Assessing the Effects of Mangrove Patch Size on the Density and Diversity of Bird Species in the Pablo Arturo Barrios Wildlife Refuge

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Working days: 21
Field days: 3.5

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ACKNOWLEDGEMENTS

We would like to take this opportunity to express our gratitude towards all who made this achievement possible.

Primarily, we would like to thank the Azuero Earth Project NGO and our supervisor Ruth Metzel for putting us in contact with people of the Pedasí community and using our research to support the management of the Pablo Arturo Barrios Wildlife Refuge. A special note to the Azuero Earth Project staff, volunteers and Peace Corp volunteers, particularly Jairo Batista Bernal and Timothy Viel, for their support and lively bird talks.

Similarly, we would like to recognize the help of Robert Shahverdians and Isabelle Guenet for their contribution to the initial stages of the investigation in exploring the different ecosystems of the refuge, and in understanding how the state of the refuge has evolved through the years. We also recognize their continual efforts in promoting sustainable practices, encouraging conservation of the area and their work with Tortugas Pedasí.

Next, we express our gratitude to the kindness of the Pedasí community, and their support concerning our research efforts. A special note to all the taxis of Pedasí for being there for us day and night.

Further, we thank nature photographer Matt Stirn for creating a documentary video on the refuge. We were delighted to work with him on the bird portion of this documentary, and thank him greatly for sharing his stunning pictures.

After, we would like to thank Hector Barrios, Catherine Potvin, Lady Mancilla and all people that McGill University and STRI that make the McGill Panama Field Study Semester possible, and for us to live this incredible opportunity.

Then, we want to express our sincere gratitude to George R. Angehr, one of the authors

of the book *The Birds of Panama*, for having taken to time to look through our unidentified bird pictures and recordings.

Finally, we would like to recognize the power of all bird Gods, without who, this experience would not have been possible.

AGRADECIMIENTOS

Nos gustaría aprovechar esta oportunidad para expresar nuestra gratitud hacia todos los que hicieron posible este logro.

En primer lugar, nos gustaría agradecer a la ONG Proyecto Ecológico Azuero y nuestra supervisora Ruth Metzel por ponernos en contacto con personas de la comunidad de Pedasí y utilizar nuestra investigación para apoyar la gestión del Refugio de Vida Silvestre Pablo Arturo Barrios. Una nota especial para el personal del Proyecto Ecológico Azuero, sus voluntarios y voluntarios de Peace Corp, particularmente Jairo Batista Bernal y Timothy Viel, por su apoyo y animadas charlas de pájaros.

Del mismo modo, quisiéramos reconocer la ayuda de Robert Shahverdians e Isabelle Guenet por su contribución a las etapas iniciales de la investigación en la exploración de los diferentes ecosistemas del refugio y en la comprensión de cómo ha evolucionado el estado del refugio a través de los años. También reconocemos sus continuos esfuerzos para promover prácticas sostenibles, alentar la conservación del área y su trabajo con Tortugas Pedasí.

A continuación, expresamos nuestro agradecimiento a la amabilidad de la comunidad de Pedasí y su apoyo a nuestros esfuerzos de investigación. Una nota especial a todos los taxis de Pedasí por estar ahí para nosotros día y noche.

Además, agradecemos al fotógrafo de naturaleza Matt Stirn por crear un video documental sobre el refugio. Estuvimos encantados de trabajar con él por la parte de aves de este

documental, y le agradecemos enormemente por compartir sus impresionantes imágenes.

Después, nos gustaría agradecer a Héctor Barrios, Catherine Potvin, Lady Mancilla y todas las personas de la Universidad McGill y STRI que hacen posible el Panama Field Study Semester y para lo que podamos vivir en esta increíble oportunidad.

Luego, queremos expresar nuestro sincero agradecimiento a George R. Angehr, uno de los autores del libro *The Birds of Panama*, por haber tomado tiempo para revisar nuestras fotos y grabaciones de aves no identificadas.

Finalmente, nos gustaría reconocer el poder de los Dioses de las aves, ya que sin ellos esta experiencia no sería posible.

EXECUTIVE SUMMARY

English

In Panama, 34.43% (2.6 million hectares) of the country land and water are considered protected areas. In 2009, efforts from the community of Pedasí, in the province of Los Santos, finally led to the officialization of the Pablo Arturo Barrios Wildlife Refuge (PABWR) as one of these numerous areas. The PABWR has an area of more than 15 thousand hectares along the Eastern coast of the Azuero peninsula facing the Golf of Panama. This refuge holds a rich diversity of ecosystems, including mangroves, dunes and dry tropical forests, each uniquely contributing to the biodiversity of the refuge and adjacent regions. Nevertheless, it suffers from a substantial deficiency of management mainly due to the lack of an officially established management plan. Actually, little data exists on the environmental status or composition of this refuge. The local NGO Azuero Earth Project has been trying to get one approved, but have yet to receive an response from the ministry of environment MiAmbiente. Therefore, in an effort to support the local community in the establishment of a plan and to promote sustainable practices by raising awareness, we have completed bird surveys across the refuge to provide the Azuero Earth Project with a complete list of the identified bird species of the area, and we have also assessed whether the size of mangrove patch affects the density and diversity of bird species.

Our surveys were completed in 4 different ecosystems namely mangroves, dunes, tropical dry forest and coast. To compare density and diversity of birds in differently sized mangroves, we investigated two different mangrove areas, one large and one small, which we both surveyed twice. Thus, there were 7 field days in total. Each field day, the selected site was sampled twice: once in the morning at sunrise (~6:30 a.m. to 8 a.m.) and once in the afternoon before sunset (5 p.m. to ~6:30 p.m.). During sampling, the characteristics of any bird observed without width or

height distance limit was noted with as many details as possible. Binoculars were used to improve sight, and pictures and recordings were taken when possible. Based on the information collected, we later identified bird species using the book *Birds of Panama* (2010). Then, mangrove data was analyzed for diversity and density.

All together, we have identified a total of 51 bird species across the refuge. This include 4 species on the Partners in Flight Watchlist Yellow which highlights birds that require particular conservation attention for their worrying population demographics, and also 1 species on the Partners in Flight list of Common Bird in Steep Decline which includes birds that have lost more than 50% of their worldwide population since 1970. Analysis of mangrove data has shown that the large mangrove is as diverse and as densely populated as the small one. However, only 31.25% of species are common to both sites.

