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An Avian Biological Gradient Across Tropical Dry Lowland Local Habitats at Playa Venao, Los Santos Province, Panama

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Abstract

There are a myriad of forest types within Panama, varying by elevation, precipitation and other abiotic factors, which hosts a wide variety of native and migratory species in uniquely-structured avian communities. Panama has been well assessed for presence and distribution of its 987 collective avian species (Angehr, 2014). However most studies in Panama have been broad in scope, overlooking the highly specified habitats that are uniquely structured to host a certain range of avifauna communities. The distinctions in community structure of avifauna along a coastal to inland gradient were assessed among three specialized habitats: the Central Pacific coast, partially deforested tropical dry lowland forest edge and the forest on a roadside. All avifauna were identified using systematic radial point counts in six locations within 100m from each other, totaling 120 observation events over a ten day period. It was investigated whether there were significant differences in diversity (Shannon-Wiener Index, D_h), richness (r_h) and community composition (Beta diversity, β_a) among the three habitats. Diversity was slightly higher among the Pacific coast ($D_c= 2.35$, $p=0.96$) and scattered tropical dry lowland forest ($D_f=2.38$, $p=0.94$) than the roadside location ($D_r=2.04$, $p=0.81$). Abundance was comparatively lowest at the Pacific Coast ($a_t=519$, $p=0.03$), higher at the roadside habitat ($a_t=572$, $p=0.95$), and highest at the tropical dry lowland forest edge ($a_t=628$, $p=0.02$). The species exclusivity ratio was notably highest at the Pacific coast ($x_c=0.29$) when compared to the roadside and forest locations ($x_r=0.18$, $x_f=0.10$). Beta diversity by average abundance indicated that there were three distinct communities within the region of study ($\beta_a= N = 3.0$). Chi square statistical probabilities determined that species richness and diversity were not statistically variable, therefore the null hypothesis was not rejected. These results convey the relevance of localized habitat areas as separate and distinct, in which an immense array of endemic, residential and migratory species occupy a variety of highly specified niches. Recognition of the presence of specialized habitats demonstrates importance of such coastlines and tropical dry lowland forests as a golden zone for high diversity and endemism.

Acknowledgements

Table of Contents

Introduction

Panama lies between 7° and 10° north of the equator, hence the warm tropical climate at 32-34°C. These conditions host a multitude of forest habitats that are uniquely defined based on abiotic and biotic characteristics such as precipitation, soil composition, and elevation as well as flora composition and density (Connell, 1978). This high diversity of forest habitats fosters an immense variation of fauna (Gwynne, Ridgeley, 1984). Avian populations within Panama are of particular fascination and they are studied extensively. This is due to an ideal geographical location – the Isthmus of Panama is centrally located between South America and North America as the terrestrial bridge at which avian species that are native to North and South America. Climate also plays a significant factor, in which the warm tropical temperatures harbor growth of ample foods and vegetation for avian species to forage and roost. Panama hosts a total of 987 species of avifauna, of which 122 species are migratory (Angehr, 2014). However, populations of avifauna are diminishing from increasing forest fragmentation and habitat isolation - over eighty years since the Panama Canal was constructed, thirty-five percent of the originally present 200 resident species have disappeared in the surrounding tropical lowlands forest (Robinson 2001). Communities of avifauna within the tropics are particularly vulnerable due to their remarkably high degree of diversity (Karr, 1982; Connell, 1978). Tropical forests host a great array of specialized niches in which species occupy without pressures from interspecific competition, so populations naturally thrive in lower abundances within tropical forests. A greater proportion of species in the tropics are rare, which increases the likelihood of species fluctuations and extinctions from habitat disturbances (Karr, 1982; Connell, 1978). With these conditions of high vulnerability it is important to gain a more detailed understanding of local communities of avifauna so that conservation initiatives may be put in place.

Coastal shorelines additionally support diverse communities of invertebrates and fish, provisions which are consumed by shorebirds, wading birds and pelagic seabirds (Figuerola, Green, 2003). Therefore it is important to attain a detailed census on coastal avifauna in local habitats to convey the necessity of implementing conservation practices to maintain the high diversity of species. Numerous census studies of avifauna of the tropics have been conducted along the coasts (Green, 2003; Rappole 1995; Butler, 1997). However, no apparent studies on avifauna have been conducted on the Eastern side of the Azuero Peninsula. Only anthropogenic-centered studies have been conducted in this region, including agricultural research (Sain, Pereira de

4

Herrera, 1999). Most studies on tropical avifauna have methodologies that are less elaborate, resulting in a lack of precision with data collection. With previous researchers conducting more regionalized to transnational studies, specific coastal regions that may be more finely distinct than others have remained under-researched undervalued. Most studies on shorebirds are too overarching, covering a broad range of coverage and too small of a duration to yield precise and accurate bird counts. In a brief, month-long census study involving habitat affiliations of coastal birds in Panama, counts of large flocks of migratory birds were conducted by flying a by-plane across the Pacific coast of Panama (Butler, 1997). Studies such as these that are too broad in scope to yield results, which oversees the significance of minute habitats that exhibit a high degree of specialization. Such localized habitats foster high diversity of avifauna and other taxa, providing valuable products and services for humans. A promising approach is to conduct a more meticulous study within varying habitats at a finer scope and collect detailed data while quantifying species to assess the differences in avifauna community structure.

