon Jug, with 0.1069, and it is lowest in Punta Gorda, with 0.00443. Shannon and Equitability are both the highest in Punta Gorda, with 5.446 and 0.9936 respectively, and they are both the lowest at Gallon Jug, with 3.008 and 0.6591 respectively.

Figure 4: Relative Species Abundance

- Top ten most observed birds and their counts for each region (15 mi. diameter circles)

BELMOPAN	#	GALLON JUG	#	COCKSCOMB BASIN	#	PUNTA GORDA	#
Orchard Oriole	35	Tropical Kingbird	335	Great-tailed Grackle	435	Squirrel Cuckoo	15
Couch's Kingbird	29	Blue Grosbeak	251	House Wren	407	Ruddy Ground-Dove	14
Wood Thrush	29	Blue-gray Tanager	230	Gray Catbird	310	Muscovy Duck	12
Blue-black Grosbeak	27	Black Vulture	215	Baltimore Oriole	108	Plain Chachalaca	12
Golden-fronted Woodpecker	27	Gray Catbird	215	Squirrel Cuckoo	15	Tropical Kingbird	12
Montezuma Oropendola	27	Plain Chachalaca	18	Ruddy Ground-Dove	14	Golden-hooded Tanager	11
Magnolia Warbler	26	Turkey Vulture	16	Muscovy Duck	12	Hooded Warbler	11
Masked Tityra	24	American Redstart	8	Plain Chachalaca	12	Montezuma Oropendola	11
Red-lored Parrot	24	Black-headed Saltator	6	Tropical Kingbird	12	Northern Waterthrush	11
American Redstart	23	Dusky Antbird	6	Golden-hooded Tanager	11	Social Flycatcher	11

Overlapping species are color coordinated, and unique species are white. While there is some overlap between each region for specific birds being prevalent, each region also appears to favor different bird species.

Figure 5: Area estimates (in hectares and percentages) of major vegetation and land use categories for each 15-mile-diameter circle region

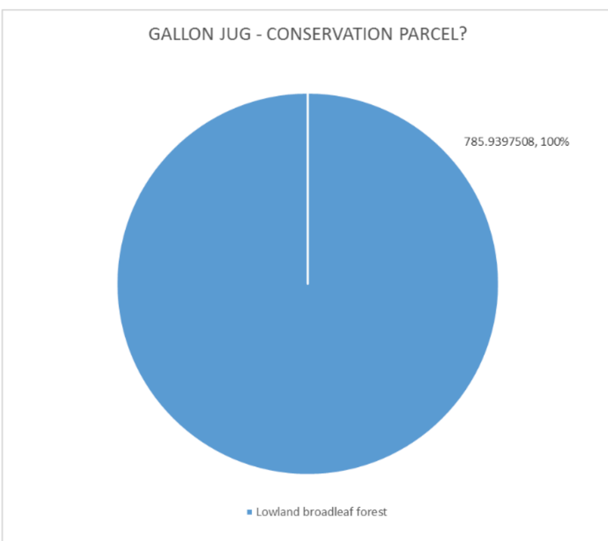
- *Note: color coding may NOT be consistent between pie charts.*

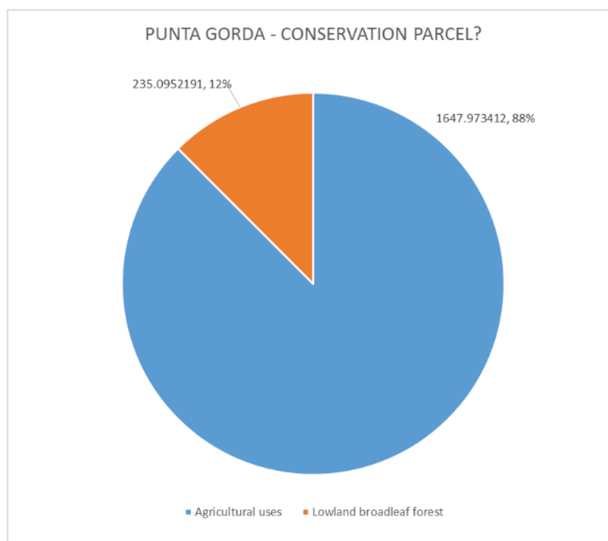
Source data from GIS analysis of land use mapping by Meerman & Sabado (2004).