We believe that our results show that two ecosystems equivalent in nature can host widely different organisms. This exposes the complex nature of ecosystems and the inevitable interactions that exist between their different parts. With the 51 species we have observed in total across the Pablo Arturo Barrios Wildlife Refuge, our research emphasizes the pressing need for the establishment a management plan. Indeed, with several species showing dangerous population trends, we believe that immediate action is imperative to the safeguard of the biodiversity of the refuge.

Español

En Panamá, 34.43% (2.6 millones de hectáreas) de la tierra y el agua del país se consideran áreas protegidas. En 2009, los esfuerzos de la comunidad de Pedasí, en la provincia de Los Santos, finalmente llevaron a la oficialización del Refugio de Vida Silvestre Pablo Arturo Barrios como una de estas áreas. Este refugio tiene un área de más de 15 mil hectáreas a lo largo

de la costa Este de la península de Azuero frente al Golfo de Panamá. Posee una rica diversidad de ecosistemas, incluidos manglares, dunas y bosques tropicales secos, cada uno de los cuales contribuye de forma única a la biodiversidad del refugio y de las regiones adyacentes. Sin embargo, adolece de una deficiencia sustancial de gestión debido principalmente a la falta de un plan de manejo oficialmente establecido. En realidad, existen pocos datos sobre el estado o la composición ambiental de este refugio. El ONG local Proyecto Ecológico Azuero ha estado tratando de obtener uno aprobado, pero aún no ha recibido una respuesta del ministerio de medio ambiente MiAmbiente. Por lo tanto, en un esfuerzo por apoyar a la comunidad local en el establecimiento de un plan y promover prácticas sostenibles mediante la sensibilización, hemos completado censos de aves a través del refugio para proporcionar al Proyecto Ecológico Azuero una lista completa de las especies de aves identificadas, y también hemos evaluado si el tamaño del parche de manglar afecta la densidad y la diversidad de las especies de aves.

Nuestras encuestas se completaron en 4 ecosistemas diferentes: manglares, dunas, bosque seco tropical y costa. Para comparar la densidad y la diversidad de las aves en manglares de diferentes tamaños, investigamos dos áreas diferentes de manglares, una grande y otra pequeña, que ambos encuestamos dos veces. Por lo tanto, hubo 7 días de muestra en total. Cada día de muestra, el sitio seleccionado se muestreó dos veces: una vez en la mañana al amanecer (~ 6: 30 a.m. a 8 a.m.) y una vez en la tarde antes del atardecer (5 p.m. a ~ 6: 30 p.m.). Durante el muestreo, se anotaron las características de cualquier ave observada sin límite de distancia de ancho o alto y con tantos detalles como fuera posible. Los binoculares se usaron para mejorar la vista, y se tomaron fotografías y grabaciones cuando fue posible. Con la información recolectada, identificamos las especies de aves usando el libro *Birds of Panama* (2010). Luego, se analizaron los datos de los manglares por diversidad y densidad.

En totalidad, hemos identificado un total de 51 especies de aves a través del refugio. Esto incluye 4 especies en la Watchlist Yellow de Compañeros de Vuelo que destaca aves que requieren atención de conservación particular para su población demográfica preocupante, y también 1 especie en la lista Common Bird in Steep Decline Compañeros de Vuelo que incluye aves que han perdido más de 50 % de su población mundial desde 1970. El análisis de los datos del manglar ha demostrado que el manglar grande es tan diverso y tan densamente poblado como el pequeño. Sin embargo, solo 31.25% de las especies son comunes a ambos sitios.

Creemos que nuestros resultados muestran que dos ecosistemas equivalentes en teoría pueden albergar organismos muy diferentes. Esto expone la complejidad de ecosistemas y las interacciones inevitables que existen entre sus diferentes partes. Con las 51 especies que hemos observado en total en todo el Refugio de Vida Silvestre Pablo Arturo Barrios, nuestra investigación enfatiza la necesidad urgente de establecer un plan de manejo. De hecho, con varias especies que muestran tendencias de población peligrosas, creemos que la acción inmediata es imprescindible para salvaguardar la biodiversidad del refugio.

INTRODUCTION

Context

In Panama, 34.43% (2.6 million hectares) of the country land and water are considered protected areas (El Sistema Nacional de Áreas Protegidas de Panamá, 2008). In 2009, efforts from the community of Pedasí, in the province of Los Santos, finally led to the officialization of the Pablo Arturo Barrios Wildlife Refuge (PABWR) as one of these numerous areas (Nueva área protegida en la villa de Los Santos, 2009). The PABWR has an area of more than 15 thousand hectares along the Eastern coast of the Azuero peninsula facing the Golf of Panama (El Sistema Nacional de Áreas Protegidas de Panamá, 2008).

This refuge holds a rich diversity of ecosystems, including mangroves, dunes and dry tropical forests, each uniquely contributing to the biodiversity of the refuge and adjacent regions (Herrmann Alvarez Cienfuegos & MacInnis, 2016). To name a few, mangroves are ecologically valuable to fish reproduction, and the Los Lagartos beach is an important sea turtle egg-laying location (Ubicación de playa Los Lagartos – Los Lagartos beach location, 2013). Dunes are also the main barrier to erosion in this region (I. Guenet, personal communication, January 30, 2018). It is worth noting that the majority of the land area of the refuge is constituted of tropical dry forest which is the type of forest the most threatened by deforestation in Panama (Proyecto Ecológico Azuero, 2010).

Additionally, the PABWR comprises economic benefits to the surrounding communities. Laws allow only subsistence fishing, and ban even the presence of large fishing boats (Herrmann Alvarez Cienfuegos & MacInnis, 2016). Tourism in this area is also very popular especially for its attractive beaches (I. Guenet, personal communication, January 30, 2018). Fishermen offer boat rides to the nearby and popular Isla Iguana, including sightseeing of the marine wildlife

during the trip (J. Batista Bernal, personal communication, January 30, 2018). This influx of tourists evidently fructifies the economy of the small towns, emphasizing the cruciality of the conservation of this refuge (Gagné-Landmann, 2017).

Nevertheless, the legal reality of the PABWR is not as delightful: the refuge still does not have any official management plan installed. The Sistema Nacional de Áreas Protegidas (SINAP) is the national agency that coordinates protected areas in Panama (Herrmann Alvarez Cienfuegos & MacInnis, 2016). SINAP itself is under the administration of the Ministerio de Ambiente (MiAmbiete) of the government of Panama (Herrmann Alvarez Cienfuegos & MacInnis, 2016). However, since 1998, it was the Autoridad Nacional del Ambiente de Panamá (ANAM) that oversaw SINAP (Ministerio de Ambiente de Panamá (Miambiente), n.d.). ANAM was autonomous from the Panamanian state, thus making their influence and resources limited (Herrmann Alvarez Cienfuegos & MacInnis, 2016). It was only in 2015 that the government converted ANAM to MiAmbiente – a ministry (Ministerio de Ambiente de Panamá (Miambiente), n.d.). It is the hope of all that the creation of a ministry of the environment would help the protection and sustainability of Panama's protect areas like the Pablo Arturo Barrios Wildlife refuge (R. Shahverdians, personal communication, January 30, 2018).