Literature Review
Climate, Economy, and Forest Structure in the Eastern Azuero Peninsula
The eastern region of the Azuero peninsula within in Los Santos province, Panama consists of hilly lowlands with elevations ranging from 10 to 40m above sea level (Sain, Pereira de Herrera, 1999). The average annual rainfall is 975 mm, mainly distributed in the seven months from May to November (Sain, Pereira de Herrera, 1999). In this Central American nation rainfall patterns divide the agricultural year into two seasons. The beginning of the first season coincides with the beginning of the rains in May and ends in September, when the second season begins. The second season extends from September until the beginning of the dry season or summer (Sain, Pereira de Herrera, 1999). Being located at the rain shadow side of the Central American Cordilleras Mountain range, at the foothills of the Pacific slope, this region is notably the driest in all of Panama. The composition of the soils in this region are slightly acidic (pH=5.6 to 5.9), with a sandy clay loam texture (Sain, Pereira de Herrera, 1999). In an agroeconomic-centered study on the possible adoption of conservation tillage for maize farms, it was stated that there are prominent farmlands for maize production, aquaculture and livestock within this region (Sain, Pereira de Herrera, 1999). Fish such as tuna are cultivated in aquaculture farms near the Pacific coast, while local subsistence farmers grow maize, clear ample hilly lowland forests for livestock pastures, or do both. More than 70% of the maize farmers in the region dedicate between 60% and 90% of their area to livestock production (Sain, Pereira de Herrera, 1999). With an economy centered in agriculture and aquaculture in this region, the tropical dry lowlands of Los Santos have been subject to moderate to heavy deforestation in the past two decades, with the greatest threat being livestock grazing and aquaculture.

Threats to Local Avian Diversity
Several long-term studies in the American tropics have documented the decline of arboreal and coastal avian populations, conveying that increased deforestation for agriculture and large-scale tourism is to blame for such losses (Sain, Martin, Blackburn, 2010; Van Bael, et. al., 2007; Robinson, 2001; Sain, Pereira de Herrera, 1999). One study discovered that farmlands are particularly poor in supporting forest habitats for hosting specialist and endemic species (Martin, Blackburn, 2010). The current high coverage of farmlands in the previously-forested region Eastern Azuero region has undoubtedly altered the avian community structure over the past century. Most lowland forest fragments in Panama are privately owned by individuals and are

under constant threat of deforestation for lumber as well (Van Bael, et. al., 2007) Such mass destruction of forest habitat threatens diversity of arboreal avian species that are finely adapted to specific niches that the forest harbors. In a comparative study within organic cacao farms and a nearby forest fragment in the lowland Caribbean slope of the Bocas del Toro province, researchers investigated the distinctions in avian diversity and community structure. The results suggested that some bird communities are forest-dependent and cannot be supported in cacao landscapes (Van Bael, et. al., 2007). The research reveals that over-simplified and heavily-managed systems such as cacao farms, aquaculture fisheries, and maize plots are detrimental to the diversity of arboreal avifauna that depend on the security of specific niches for foraging. (Van Bael, et. al., 2007). In a long-term comparative chronological study on avifauna population variations on Barro Colorado Island, there was a complete lack in recolonization of forest-interior species (Robinson, 1999). Local extinction in interior forest isolates such as Barro Colorado Island is highly prevalent due to high vulnerability from limited habitat space. These effects apply to the tropical region of Los Santos, as the increasing coverage of agricultural, aquacultural and tourism-developed lands continue to increase the number of small forest fragments. These instances of mass deforestation and fragmentation shift local communities of avifauna and threaten forest species present in low abundances. Therefore performing studies on local habitats within this region could prove beneficial for conserving avian diversity in the future.

Comparing Localized Habitats using Quantitative Analysis

The understanding of smaller-scale ecological communities remains poor in this region (Robinson, 2001; Sain, Pereira de Herrera, 1999). There are numerous comparative studies on the relation between tropical forest type and avian species community structure that are highly thorough with data collection (Van Bael, et. al., 2007; Robinson, 2001; Butler, et.al, 1997). Though such studies there is much conclusive evidence demonstrating the significance on localized forest or coastal habitats. Despite these conclusions concerning habitats and avian community structure there is a lack in more localized studies over a vast area. Many local studies involve collecting great quantities of detailed data on tropical forest vegetation, which in consequence are conducted in very small plot areas due to time, effort and budgetary constraints. In a previous study on the tropical dry forest structure and condition in the Las Perlas Archipelago only two sample sites were taken within the entire island (Guzman, et. al., 2012). Tropical dry lowland forests remain to be under-researched, and most studies yield either raw data on the structure of the forests, or center around the ecosystem services that local communities value economically (Angehr, 2014, Guzman, et. al., 2012). It is therefore important to gain more knowledge on the dynamics of multiple unique avifauna communities within highly specified tropical habitats, to recognize the significance of such specialized habitat areas, and to implement conservation strategies and policies to protect these important zones of biodiversity.

Tropical Forest Conservation

In the past century, Panama has been moderately established in terms of forest conservation – more than 17% of its total area is protected through the designation of local municipal, national, and international parks, including the Natural Metropolitano de Panamá, Parque Nacional Soberanía and Parque Internacional la Amistad (Rappole, 1995). However, large areas of forest continue to be lost without having been surveyed, most especially due to a lack in conservation management strategies. Panama consists of five hotspots of biodiversity and endemism, one of

which is completely unprotected by law or enforcement. The tropical humid lowland forest of western Chiriquí faces anthropogenic pressures through mostly deforestation, and a substantial number of endemic species are considered endangered on a national level (Gwynne, Ridgeley, 1989). Even within these parks, the environmental management and conservation authority, Ministerio de Ambiente de Panamá, continues to be severely underfunded and under-staffed (Gwynne, Ridgeley, 1989), resulting in a lack of basic park maintenance and enforcement of conservation laws. Often such conservation initiatives are scarce due to a lack of support or a fault in the Panamanian government's ability to collaborate between sectors.