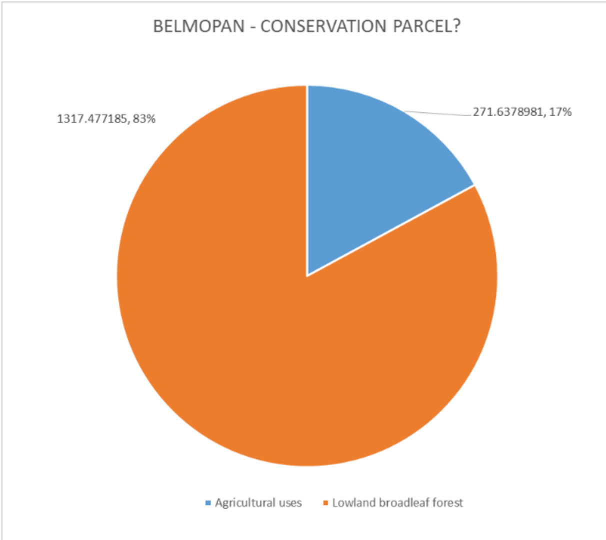
The land use of each of the larger 15 mi. diameter circular regions varies. Punta Gorda is dominated by agriculture (49%) and lowland broadleaf forests (47%) and has around 1% or less of each of the following land uses: lowland pine forest, mangrove and littoral forest, urban, wetland, and water. Gallon Jug is mostly lowland broadleaf forest (97%), with 2% agricultural and 1% wetland. Cockscomb Basin is about half lowland broadleaf forest (53%,) with additional land types of 18% lowland savannah, 17% agricultural use, 5% mangrove and littoral forests, 4% lowland pine forest, 2% wetland, 1% water, and less than 1% urban. Belmopan is 75% lowland broadleaf forest, 13% agricultural, 6% submontane pine forest, 2% each lowland savannah and submontane broadleaf forest, and 1% each lowland pine forest and urban.

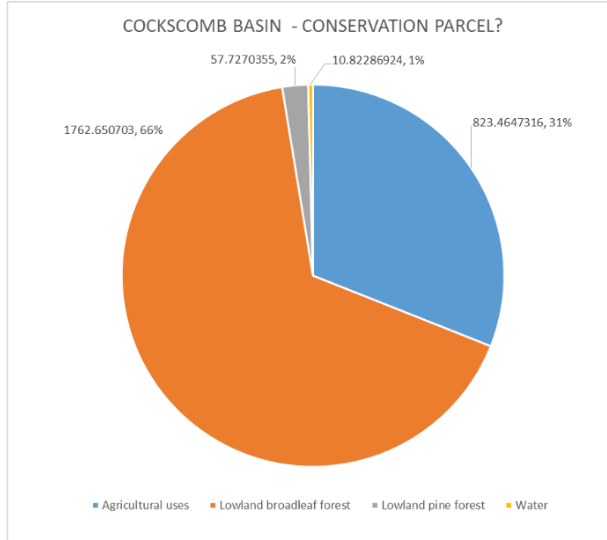
Figure 6: Area estimates, in hectares and percentages, of major vegetation and land use categories for each of the *specific parcels* being considered for possible conservation acquisition within each region

- *Note: color coding may NOT be consistent between pie charts.*









Source data from GIS analysis of land use mapping by Meerman & Sabado (2004).

The land use categories for the specific sites being considered for acquisition and conservation are less intermixed than the larger regions they are within. Gallon Jug is 100% lowland broadleaf forests. Punta Gorda is 88% agricultural and 12% lowland broadleaf forests. Belmopan is 83% lowland broadleaf forests and 17% agricultural. Cockscomb Basin is 66% lowland broadleaf forests, 31% agricultural, 2% lowland pine forests, and 1% water.