Nevertheless, even with the installation of the ministry, advancements still seem to be slow and regulations are not being enforced (R. Shahverdians, personal communication, January 30, 2018). Indeed, as of today, there are no Panamanian laws on refuge management (Gagné-Landmann, 2017). A management plan needs to be established and approved by MiAmbiente in order for laws and regulations to be implanted in wildlife refuges (Gagné-Landmann, 2017). Still, a few national laws can directly affect refuge management. For example, according to Panamanian laws, 100% of mangroves should be protected, making any modification or

deforestation illegal (Herrmann Alvarez Cienfuegos & MacInnis, 2016). Yet, mangroves in Panama are being rapidly and extensively deforested (Proyecto Ecológico Azuero, 2010). One reason for this inconsistency is that different aspects of protection laws are enforced by different organizations (Herrmann Alvarez Cienfuegos & MacInnis, 2016). In PABWR, this is exemplified by private and touristic development projects in the area, forest deforestation and beach erosion, and treats to privatize the fishing port (En alerta con el Refugio de Vida Silvestre Pablo Barrios de Pedasí, 2015). In short, the conservation of the PABWR is at stake, making the adoption of a management plan imperative.

The Azuero Earth Project is an environmental NGO, situated in the town of Pedasí, dedicated to the promotion of sustainable land-use, reforestation and conservation of Panamanian ecosystems (Proyecto Ecológico Azuero, 2010). They work particularly through educational activities for conscientization and with the youth (Proyecto Ecológico Azuero, 2010). In relation of the Pablo Arturo Barrios Wildlife Refuge, they aim to support the Pedasí community in achieving the tools necessary for its protection and conservation, as well as building a solid relation between the community and MiAmbiente for resource co-management (R. Metzel, personal communication, January 18, 2018). Since its establishment in Pedasí in 2010, the Azuero Earth Project has submitted several management plans to MiAmbiente, but approval is still pending (R. Metzel, personal communication, January 18, 2018).

From our preliminary investigations of the area and discussions with locals and Azuero Earth Project staff, we have recognized that one factor slowing the adoption of a management plan for the Pablo Arturo Barrios Wildlife refuge is the significant lack of scientific knowledge on its wildlife population. To address this problem, in partnership with the Azuero Earth Project and their volunteers, we will also be building a list of bird species present in the refuge.

Background

Study site: Mangroves

Mangrove forests present a unique ecosystem sprouting where land, freshwater and saltwater meet. Due to this, they have become of high interest to many different groups of people - including conservationists and biologists - and have so for many years (Kathiresan & Bingham, 2001; Lopez-Angarita et al., 2016). Plants in these areas have shown amazing adaptations to the extreme conditions under which they live, i.e. high salinity, fluctuating tides, strong winds, high temperatures and muddy anaerobic soils (Kathiresan & Bingham, 2001). Furthermore, they provide highly valued ecosystem services. First, mangrove forests protect coastlines from erosion caused by strong winds and storms which would otherwise have the potential to cause damage to infrastructure and beaches (Lopez-Angarita et al., 2016; McGowan et al. 2010). Erosion becomes an increasing problem with the rising of ocean levels (Kathiresan & Bingham, 2001). Second, they provide important breeding and feeding areas for many fish species, including some commercially valuable species (McGowan et al., 2010). As well as being host to many mammals, birds, reptiles and more (Kathiresan & Bingham, 2001; Alongi, 2012). Next, mangroves are carbon rich forests, storing much of their carbon in the soil and their roots. The older the root, the more carbon it stores and many dead roots will have a high amount of carbon in them (Alongi, 2012). Therefore, they might have a key role in carbon sequestration and mitigating the current high rates of atmospheric CO2. They also have a commercial value for their highly resistant wood which can be used as both fuel and construction materials (Lopez-Angarita et al., 2016).

However, many of these forests have been highly destroyed due to logging and the landscape has become patchy. In Panama, the loss due to clearance is high. Urban expansion

remains one of the biggest threats in this regard. Only 1.18% of the remaining mangroves fall under some sort of environmental protection, and even then, laws surrounding these protected areas will often not be enforced (Lopez-Angarita et al., 2016).

In the PABWR there are three main locations with larger mangrove sites. These are Punta Mala, Playa Arenal and Punta del Tigre. Moreover, smaller patches of mangrove forest can be found at many poinst along the coast.

Study subject: Birds

Many species of birds inhabit mangrove estuaries whether permanently, nesting and feeding in the forest or passing through during seasonal migrations (Kathiresan & Bingham, 2001; Lefebvre & Poulin, 1996; Butler et al., 1997). Many insectivorous species are attracted to the habitat as it provides a somewhat stable area to feed (Lefebvre & Poulin, 1996). To add, other shorebirds and waterfowl can often be found nearby for similar reasons. Many species thrive and depend on this environment for their survival (Kathiresan & Bingham, 2001; Butler et al., 1997). For this reason, it is not surprising that the effects of changes in mangrove habitat health can have strong influences on their bird residents (Kathiresan & Bingham, 2001).

In the PABWR, research on birds has yet to be done. To date, little research can be found on the possible types of species present in the refuge and how they are being affected by anthropogenic factors, if at all. Miller et al., in 2015, published an annotated checklist of bird species in Cerro Hoya National Park located nearby on the Azuero Peninsula. They recorded 225 different species, out of which nine were classified as IUCN globally threatened, three had extended their range 150 km and two were new taxa. In addition to this, a bird count of one hour duration was done in 2013 in association with the Azuero Earth Project where they recorded 25 species in the PABWR. From these and our own preliminary walks around the refuge, it is clear

the potential for research is abundant and could prove quite fruitful.

For this research project, we want to investigate whether the density and diversity of mangrove bird species in the Pablo Arturo Barrios Wildlife Refuge are affected by variations in mangrove size. We hypothesize bigger mangroves will hold a greater density and diversity of bird species. We aim to obtain a GIS estimate of the size of the mangrove patches in order to assess their diversity and density of bird species.