An increase low-impact ecotourism could perhaps attribute to conservation of Panama's tropical lowland forests. In a study assessing the state of tropical dry lowland forest over the past three decades in the Las Perlas Islands, Guzmán, et. al. noted that the reduction in agricultural pressure appears to have allowed some recovery and growth of secondary forest in these isolated areas (2012). Tropical dry lowland forest conservation is highly significant in preserving the rich array of endemic and migratory species that thrive within such a protective and provisional habitat.

Avifauna as Keystone Species
It is convenient to concentrate on avian species for habitat research because they are excellent indicators of environmental distinctions among important biological zones (Figuerola, Green, 2003). A comparative assessment of avian communities as indicators of habitat distinctions could also relay the importance of conserving other taxonomic groups within the ecosystem web (arthropods, anurans, etc.) It is a promising approach to perform such research at a grand scale, (ex. regional) to correspond with distinctive biogeographic populations of migratory birds. Numerous studies have been conducted at this scale. In a study on aquatic avifauna as indicators of wetland health, researchers were detecting declines in populations of some aquatic species, which indicate a destruction and loss in wetland habitat (Figuerola, Green, 2003). On a smaller scale, the abiotic characteristics of wetland areas (ex. size, profile depth, shape, presence and distribution of emergent vegetation etc.) has an immense influence on the diversity and abundance of aquatic birds (Figuerola, Green, 2003). For example, oceanic fishing birds like *Sterna H. hirundo* have a strong relation with trophic resources, and they distribute based upon the availability of fish (Figuerola, Green, 2003). The high capacity of avifauna to disperse over a wide area allows them to respond faster to change in the expanse of habitat available, especially pelagic and coastal species (Figuerola, Green, 2003). Populations of birds that are strictly sedentary are highly affected by habitat changes, in which changes in population size reflect changes in habitat structure or space. (Figuerola, Green, 2003). Therefore avian community structures among local, specialized habitats would serve as excellent models to determine any degrees of variation among these habitats.

Research Question
Is there a significant difference in the species richness (r_h), diversity (D_h), and community composition (β_a) of avifauna across Pacific lowland tropical forest habitats, from oceanic to inland locations, in the tropical dry lowlands of the Southern Azuero region? Richness signifies the number of different species observed, while diversity (Shannon-Wiener index) indicates the level of avifauna variety within a community utilizing abundance. Beta diversity is partially defined as the degree of community differentiation in relation to a complex environmental pattern or gradient (Whittaker, 1960; Jost, 2007). This defines designated communities as locally

distinct within the region of study. In this study I attempt to disprove that avian species richness, diversity and community composition are not significantly different across the three Pacific tropical lowland forest habitats, among the Pacific Oceanside, the center of the scattered tropical dry lowlands forest, and the roadside edge. The aim is to convey any distinctions in avifauna community structure across an oceanic to inland gradient (Pacific oceanic coast, scattered lowland tropical woodlands, roadside edge) at Playa Venao, Los Santos Province, Panama.

Materials and Methods

Preliminary Markings and Location Descriptions

All avifauna were observed and identified, and the environmental sound was recorded (Martin, Blackburn, 2010; Sutherland, 2004) in three selected habitats, ranging from the outer ocean coast to the edge of the tropical dry lowland forest. The first habitat was located at the edge of the partially cleared tropical forest lands and the Pacific Ocean coast. The second habitat was located in the center of the partially cleared tropical forest lands, and the final habitat was located at the edge of the main roadway and the tropical dry lowland forest. Each habitat consisted of two observation points, with each point being 100m from each other (Bibby, et. al., 2002). Observation points between habitat locales were approximately 100m apart (see diagram 1). A compass was used to orient the six total observation points 90° from each other, and each point was marked and labeled with flagging tape. At each location of observation the UTM coordinates were plotted using a Garmin 64s portable GPS (Butler, et al., 1997) (see diagram 2). Before point count observations were made, each habitat site was described in detail. All abiotic and biotic factors were noted, including but not limited to flora composition, density of vegetation, apparent height of vegetation, degree of shade and observed sources of food that avifauna could consume.
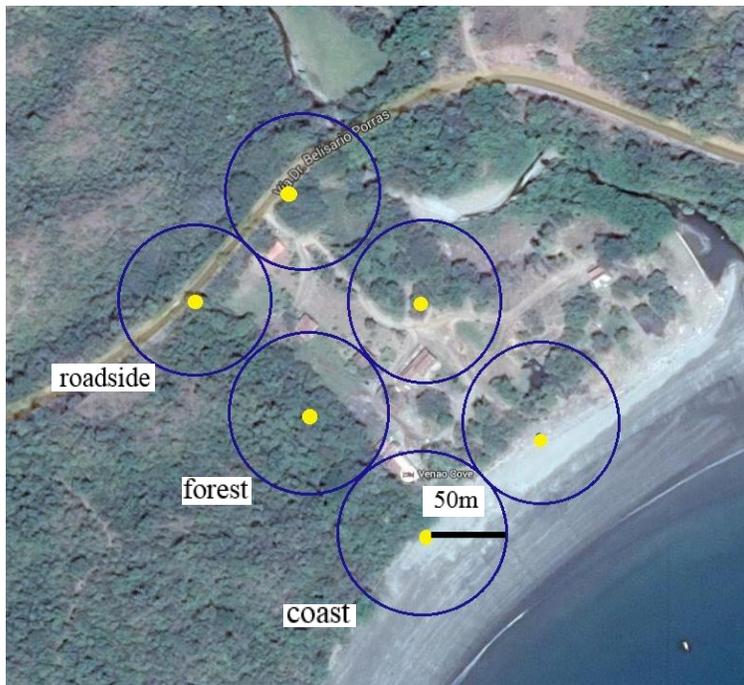