Discussion:

Both Punta Gorda and Cockscomb Basin clearly had more bird species than Gallon Jug or Belmopan, at specific sites and within the overall regions. Neither of the specific sites in Punta Gorda nor Cockscomb Basin was adequately sampled, but they still both outperformed the other locations with the cumulative number of species at the site level. The Cockscomb Basin region had more Dominance than Punta Gorda, mostly due to high populations of Great-tailed

Grackle (435), House Wren (407), Gray Catbird (310), and Baltimore Oriole (108). This could be related to seasonal migration into and through the region of some of these birds, and additional bird point count and McKinnon list observations during different seasons could help to determine how the number of each species varies throughout the year and help to identify which species are year-round residents and which are seasonal residents (Smith & Smith, 2015). Both the Shannon and Equitability diversity indices were also higher for Punta Gorda than for Cockscomb Basin. All of this indicates that there is greater bird biodiversity and equitability of species distribution in the Punta Gorda region than in the Cockscomb Basin region (Smith & Smith, 2015; Wilson & Gownaris, n.d.). However, while there were the same number of species at both locations, there were almost twice as many birds observed in the Cockscomb Basin region than in the Punta Gorda region, and even if some of these birds are seasonal, protection of migration corridors is an important aspect of bird diversity conservation (Smith & Smith, 2015). With a much lower number of species found than at the other two sites, Gallon Jug and Belmopan are both less favorable locations for the acquisition and protection of biodiversity, despite the facts that both specific sites are majority lowland broadleaf forests and that Belmopan performed better on non-species count diversity indices than Cockscomb Basin.

When it comes to land use and vegetation, there was more habitat variety in the Cockscomb Basin than in the other three locations at both the region and specific site levels. Generally, a wider variety of vegetation, food sources, and habitat types tend to support a wider variety of animals, including birds (Smith & Smith, 2015). The results from this analysis found this correlation to be mostly true for the regions and sites sampled, but this was not an exact correlation, potentially due to other factors like the varying degree of bird diversity impacts of different land uses. The specific site being considered for acquisition and conservation in Cockscomb Basin is only 33% agricultural land, but the Punta Gorda site being considered is 88% agricultural land. Unfortunately, while some crops may provide a food resource for birds, agricultural land tends to favor only a few bird species and conversion to agricultural land tends to reduce overall biodiversity (Mahiga et al., 2019; Rurangwa et al., 2012; Smith & Smith, 2105). This is at least in part because bird biodiversity is reduced by lower vegetation height, decreased plant structural variety, and lower food variety found on agricultural lands relative to forested lands (Smith & Smith, 2015). Generally, more agricultural land use seemed to reduce bird diversity in Belize by a larger proportion than lowered diversity of land use and vegetation.

If the goal is to protect one or more specific endangered bird species, then the top ten bird counts for each region could be a useful starting point for identifying where these birds are more prevalent. However, additional site-specific McKinnon list observations should be continued until adequate sampling is indicated before utilizing any top ten bird data at the site level. Finally, year-round observations at both the region and site levels could also help to identify any specific endangered bird species that migrate through the region or only live there seasonally.

If the purpose of acquiring this site is for rehabilitating a degraded environment and expanding the existing range of birds, then Punta Gorda would be my recommendation. Unfortunately, restoration takes much more effort and time than preservation (Khan Academy Partners, 2019). Additionally, since we are currently facing the sixth global mass extinction, preservation may be the most effective “first aid” strategy for saving more species from extinction and for protecting more biodiversity. However, rehabilitation of degraded regions will likely need to be completed eventually as well.

If resources are limited for the rehabilitation of land and/or the priority is to protect existing habitats that support bird biodiversity in Belize, then I would recommend acquiring the Cockscomb Basin site because, between the two sites with the most bird species present, this one has more land with forests including some pine forests and even some water habitat for any water-dwelling bird species. Additionally, the Cockscomb Basin region had more birds in total, which may mean that they are more likely to compete with one another for resources like food and habitat (Smith & Smith, 2015). Adding a protected site within this region containing more birds could help to prevent that bird population from reaching ecosystem limitations (like the limitations caused by interspecific and intraspecific competition for finite resources) as quickly by reducing human competition for the land and preventing agricultural degradation (Smith & Smith, 2015).

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