The product agreed upon with the Azuero Earth Project organisation is a comprehensive species list of the birds in the Pablo Arturo Barrios Wildlife Refuge including their English common name, scientific name, Spanish common name, area found, IUCN status, IUCN population trend and PIF score. In addition, we provided them with bird song recordings, pictures of birds and the refuge, and we designed an informative pamphlet that includes some of the birds we have identified (refer to *Supplemental Text* for details and complete products).

METHODS

General

Our study sites are two mangrove estuaries in the wildlife refuge. The first site (large port mangrove A) is located near Playa Arenal, a 45 minutes walk from Pedasí center. It is used by local fishermen, and a public cement dock has thus been constructed in it. The second is located by Playa El Toro, also around 45 minutes walk from Pedasí center. To access it, one must walk the beach about 500 m, making it, according to local knowledge, much less visited by people (I. Guenet, personal communication, January 30, 2018).

The area of each mangrove was estimated using ArcGIS online (Esri, “Imagery”; Esri, “Topography”). Two basemaps were overlaid - the first showed satellite imagery so that it was possible to see where the treeline began and ended. Next, the topographic map was placed as it

showed the limits of the Pablo Arturo Barrios Refuge. Both maps were provided by ESRI. The area was found in square kilometers using the measure-area tool.

Data was collected over 2 days at each site for a total of 4 days. Each day, sites were sampled twice: once in the morning at sunrise (~6:30 a.m. to 8 a.m.) and once in the afternoon before sunset (5 p.m. to ~6:30 p.m.). Point counts of 10 minutes each were conducted every 100 m for a total of 3 times (i.e. 300 meters total). During that time, any bird species seen or heard and the frequency of sightings without width or height limits were marked down with as many details as possible. Additionally, binoculars were used to improve sight, and pictures and recordings were taken when possible. Due to the nature of the mangrove sites, randomization of points was difficult. In the larger mangrove near Playa Arenal, there are some short trails that are also quite easily navigable. However, besides this, the forest nearby is often dense, and crocodiles are abundant in the area. The only way to navigate both mangroves was thus by kayak. The first point of every transect was randomized by paddling 10 strokes from the edge of the mangrove. Nevertheless, out of the 4 sampling occasions of each mangrove site, 1 was pursued by foot through the mangrove forest.

Later, the birds observed were identified based on our notes, pictures and recordings using the book *The Birds of Panama* (2010) and discussion with Azuero Earth Project staff. Unidentifiable pictures and recordings were sent to Georges Angher, Research Associate at the Smithsonian Tropical Research Institute and author of this same book, for further investigation.

Statistical Analysis

Sightings of identified species were organized by sampling occasion and site, and the alpha-diversity, beta-diversity and density of the two mangrove sites were assessed.

For alpha-diversity, the non-parametric first-order Jackknife index was evaluated for each

sampling occasion, i.e. mangrove A morning February, mangrove A evening February, mangrove A morning March, etc. The first-order Jackknife index was employed because we assumed that although size was not underestimated, the number of species observed was. Following this, we conducted a two-sample t-test assuming unequal variances to contrast alpha-diversity between the two mangrove sites.

Next, beta-diversity was evaluated using Jaccard similarity coefficient, where 0 means that no species were shared between the two sites and 1 means that all species were shared. This index was computed using the pooled species list of the four sampling occasions at mangrove A and B.

Finally, the density of each mangrove site was also evaluated, analyzed and compared. Density is defined as the number of individuals per unit area (Lambers et al., 2002). For this research, each transect was 300m in length and 40m wide (20m each side) by arcmap estimate and the limit at which it was possible to observe birds both visually and auditorily. As a result, the area estimated to have been sampled on every occasion was 12000 m^2. The number of individuals was tallied for each sampling occasion to calculate density per area. Again, we conducted a two-sample t-test assuming unequal variances to contrast density of individuals between the two mangrove sites.

Sightings organization and indices estimations were done using Excel (2016). All statistics and graphs were generated using the JMP statistical software (SAS Institute Inc., 2016). No data was modified, and only unidentifiable sightings were omitted from the analyzed dataset. All results are reported as mean ± SEM with N being the number of sampling occasions per sites. Significance was assessed at $p < 0.05$.

***Code of Conduct* of McGill University**

All research, surveys and informal interviews were carried out following the McGill University's research *Code of Ethics* and in agreement with the rules of the Canadian Panel on Research Ethics (Appendix C).

RESULTS

We surveyed two mangrove patches of the Pablo Arturo Barrios Wildlife Refuge in Pedasí to assess whether the size of these patches affected the diversity and density of bird species.

We started by estimating the size of both mangroves using ArcGIS online. With the tool measure-area, we found that the larger port mangrove was 321,615.60 km^2, and that the smaller beach mangrove was 7,571.70 km^2. This yields a 2.35 ratio between the large and the small mangrove, thereby justifying the basis of our comparison between the two sites (Figure A1). Over the span of our study, we observed between the two mangroves a total of 32 bird species: 24 were observed in the large mangrove and 17 in the small mangrove site. Of these species, 14 were only seen in the large mangrove, and 7 only in the small one (i.e. there were only 10 species in common between the two sites). Both sites combined, 4 species were identified by the sighting or sound of a single individual (Figure A2).

To begin analysis, we first estimated alpha-diversity using the non-parametric first-order Jackknife test on each sampling occasion at both mangrove sites (Figure A3). This index evaluates the actual diversity present based on the number of 'singletons' in the data, i.e. the number of species that were only observed once per sample (Smith & Pontius, 2006). Using these results and based on histogram analysis of the data (not shown), we performed a two-sample t-test assuming unequal variances, and did not detect any significant difference between

the alpha-diversity of the two mangroves (*A*: 13.50 ± 1.15, N = 4; *B*: 10.1 ± 3.01; t = -1.06, df = 3.87, p = 0.35).

Next, beta-diversity was evaluated with the Jaccard index comparing the port mangrove (A) and the beach mangrove (B). Results showed that the amount of species shared between the two mangroves was evaluated to 31.25%.

Finally, the density of individuals sighted per area for each mangrove was analyzed and compared (Figure A1and A4). Using these results and based on histogram analysis of the data (not shown), we again performed a two-sample t-test assuming unequal variances, and did not detect any significant difference between the density of individuals of the two mangroves (*A*: 0.0039 ± 0.00054, N = 4; *B*: 0.0027 ± 0.0018; t = -0.59, df = 3.53, p = 0.59).