Diagram 1: Point counts across Pacific coastal, forest edge and roadside habitats

Diagram 2: GPS waypoints of observation sites

Avifauna Observations
One observer remained at each point for eight minutes, as counts of this optimal duration reduce the likelihood of double contact recording while still enabling high detection rates (>80%) in the point count area (Lynch, 2005; Robinson, 2001; Robinson, 1999). Observations of avifauna were made for up to a 50m radius from that location (Van Bael, et. al., 2007) (see diagram 1). Before observation, a waiting period of two minutes was allowed for the resident birds to settle down from the observer's movements (Bibby, et. al., 2002). A recorder was placed at the center of the observation point to record all bird vocalizations for the eight minute observation duration, as a reinforcing mode of bird identification. When an unidentified call was heard the exact time was recorded for later reference. All conspicuous and distinctively identifiable avian species were immediately identified and recorded at each point. In the condition of low visibility, inconspicuous or species, or species that were difficult to distinguish, any visual silhouettes, coloration, patterns, head shape, bill shape, bill length, flight patterns and other characteristics were noted for later identification (Bibby, et. al., 2002). Non-immediate identification of avifauna was conducted using the meticulously recorded descriptions and the *Guide to the Birds of Panama* (Ridgeley, Gwynne 1989). Recordings were replayed in spectrogram format on Audacity and known calls were matched from a database with a range of avian vocalizations, the Cornell Macauthy Ornithology Lab, for species identification (Sutherland, 2004). Observations were made at each point in two sessions per day, after dawn between the hours of 6am and 9am, and in the evening before dusk, between 3pm and 6pm (Sutherland, 2004; Robinson, 1999). For each observation day, precipitation and cloud cover were noted (Butler, et al., 1997). The observation procedure occurred for a duration of ten days, summing 120 total observation events within and around the tropical dry lowland forest (Bibby, et. al., 2002).

Results and Statistical Analysis
The total area of observation was calculated by squaring the radial distance of each observation point, multiplying each squared distance by pi (π*[detection distance]^2) and then multiplying the observation area by total number of observation points (Robinson, 1999). All identified avian species, including common name, scientific name and abundance were recorded in three Microsoft Excel sheets, separating data among the three observation locations (Coastal, Forest, Roadside). Each sheet contained two headings, specifying the species collected for the morning and evening sessions, and two sub-columns within each heading, separating the species identified between sites A and B (see diagram 2). The rows of the first column contained the date on which each species was identified. A fourth sheet was used to record, in each column, the date, the cloud cover (clear, scattered clouds, partly cloudy, broken overcast or full overcast) and precipitation (Y or N?) for each of the ten observation days. Analysis consisted of composing a table of overall species abundances, in which six columns demonstrate, scientific name, common name, abundance at the coast (a_c), abundance in the forest (a_f), abundance at the roadside (a_r), total abundance per species (a_t) and total abundances in each habitat (a_h). Another table was composed to demonstrate richness and diversity indices for each of the three habitats, the latter being determined by the Shannon-Wiener formula.

$$-\sum p_i * \ln(p_i)$$

Where p_i represents a proportion, equaling the quotient of the abundance of individual species in the habitat over the total abundance in the specified habitat. A Chi square test was used to

determine the p-values of each of the diversity indices. The diversity values were tested for deviation from the expected value, serving as the average diversity index among the three habitats (Teachman, 1980). Chi square p-values were also determined with total abundances per habitat, with the expected value being the average of the total abundances across all three habitats. Additionally the Sørensen formula was utilized with the three indices (Q_s) shown in a table, demonstrating degree of species overlap between each of the habitats (Chao et al., 2012).

$$Q_s = \frac{2(A \cap B)}{|A| + |B|} = \frac{2C}{A+B}$$

Whereas A and B represent the species richness of species exclusive to each of the habitats A and B respectively, and C represents the number of species in common between habitats A and B. A simpler community comparison formula was utilized to determine the Jaccard similarity coefficient (J) (Tan, et. al. 2005).

$$J(A,B) = \frac{|A \cap B|}{|A| + |B| - |A \cap B|}$$

This coefficient is a quotient with the numerator representing the total richness of species in common with habitats A and B. The denominator is equivalent to the difference between the sum of the richness within habitats A and B, and the value of the numerator. Exclusivity ratios were determined per habitat (x_h) by calculating the quotient of total species exclusive to a habitat (v) over the total species richness of the habitat (r_h). Such ratios were placed in a table format.

$$x_h = \frac{v}{r_h}$$

Alpha (α_r), gamma (γ_r) and beta (β_r) diversities were obtained with respect to richness, and demonstrated in a table (Whittaker, 1960; Jost, 2007). Additionally the three diversity types were obtained (α_a, γ_a, and β_a) as an average of the top ten species with respect to abundance (Whittaker, 1960; Jost, 2007). In this study, alpha diversity is defined as the average abundance or richness of avifauna across the three local habitats, while gamma diversity is the total abundance or richness across the entire region of study. Beta diversity is defined as the ratio between gamma (regional) and alpha (local) diversities, therefore determining the number of distinct communities within a region (N=β) (Whittaker, 1960; Jost, 2007). A bar graph, displaying the top ten species names by total abundance on the X-axis, and displaying their abundances by habitat on the Y-axis, was constructed to visually convey the distinctions in community composition among the three habitats.