DISCUSSION

All in all, we have extensively surveyed two mangrove ecosystems of the Pablo Arturo Barrios Wildlife Refuge to assemble of list of the different bird species present and compare their diversity and density. Our analyses have shown that neither alpha-diversity nor density of bird species differed between the two mangrove patches studied. Nevertheless, beta-diversity analysis reveals a 31.25% similarity in species composition. We have also complemented our research with a product for our host organization, Azuero Earth Project, consisting of a detailed list of the bird species present over the different ecosystems of the PABWR. Overall, we prove that regardless of size, the mangrove ecosystems of the PABWR are hosts to a large variety of bird species.

We successfully mastered the ArcGIS measure-area tool to evaluate mangrove size, but there was still uncertainty on the certitude of the results. Although the limits of the refuge were provided in the map used, the exact delimitations of the mangrove forest were not as clear.

Indeed, for the relatively low quality of the map, it was not possible to obtain clear close views. Since part of the mangrove forest was surrounded my tropical dry forest, it has also been a challenge to mark the exact outline. To refine our estimates, it would be necessary to construct the area based on GPS coordinates collected in the field. Although conscious of the limitations of our evaluation, we nevertheless show that the port mangrove is considerably larger than the beach mangrove.

Over the span of this investigation, we have identified a total of 32 bird species, 19 of which had only one individual spotted. The comparison of alpha-diversity using the first-order Jackknife index revealed no significant difference in diversity between the two mangrove sites. This means that both mangroves had an equivalent richness of species. This contradicts our original hypothesis that the larger mangrove would have a greater diversity of species as its size would be able to support more niches, and thus promote richness (Holt, 2009). We could pose several hypotheses to explain these results. First, quantitatively, the first-order Jackknife index compensates for a believed under-sampling of the species (as opposed as Chao which compensates for under-representation of the area) (Gotelli & Chao, 2013). As we did not judge ourselves as expert birders, we believe that we were not able to identify all birds sighted nor heard, but that the area was appropriately sampled. This is supported by our total of 103sighted, but unidentified, bird individuals – a number which is most certainly undervalued as those without any distinguishable features were not necessarily documented. Plus, we realized that we were often not able to look at all birds simultaneously flying around us which again underestimates the true number of species. That said, the first-order Jackknife formula uses the number of singletons (number of birds observed only once in the sample) as a basis to estimate the true number of species observed assuming the lesser probability of seeing rarer species

(Levin, 2013). Hence, although there were 12 singletons for both sites when considered separately, there were less sightings obtained in the smaller mangrove (132 versus 186 in the large mangrove), increasing the overall incidence of singletons relative to the total number of species observed at every sampling occasion (48% singletons small mangrove; 25% singletons large mangrove). A higher number of singletons could have overestimated the alpha-diversity value in the small mangrove. Additionally, we assumed that bird activity would be similar at sunrise and sunset. However, from our results, we can graphically certify that, for the small mangrove only, there were significantly less birds observed in the evening than in the morning (Figure A5). This discrepancy between the two mangroves is unexpected, and might enhance the overestimation error via singletons. This is unsupported by recent literature which reveals that tropical birds are most active in the morning and in the evening, when light intensity is lesser (Bonter et al., 2013). Moreover, the overall lower activity of the smaller mangrove might have biased us to counting more vigorously far-passing individuals which we had less time to pay attention to while in the larger mangrove. For example, one sampling occasion in the small mangrove included 14 Magnificent Frigatebirds and 56 Orange-Chinned Parakeets. These types of birds fly high over the canopy, and we would tend not to see them if we are observing other birds at eye-level. Thus, the number of sightings of the large mangrove is probably an underrepresentation. On the whole, although our richness analysis through alpha-diversity comparison of the two mangrove sites shows that their diversity of bird species did not significantly differ, there were many unexpected biases during data collection that could have attenuated this potential difference.

Thereafter, to deepen our analysis of the distribution of bird species between the two mangrove sites, we analyzed their similarity using the Jaccard similarity coefficient for beta-

diversity (Levin, 2013). As we obtained 31.25% similarity, it suggests that there is a low similarity of bird species between the small beach mangrove and the large port mangrove. It is surprising to witness that although both ecosystems are mangroves estuaries, they host widely different bird species. Additionally, relating this result to alpha-diversity, we could suggest that although the two mangrove sites are similar in diversity, their diversity is composed in majority of different species. This could be a direct result of the relative sizes of the mangroves. The larger size of the port mangrove could allow it to harbor more species through increased area allowing cohabitation, increased diversity of niches attracting species variety, and increased pool of resources for greater support through ecosystem services (could expend; sources). Alternatively, we have visually assessed that the smaller mangrove might have been less healthy than the larger one, and as a result might not support all bird livelihoods as well. Indeed, there was a lot of human pollution around the entrance of the mangrove through the beach as well as in the first 100 meters of water and through the mangrove roots. This type of pollution negatively affects the health of the ecosystem (Hamilton & Crabbe, 2009). On the other hand, the port mangrove was mostly polluted by fish debris and old fishing nets which, instead, might attract birds and contribute to the ecosystem by enhancing nutrient composition (Lee & Bukaveckas, 2002). Also, there was strong deforestation around the small mangrove. We have observed agricultural lands on one side about 300 meters from the beach and 10 meters from the mangrove water, and an unused private land plot cornering the other side of the mangrove and the beach. Deforestation can have major impacts of the surrounding areas including water retention, nutrient flow and biodiversity composition (could expend; sources). Therefore, it is possible that the health of the mangrove is decreasing because of the surrounding deforestation. Similarly, the change in surrounding land is a prone to attract birds of different types of ecosystems which we

could have certainly observed while surveying the mangrove. Further, as the surveyed in the dry season, the mangrove never connected with the sea. The lack of water flow and input in addition to the other factors mentioned before could have contributed to the decreased quality and quantity of ecosystem services that mangrove normally provide to organisms, in turn changing resident bird species. Overall, beta-diversity analysis has proven that the similar diversity of both mangrove sites is composed of widely different species which could be explained by the difference in size, but also by dissimilarity in biotic and abiotic factors.

Furthermore, in terms of density of individuals per area surveyed, the two mangrove sites did not significantly differ either. Based on our previous finding that bird species do not significantly differ between the two mangroves, this result was not surprising. In fact, species will group equally regardless of the absolute size of their environment, but vary across time and with ecosystem changes (Keller et al., 2003). Hence, since species composition is the same, we do not expect the density of individuals to change. However, the formerly acknowledged sampling limitations that could affect the alpha-diversity estimate apply as well to the computation of density. In particular, the over-representation of far-passing species in the smaller mangrove due to lesser overall activity might have contributed greatly to erroneously increase the density of this area relative to the large mangrove. A difference in density could have suggested differences in ecosystem services quality. We would expect bird demographics to change as a response to limitations in services such as food or shelter (Keller et al., 2003). To further verify these results, we should not only increase the number of sampling repeats, but also limit the range of observations in order to eliminate the over-representation of far-flying individuals in calmer areas. Nevertheless, our present results suggest that both mangrove sites host the same density of individuals.

Similarly, there are other factors that could have influenced species and individual count. First, 56 additional sightings could not be identified at the species level, mainly including hummingbirds, swallows and woodpeckers. These types of birds are inherently more difficult to identify for their rapid flight, small size and forest camouflage. Second, as we were forced to make the distance between our survey points was relatively short because of the absolute length of the small mangrove, the probability of double counting was increased. Indeed, as flying organisms, birds can cover a large distance in a short time (Bonter et al., 2013). Although the number of species and individuals might have been underestimated, this type of error is systematically the same between sites thereby conserving the validity of the comparison.

Nevertheless, we propose additional thoughts to improve the overall certainty and validity of results for future research. We believe it is evident that increasing the number of sampling occasions would resolve some uncertainty by accumulating more detailed characteristics, pictures, recordings and obviously sighting frequency. Furthermore, since a significant part of our identifications were done using pictures, we suggest heightening the length of the lens to improve definition of bird features. Similarly, obtaining a bird recorder with a pole would definitely allow more identifications as most of the recordings were too faint to distinguish sounds. Likewise, including a person responsible for only photography and recording would reduce the need for multitasking from which the quality of all tasks would benefit.

Taken as a whole, our findings highlight important implications in terms of species conservation, biodiversity interaction and sustainability practices. In fact, the difference in species observed between the two mangrove sites exposes that two theoretically similar ecosystems can support different types of lifeforms. Notably, all species identified are listed on the IUCN Least Concern list emphasizing the need for conservation attention to these birds

before their status worsens (IUCN, 2018). Even more distressing is that four of the identified birds, namely the Magnificent Frigatebird (*Fregata magnificens*), the American Oystercatcher (*Haematopus palliatus*), the Yellow-Crowned Parrot (*Amazona ochrocephala*) and the Mangrove Cuckoo (*Coccyzus minor*), are part of the Partners in Flight (PIF) Watchlist Yellow (Partners in Flight Watch List, n.d.). The majority of the other species also show to have worrying demographics according to PIF (Partners in Flight Watch List, n.d.). Moreover, the Green Heron (*Butorides virescens*) was recognized in the Partners in Flight list of Common Bird in Steep Decline which includes birds that have lost more than 50% of their worldwide population since 1970 (Partners in Flight Watch List, n.d.). This shows the importance of diversity surveys in species conservations. Specific to our research initiative, many sighted birds depend exclusively on mangroves for reproduction, namely Common black hawk (*Buteogallus anthracinus*), Green kingfisher (*Chloroceryle Americana*), Wood stork (*Mycteria Americana*), Mangrove cuckoo (*Coccyzus minor*), Magnificent frigatebird (*Fregata magnificens*), Brown pelican (*Pelecanus occidentalis*), White ibis (*Eudocimus albus*) and Panama flycatcher (*Myiarchus panamensis*) (Partners in Flight Watch List, n.d.). It is worth noting that we have personally spotted a Common black hawk nest in the forest boarding the large mangrove including two adults flying in and out of it. Hence, this analysis proves that the mangroves of the PABWR are essential to the maintenance of the biodiversity, and calls for improved management of the refuge.

Overall, our research indisputably shows the importance of enforcing sustainable practices in the PABWR. As noted before, Panama's management approach regarding its protected areas is clearly not appropriate to the requirements and needs to be re-evaluated. Past research and observations we made while surveying in the refuge expose the evident lack of responsible management (refer). The overwhelming pollution found on the beach spreads to

mangrove rivers and is enhanced by the passing of fishermen and recreational activities. Claimed plots and agricultural land across the refuge promote deforestation and decrease vegetation diversity (e.g. teak plantations). Not to mention that private developments inside the refuge have a strong impact on the overall ecosystem through noise disturbance, light pollution, increased human activity, obvious deforestation and destruction of ecosystem services for animals. The challenges faced inside the refuge do not have isolated repercussions, that is, every part of an ecosystem is connected in some way directly or indirectly such that any type of lack of management has rippling effects throughout the whole refuge. Similarly, what happens outside of the limits of the refuge can impact its health. For example, the nearby Isla Iguana hosts Magnificent Frigatebird nests, and these birds come to feed on the coast of the refuge. However, the conservation biologist Hector Guzman has informally revealed to his students that many of these nests have been destroyed in the recent detonation of 5 WWII bombs on the island. Therefore, assessing the health of the mangrove sites would also contribute to evaluate what kinds of threats face the birds of the refuge as well as the threats compromising mangrove integrity.

All in all, we were successful in surveying the mangrove patches of the Pablo Arturo Barrios Wildlife Refuge in Pedasí, and, demonstrate that these two patches did not differ in diversity or density of bird species present, but still could be contrasted in species composition. This wildlife refuge – like many others in Panama –, is still waiting for an official management plan to be developed, approved and implemented. Although there is local involvement, a recognized plan would promote well targeted efforts, and raise awareness in the community. We believe that our research and host product make a significant contribution to accentuating the need for the officialization of a management plan in the Pablo Arturo Barrios Wildlife Refuge by

exposing the substantial contribution it makes to wildlife diversity. With our research being the first of its kind done in this refuge, we acknowledge the need and encourage further sampling and analysis of other ecosystem indicators, such as mangrove health, to defend the critical plea for better management of this refuge. Survey research is an essential and integral part of the appropriate development of management plans, and of tracking the state of protected areas, both of which are vital to the safeguard of Panama's ecosystem diversity.

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APPENDICES

APPENDIX A – *Research Products*

a

b

Figure A1 Area estimate. ArcGIS estimate of the area in square meters of (a) the large port mangrove A and (b) the small beach mangrove B.