Site Description: Pacific Coast
Pacific Ocean on south coast of Panama, Los Santos province on the Azuero peninsula. Flat sandy beach with some wood, coral, leaf, mollusk and trash debris. Rocky shore lined w med height full cover fruity trees and palms. Beach flanked on both sides by dense tropical dry forest. Beach has ample sand fleas, flies, hermit crabs, sea snails and clams. Ample fish, crabs and stingrays in ocean. Width of beach 1-15m. Light-med waves 1-4m high. Full sun. Humidity med-high.
Site Description: Tropical Dry Lowlands Forest Edge

Tropical dry scrubby lowlands. Partially cleared areas with open tall grass patches, scattered medium-tall height shady trees and sparse dead trees. Scattered fruit trees (papaya, plantain) and attractive flowery hedges around hostel. Seven widely spaced buildings w gravel roads, human disturbance low-medium height varies throughout the day (ex. building construction, guests coming and going, cars occasionally coming in and out). Plenty of dragonflies, butterflies, mosquitoes, flies, grasshoppers, ants, lightning bugs, beetles and other insects. Other animals include common house geckos and bats. Partial shade. Low-med humidity.

Site Description: Roadside-Forest Edge

Dry scrubby lowlands. Tall grassy strip on roadside, lined w med-tall shady and seedy trees. Second growth patchy dry forest beyond roadside. Shallow, clear rocky river runs under road at site A. Plenty of spiders, ants, flies, mosquitoes, grasshoppers, crickets, butterflies, dragonflies and other insects. Other animals present include squirrels, common house geckos, white-faced capuchins, and travelling packs of 8-12 howler monkeys. Occasional fast-moving cars, trucks, taxis, busses and most notably, semi-trucks with high noise pollution. Partial shade. Low-med humidity.

Results

The total area coverage for avifauna observation was $47,124m^2$. During the wet season in the month of November, precipitation occurred two out of the ten days of observation (Table 1). An El Niño event also took place this year, further intensifying the dry conditions in the tropical dry lowlands. Notably, with eight out of the ten days there was at least partial to full overcast.

Date	Weather	Precipitation
10-Nov	Broken Overcast	N
11-Nov	Partially clear, partially overcast	N
12-Nov	Scattered clouds	N
13-Nov	Broken Overcast	N
14-Nov	Clear	N
15-Nov	Overcast	N
16-Nov	Overcast	N
17-Nov	Broken Overcast	N
18-Nov	Overcast	Y
19-Nov	Overcast	Y

Table 1: Daily weather conditions

On the Pacific coast of Playa Venao, abundance was highest for *Coragyps atratus* (a_c=127), *Sterna H. hirundo* (a_c=119), followed by (a_c=67) for *Actitis macularia* (Table 2). Among the scattered tropical dry lowland forest abundance was highest for the species *Brotogeris j. jugularis* (a_f=186), *Cassidix mexicanus peruvianus* (a_f=110) and *Troglodytes aedon inquietus* (a_f=59). At the roadside habitat, abundance was highest for *Brotogeris j. jugularis* (a_r=297), followed by *Cassidix mexicanus peruvianus* (a_r=55) and *Eupherusa eximia* (a_r=27) (Table 2).

	Scientific name	Common name	Abundances

			Coastal	Forest	Roadside	Total
1	*Tigrisoma mexicanum*	Bare-throated tiger heron	1	0	2	3
2	*Casmerodius albus egretta*	Great egret	1	0	1	2
3	*Egretta Caeruela*	Little blue heron	1	0	0	1
4	*Eudocimus albus*	White ibis	7	0	0	7
5	*Fregata magnificens*	Magnificent frigatebird	3	0	0	3
6	*Pelecanus occidentalis leucogaster*	Brown pelican	3	0	0	3
7	*Charadrius wilsonia beldingi*	Wilson's Plover	26	3	0	29
8	*Actitis macularia*	Spotted sandpiper	67	7	0	74
9	*Catoptrophorus semipalmatus inornatus*	Willet	4	0	0	4
10	*Numenius phaeopus hudsonicus*	Whimbrel	1	0	0	1
11	*Sterna H. hirundo*	Common tern	119	0	0	119
12	*Pandeon Haliaetus*	Osprey	3	1	0	4
13	*Buteogallus a. annthracinus*	Common black hawk	3	2	0	5
14	*Milvago chimachima*	Yellow-headed caracara	3	13	11	27
15	*Leptotila v. verreauxi*	White-tipped dove	1	3	14	18
16	*Columbina talpacoti rufipennis*	Ruddy ground dove	0	3	0	3
17	*Brotogeris j. jugularis*	Orange-chinned parakeet	28	186	297	511
18	*Aratinga pertinax ocularis*	Brown-throated parakeet	2	0	0	2
19	*Piaya cayana thermophila*	Squirrel cuckoo	0	1	1	2
20	*Amazilia t. tzactl*	Rufous-tailed hummingbird	0	1	1	2
21	*Eupherusa eximia*	Stripe-tailed hummingbird	7	34	27	68
22	*Chloroceryle amazona Mexicana*	Amazon kingfisher	1	0	0	1
23	*Ceryle t. torquata*	Ringed kingfisher	4	1	0	5
24	*Melanerpes rubricapillus wagleri*	Red-crowned woodpecker	0	12	17	29
25	*Thamnophilus doliatus nigricristatus*	Barred antshrike	0	0	7	7
26	*Tyrannus melancholicus chloronotus*	Tropical kingbird	6	28	9	43
27	*Myiarchus crinitus*	Great crested flycatcher	2	0	2	4
28	*Pitangus sulphratus guatimalensis*	Great kiskadee	10	48	23	81
29	*Megarhynchus pitangua mexicanus*	Boat-billed kiskadee	6	6	9	21

30	*Tityra semifasciata costaricensis*	Masked tityra	0	0	1	1
31	*Troglodytes aedon inquietus*	House wren	8	59	20	87
32	*Protonotaria citrea*	Prothonotary warbler	1	0	1	2
33	*Piranga r. rubra*	Summer tanager	0	12	0	12
34	*Coereba flaveloa mexicana*	Bananaquit	0	1	0	1
35	*Euphonia luteicapilla*	Yellow-crowned euphonia	3	16	16	35
36	*Thraupis palmarum atripennis*	Palm tanager	0	1	1	2
37	*Thraupis episcopus cana*	Blue-grey tanager	17	46	22	85
38	*Volatinia jacarina splendens*	Blue-black grassquit	0	4	2	6
39	*Psarocolius decumanus melanterus*	Crested Oropendula	0	2	1	3
40	*Cassidix mexicanus peruvianus*	Great-tailed grackle	53	110	55	218
41	*Progne c. chalybea*	Gray-breasted martin	0	8	8	16
42	*Coragyps atratus*	Black vulture	127	17	11	155
43	*Cathartes aura*	Turkey vulture	1	0	1	2
44	*Chiroxiphia lanceolata*	Lance-tailed mankain	0	0	2	2
45	*Manacus vitellinus*	Golden-collared manakin	0	1	1	2
46	*Cyphorhinus phaecophalus lawrencii*	Song wren	0	1	1	2
47	*Elaenia flavogaster pallidorsalis*	Yellow-bellied elaenia	0	1	5	6
48	*Thyrothorous rufalbus castanonotus*	Rufous-and-white wren	0	0	1	1
49	*Campylorhynchus albobrunneus*	White-headed wren	0	0	1	1
50	*Dendroica petechia aestiva*	Yellow warbler	0	0	1	1
	Total abundances (per habitat)		519	628	572	1719

Table 2: Abundances of avifauna by habitat location

Over the ten day observation period, abundance was comparatively lowest along the Pacific Coast (a_t=519, p=0.03), higher at the roadside habitat (a_t=572, p=0.95), and highest at the tropical dry lowland forest edge (a_t=628, p=0.02). Total overall avifauna abundance for the ten observation days was notably high (a_t=1719). Species richness of observed avifauna was relatively even at the Pacific coast of Playa Venao (r_c=31) the tropical dry lowland forest (r_f=30) and the bordering roadside (r_r=33) (Table 3). The Shannon-Weiner diversity indices are relatively high in the Pacific coastal (D_c=2.35, p=0.96) and tropical dry lowland forest (D_f=2.38, p=0.94) when compared to the roadside habitat with a slightly lower index (D_r=2.04, p=0.81) (Table 3). The Sørenson indices with respect to richness exhibited the highest overlap between the forest to roadside habitats (Q_s=2.44), followed by low to moderate overlap comparing coast to forest habitats (Q_s=1.42). The lowest overlap was seen when comparing and coast to roadside habitats (Q_s=1.13) (Table 4).

Habitat	Richness (r)	Diversity Index (D)
Coastal	31	2.35
Forest edge	30	2.38
Roadside	33	2.04

Table 3: Richness and Diversity Indices of Avifauna

Habitat Comparisons	Sørensen Index (Q_s)
Coastal-Forest	1.42
Forest-Roadside	2.44
Coastal-Roadside	1.13

Table 4: Sørensen Indices

The Jaccard indices with respect to richness was fairly even among the habitat comparisons (J_r= 0.39, 0.54, 0.36). (Table 5).

Habitat Comparisons	Jaccard Index (J_r)
Coastal-Forest	0.39
Forest-Roadside	0.54
Coastal-Roadside	0.36

Table 5: Jaccard indices with respect to richness

The species exclusivity ratio was highest on the Pacific coast (x_c=0.29) followed by the roadside (x_r=0.18) while it was lowest at the forest edge (x_f=0.10) (Table 6).

Habitat	Species Exclusivity Ratio (x_h)
Coastal	0.29
Forest edge	0.10
Roadside	0.18

Table 6: Ratios of exclusive species to total species

With respect to abundance, the beta diversity (β_a= N = 3.0) indicated that there were three distinct communities within the region of study (Table 7).

Species	Total abundance (a_t)	α_a	γ_a	$\beta_a = N$
Brotogeris j. jugularis	511	170.33	511	3
Cassidix mexicanus peruvianus	218	72.67	218	3
Coragyps atratus	155	51.67	155	3
Sterna H. hirundo	119	39.67	119	3
Troglodytes aedon inquietus	87	29	87	3
Thraupis episcopus cana	85	28.33	85	3

Pitangus sulphratus guatimalensis	81	27	81	3
Actitis macularia	74	24.67	74	3
Eupherusa eximia	68	22.67	68	3
Tyrannus melancholicus chloronotus	43	14.33	43	3
Average	144.1	48.03	144	3