MANGROVE

PORT (A)

Family	Species Common Name	*Scientific Name*	
Accipitridae	Common black hawk	*Buteogallus anthracinus*	
Alcedinidae	Green kingfisher	*Chloroceryle americana*	
Ardeidae	Great egret	*Ardea alba*	
	Little blue heron	*Egretta caerulea*	
	Bare-throated tiger-heron	*Tigrisoma mexicanum*	
Cathartidae	Black vulture	*Coragyps atratus*	
	Turkey vulture	*Cathartes aura*	
Columbidae	Mourning dove	*Zenaida macroura*	
	Ruddy ground dove	*Columbina talpacoti*	
Falconidae	Yellow-headed caracara	*Milvago chimachima*	
	Laughing falcon	*Herpetotheres cachinnans*	
Fregatidae	Magnificent frigatebird	*Fregata magnificens*	
Icteridae	Great-tailed grackle	*Quiscalus mexicanus*	
Parulidae	Mangrove (yellow) warbler	*Setophaga petechia*	
Pelecanidae	Brown pelican	*Pelecanus occidentalis*	
Phalacrocoracidae	Neotropic cormorant	*Phalacrocorax brasilianus*	*
Picidae	Red-crowned woodpecker	*Melanerpes rubricapillus*	
Psittacidae	Yellow-crowned parrot	*Amazona ochrocephala*	
	Orange-chinned parakeet	*Brotogeris jugularis*	
Scolopacidae	Whimbrel	*Numenius phaeopus*	
	Spotted sandpiper	*Actitis macularius*	
Trochilidae	Scaly-breasted hummingbird	*Phaeochroa cuvierii*	
Troglodytidae	House wren	*Troglodytes aedon*	
Tyrannidae	Great kiskadee	*Pitangus sulphuratus*	
	Streaked flycatcher	*Myiodynastes maculatus*	

BEACH (B)

Family	Species Common Name	*Scientific Name*	
Ardeidae	Green heron	*Butorides virescens*	
Columbidae	Mourning dove	*Zenaida macroura*	
Falconidae	Yellow-headed caracara	*Milvago chimachima*	
Fregatidae	Magnificent frigatebird	*Fregata magnificens*	
Haematopodidae	American oystercatcher	*Haematopus palliatus*	
Icteridae	Great-tailed grackle	*Quiscalus mexicanus*	
Parulidae	Mangrove (yellow) warbler	*Setophaga petechia*	
Picidae	Red-crowned woodpecker	*Melanerpes rubricapillus*	
Psittacidae	Orange-chinned parakeet	*Brotogeris jugularis*	
	Yellow-crowned parrot	*Amazona ochrocephala*	
Rallidae	Grey-necked wood rail	*Aramides cajaneus*	*
Scolopacidae	Spotted sandpiper	*Actitis macularius*	
Thamnophilidae	Barred antshrike	*Thamnophilus doliatus*	
Trochilidae	Rufous-tailed hummingbird	*Amazilia tzacatl*	*
	Snowy-bellied hummingbird	*Amazilia edward*	*
Tyrannidae	Great kiskadee	*Pitangus sulphuratus*	
	Tropical kingbird	*Tyrannus melancholicus*	

* Species only seen ONCE

SHARED SPECIES

Figure A2 List of the species identified in both mangrove sites classified by families. Species highlighted in pink are sighted in both sites. Species marked by a "*" have been identified with the sighting of a single individual, other species have been seen only once during mangrove sampling, but have been seen repeatedly on other samplings across the refuge (See *Supplemental Text*).

Sampling Occasion	**Mangrove A** *(number of species)*	**Mangrove B** *(number of species)*
MORN FEBRUARY	11.6	16.7
EVE FEBRUARY	11.6	8.3
MORN MARCH	16.3	12.7
EVE MARCH	14.5	2.7

Figure A3 First-order Jaccknife alpha-diversity estimations. The alpha-diversity was estimated using the non-parametric Jaccknife index for each sample occasion in both mangrove sites A & B. There was no significant difference between the alpha-diversity of mangrove site A & B.

Sampling Occasion	**Mangrove A** *(# individuals/m²)*	**Mangrove B***(# individuals/m²)*
MORN FEBRUARY	0.00375	0.00200
EVE FEBRUARY	0.00242	0.00058
MORN MARCH	0.00442	0.00808
EVE MARCH	0.00492	0.00033

Figure A4 Density estimates. Density of individual birds identified at each sampling occasion for both mangrove sites A & B as number of individuals per meter squared. There was no significant difference between the density of individuals in mangrove A & B.

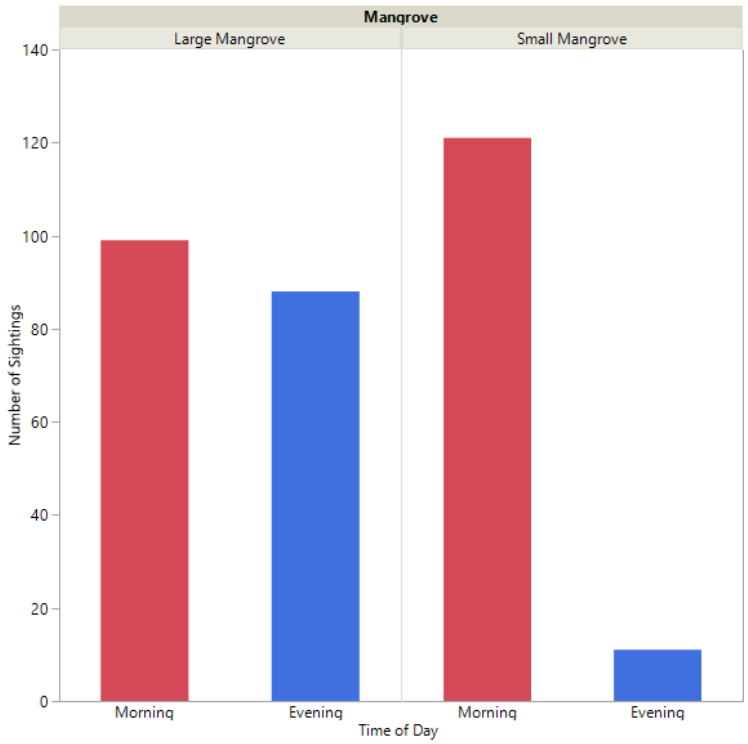


Figure A5 Number of total bird sighted at each mangrove site by time of the day. We graphically distinguished that there were less birds observed in the evening in the small mangrove relative to the morning, but that this was not the case for the large mangrove.