Table 7: Average alpha, beta and gamma diversities with respect to abundances of top ten species
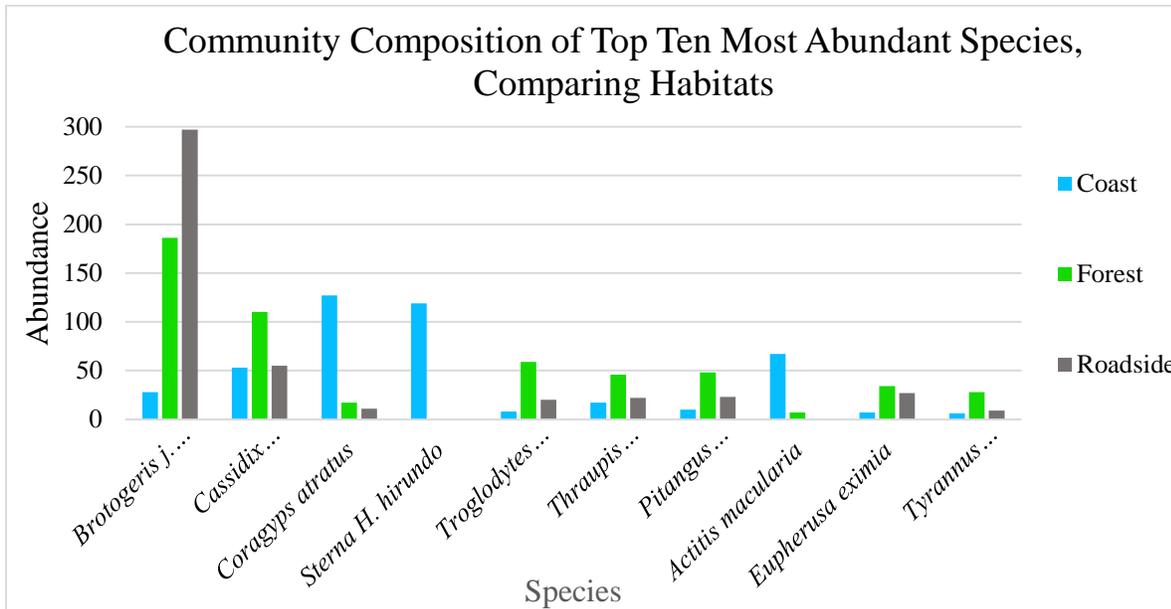

Figure 1: Community composition of avifauna at Pacific Coast, tropical dry lowland forest edge and roadside habitats.

Some errors involved with this study include GPS inaccuracy – few satellites were available with strong signaling in this location, and therefore the waypoints were inaccurately placed 20m off of the actual location. Species misidentification was the major potential source of error. With immediate observations, there was bias to observing the more proximal, visible, vocal, stationary, and conspicuous species within each point count. However, this bias was reduced through the use of non-immediate identification utilizing playbacks of observation recordings. Difference in vigilance between observation days should be noted, whereas certain times in the mornings and evenings exhibited poor lighting, and the weather caused varying visibility from day to day. Counts for avian species that tend to travel or settle in flocks, such as *Brotogeris j. jugularis* had potential to be inaccurate due to sheer high abundances. Though the well-researched optimal observation time of eight minutes was used (Lynch, 2005; Robinson, 2001; Robinson, 1999), there was still potential for error in double counting species between points. Non-immediate identification using playbacks of observation recordings was beneficial for species identification, but flawed when determining accurate abundance estimates. This difficulty in distinguishing between individuals was due to call overlapping during playback.

Discussion
In terms of weather impacts, it can be noted that there were lower counts on rainy days due to general inactive behavior of avifauna. Otherwise, cloud cover did not appear to have an effect on abundance counts from day to day. In Panama the most common species in edge or young tropical forest habitats include the Orange–chinned parakeet, Golden-collared manakin, Plain wren, Fulvous-vented euphonia, Blue-gray tanager and the Palm tanager (Robinson 2001). The presence of the highly abundant species *Brotogeris j. jugularis* (a_t=511) and *Thraupis episcopus cana,* (a_t= 85), multiple *Troglodytes* species and sparse observations of *Manacus vitellinus* and *Thraupis palmarum atripennis* at both the forest and roadside indicate that these local habitats were likely secondary edge forests. (Table 2). The presence of pelagic and shore species *Pelecanus occidentalis leucogaster, Charadrius wilsonia beldingi, Actitis macularia* and *Sterna H. hirundo* define the Pacific costal habitat as highly specified, while the presence of riparian species such as *Ceryle t. torquata, Chloroceryle amazona Mexicana,* and *Tigrisoma mexicanum* conveys the presence of river ecosystem that runs off the beach at one observation point. (Table 2). *Brotogeris j. jugularis* was most abundant on the roadside location (Figure 1). These species were typically seen travelling towards the inland forest in flocks, preferring the partially-cleared forests away from the coast. *Cassidix mexicanus peruvianus, Troglodytes aedon inquietus, Thraupis episcopus cana, Pitangus sulphratus guatimalensis* and *Tyrannus melancholicus chloronotus* were all comparatively highest in the forest edge habitat. Such species were observed either travelling inland, or occupying the scattered trees of the open areas (Figure 1). The abundances of these species demonstrates a clear preference for semi-open forests where there is a compromise between visibility and shelter from trees and shrubs. *Coragyps atratus, Sterna H. hirundo* and *Actitis macularia* were all nearly exclusive to the Pacific coast by abundances, defining the coastal location as a uniquely-defined habitat in which a certain coastal-pelagic community inhabits (Figure 1). The high degree of evenness in species richness between the three habitats (r_c=31, r_f=30, r_r=33) can demonstrate the near equal conditions of the habitats which host high diversity of avifauna, though it does not allude to a conclusion that community composition is even among the three local areas (Table 3). Diversity indices for the coastal and forest locations are moderate to high (D_c=2.35, D_f=2.38), This is likely due to a large amount of niches within each habitat that fosters a wide range of species. For example *Sterna H. hirundo* could be seen flying over the pelagic waters for fish, while *Actitis macularia* combs the shoreline for sea snails and sand insects. At the forest edge location, *Euphonia luteicapilla* reside mostly in the leafy branches of trees consuming seeds, *Melanerpes rubricapillus wagleri* thrives in the trunk areas of trees consuming wood-dwelling insects, while *Eupherusa eximia* hovers around flowery shrubs consuming nectar. The Shannon-Weiner index by the roadside was slightly lower compared to the other habitats (D_c=2.04), perhaps due to a lack in variety of specified niches or habitat space from deforestation for a paved road. (Table 3). As was expected, overlap was highest between the forest to roadside habitats (Q_s=2.44), likely attributing to the high degree of similarity in vegetative structure, whereas both locations consist of scrubby-partially cleared lowland forest edge. (Table 4). Sorensen overlap was expectedly lowest when comparing and coast to roadside habitats (Q_s=1.13), since the abiotic factors between both locations are entirely distinct. While the Pacific coast consists of all open, sandy beach with crabs, clams, sand fleas and flies, the roadside location consists of partially open dry forest with dragonflies, crickets, and spiders. This distinction in vegetation and avifauna prey can explain the low degree of overlap, since these uniquely-defined habitats host specified niches in which species exclusively inhabit. Similarly, the Jaccard index with respect to richness was

16

predictably high between the similar forest edge habitats at the forest and the roadside locations (J_r=0.54) (Table 5). The moderate overlap in richness when comparing the coast to the other locations, between the coast and forest (J_r=0.39), and between the coast and roadside (J_r=0.36), conveys the pronounced distinction in community structure mainly at the coast. Exclusivity in richness was notably highest at the coast (x_r=0.29) due to the presence of high numbers of pelagic and coastal birds, including *Casmerodius albus egretta*, *Egretta Caeruela*, *Eudocimus albus*, *Pelecanus occidentalis leucogaster, Fregata magnificens, Catoptrophorus semipalmatus inornatus, Numenius phaeopus hudsonicus and Sterna H. hirundo* (Table 6). This moderate to high ratio can be caused by the extremely distinct Exclusivity was low to moderate at the roadside (x_r=0.18), whereas some species such as *Campylorhynchus albobrunneus, Thyrothorous rufalbus castanonotus, Cyphorhinus phaecophalus lawrencii, Tityra semifasciata costaricensis, Chiroxiphia lanceolata* and *Thamnophilus doliatus nigricristatus* were observed only at the roadside. The moderate exclusivity at the roadside location is likely due to proximity to a large fragment of thick secondary forest, hosting species that conform to a niche in this habitat type rather than the open scattered shrubby woodlands at the forest edge location. The most remarkable distinction can be seen with the average beta diversity with respect to abundance. Since beta diversity signifies the degree of distinction between exclusive community abundances, it can be determined that the value (β_a=3.0) is equivalent to the number of distinct local communities within a region of study (Table 8). Beta diversity reveals that the exact number of distinguished avifauna communities is three (N=3.0). This allows for the rejection of part of the null hypothesis, in which there is no significant distinction in community composition between the coastal, forest edge and roadside habitats.

Local habitats consist of highly specific classes of vegetation, fauna and abiotic factors such as type of proximal body of water, soil composition, precipitation and humidity. These highly specified habitats host a particular set of avifauna that are well-adapted to their environment. High diversity is maintained through individuals occupying specified areas of the habitat, playing unique roles to reduce competitive exclusion, a process termed "niche diversification" (Connell, 1978). Intermediate disturbance hypothesis: diversity is higher when disturbance is intermediate, when species composition is continually changing Diversity increases because of allowance of more time for invasive species to enter the habitat ecosystem and occupy their own niche (Connell, 1978). Therefore the moderately high diversities seen in these locations could be attributed to moderate to high levels of anthropogenic disturbance.

Conclusion
There are no significant differences among richness and diversity between the three habitats that were hypothesized to be distinct. Therefore the null hypothesis cannot be fully rejected. However, beta diversity with respect to abundance indicates that exactly three distinct communities exist across the region of study (β_a=N=3.0). Additionally, the ratios of exclusivity convey a moderate degree of distinction between the specialized habitats. The ratios are fairly high among both the coastal and road habitats, thus defining such habitats as mainly separate and distinct, with the medium of the forest location serving as a buffer between the coastal and roadside habitats. Here we can gain more detailed knowledge on the previously under-researched avian communities on and near the Pacific Coast of Los Santos province. This research relays a baseline for the state of avian populations in the tropical dry lowland forests and Pacific coast of Panama, which can be utilized for further comparative studies in tropical dry lowland forests. The results of this research allow one to determine precisely how habitat type shapes the

community structure of avifauna in this tropical dry lowland region. This study highlights the significance of tropical dry lowland forests and coasts as habitats that maintain high diversity, as they consist of multiple specific niches which particular avian species will occupy to reduce pressures from interspecific competition. This conveyance of the presence of specialized habitats in the forest can demonstrate the importance of tropical dry lowlands as a golden zone for endemism and biodiversity. When these forests are deforested or degraded, biodiversity and ecosystem services are consequently diminished. Habitat destruction could result in the reduction of specified niches which fosters high richness and biodiversity. The implications of this study are that new conservation practices and policies could be implemented to reduce the impacts of tropical dry lowland forest degradation. These conservation efforts are vital, as high development of full-scale tourism complexes, requiring clear-cutting of coastal forest and involving heavy human disturbance, is reducing diversity and richness on Venao and much of the remaining tropical lowland coasts in Central America. Further research could prove relevant, as ecotourism development appears to be an up-and-coming issue in this region. One such comparative chronological study could be an investigation on the apparent change in avifauna communities in the lowland forests of the Azuero peninsula. Such studies could be a comparison of diversity and community structure for pre and post coastal development.

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