APPENDIX B – *Host Products*

Complete List of Bird Species Identified in the Pablo Arturo Barrios Wildlife Refuge

Family	Species Common Name	*Scientific Name*	Spanish Common Name	Habitat Observed In	IUCN Status	IUCN population trend	PIF score	PIF Assessment
Accipitridae	Common black hawk	*Buteogallus anthracinus*	Busardo-negro norteño	Mangrove, Tropical Dry Forest, Coast	Least Concern	Decreasing	11	PBH: Wetlands, Forests, Mangroves
	White-tailed kite	*Elanus leucurus*	Elanio maromero	Tropical Dry Forest	Least Concern	Increasing	10	Loss of 36% of the population since 1970; BBS half-life: 115 years
Alcedinidae	Green kingfisher	*Chloroceryle americana*	Martín pescador verde	Mangrove	Least Concern	Increasing	9	PBH: Mangroves, Wetlands
	Ringed kingfisher	*Megaceryle torquata*	Martín pescador grande	Mangrove	Least Concern	Increasing	8	
Ardeidae	Great egret	*Ardea alba*	Garza blanca	Mangrove, Coast	N/A	N/A	7	
	Green heron	*Butorides virescens*	Garcita verdosa	Mangrove	N/A	N/A	12	CBSD
	Little blue heron	*Egretta caerulea*	Garza/Garceta azul	Mangrove	Least Concern	Decreasing	11	High PT-c
	Tricolored heron	*Egretta tricolor*	Garceta tricolor	Mangrove	Least Concern	Stable	11	High PS-g
	Bare-throated tiger-heron	*Tigrisoma mexicanum*	Garza-tigre cuellinuda	Mangrove	Least Concern	Unknown	12	High PS-g
Cathartidae	Turkey vulture	*Cathartes aura*	Aura gallipavo	Mangrove, Tropical Dry Forest, Coast	Least Concern	Stable	5	
	Black vulture	*Coragyps atratus*	Oripopo cabeza negra	Mangrove, Tropical Dry Forest, Coast	Least Concern	Increasing	4	
Ciconiidae	Wood stork	*Mycteria americana*	Tántalo americano	Mangrove	Least Concern	Decreasing	12	High PS-g; High TB-c; PBH: Mangroves, Wetlands.
Columbidae	Ruddy ground dove	*Columbina talpacoti*	Palomita colorada	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Increasing	5	
	Mourning dove	*Zenaida macroura*	Paloma rabuda	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Increasing	6	Loss of 14% of the population since 1970
Cuculidae	Mangrove cuckoo	*Coccyzus minor*	Cuclillo del manglar	Mangrove, Tropical Dry Forest	Least Concern	Stable	14	Watch List Yellow-R; PBH: Mangroves, Forests
	Groove-billed ani	*Crotophaga sulcirostris*	Garrapatero asurcado	Tropical Dry Forest	Least Concern	Decreasing	6	BBS half-life : 66 years
	Squirrel cuckoo	*Piaya cayana*	Cuco ardilla común	Tropical Dry Forest	Least Concern	Stable	9	
Falconidae	Laughing falcon (O.R.)	*Herpetotheres cachinnans*	Guaicurú	Mangrove	Least Concern	Decreasing	10	
	Yellow-headed caracara	*Milvago chimachima*	Chimachima	Mangrove, Tropical Dry Forest, Coast	Least Concern	Increasing	5	
Fregatidae	Magnificent frigatebird	*Fregata magnificens*	Fragata magnífica	Mangrove, Coast, Ocean	Least Concern	Increasing	16	Watch List Yellow-R; PBH : Mangroves, Coasts, Oceans
Haematopodidae	American oystercatcher	*Haematopus palliatus*	Ostrero americano	Coast	Least Concern	Stable	14	Watch List Yellow-R
Hirundinidae	Southern rough-winged swallow	*Stelgidopteryx ruficollis*	Golondrina gorgirrufa	Mangrove, Tropical Dry Forest, Dunes, Coast	Least Concern	Decreasing	7	
Icteridae	Baltimore oriole	*Icterus galbula*	Oropéndola de baltimore	Tropical Dry Forest, Dunes	Least Concern	Stable	10	High PT-c; Loss of 42% of the population since 1970; BBS half-life: 81 years
	Chestnut-headed oropendola (O.R.)	*Psarocolius wagleri*	Oropéndola cabecicastaña	Tropical Dry Forest, Dunes	Least Concern	Stable	13	Mid/High scores in all categories
	Great-tailed grackle	*Quiscalus mexicanus*	Zanate mexicano	Mangrove, Tropical Dry Forest, Coast	Least Concern	Stable	4	
Laridae	Laughing gull	*Leucophaeus atricilla*	Gaviota reidora americana	Coast, Ocean	Least Concern	Increasing	9	
	Sandwich tern	*Thalasseus sandvicensis*	Charrán patinegro	Coast, Ocean	Least Concern	Stable	11	High PS-g
Parulidae	Northern waterthrush	*Parkesia noveboracensis*	Chipe charquero	Mangrove	Least Concern	Stable	8	
	Mangrove (yellow) warbler	*Setophaga petechia*	Reinita de manglar	Mangrove	N/A	N/A	8	Loss of 20% of the population since 1970
Pelecanidae	Brown pelican	*Pelecanus occidentalis*	Pelícano alcatraz	Coast, Ocean	Least Concern	Increasing	10	High PS-g ; High TB-c; PBH: Coasts, Mangroves
Phalacrocoracidae	Neotropic cormorant	*Phalacrocorax brasilianus*	Cuervo de mar	Mangrove, Coast	N/A	N/A	6	
Picidae	Red-crowned woodpecker	*Melanerpes rubricapillus*	Carpintero nuquirrojo	Mangrove, Tropical Dry Forest	Least Concern	Increasing	10	
Psittacidae	Yellow-crowned parrot	*Amazona ochrocephala*	Amazona real	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Decreasing	14	Watch List - Yellow-D
	Orange-chinned parakeet	*Brotogeris jugularis*	Catita churica	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Stable	12	
Rallidae	Grey-necked wood rail	*Aramides cajaneus*	Cotara chiricote	Mangrove	Least Concern	Stable	7	
Scolopacidae	Spotted sandpiper	*Actitis macularius*	Playero manchado	Mangrove, Coast	Least Concern	Decreasing	10	High PT-c
	Whimbrel	*Numenius phaeopus*	Playero trinador	Mangrove, Coast	Least Concern	Decreasing	12	
Thamnophilidae	Barred antshrike	*Thamnophilus doliatus*	Batará listado	Mangrove, Tropical Dry Forest	Least Concern	Decreasing	6	
Thraupidae	Palm tanager (O.R.)	*Thraupis palmarum*	Tangara palmera	Tropical Dry Forest	Least Concern	Stable	6	
Threskiornithidae	White ibis	*Eudocimus albus*	Corocoro blanco	Mangrove	Least Concern	Stable	12	High PS-g; PBH: Mangroves, Wetlands
Trochilidae	Snowy-bellied hummingbird	*Amazilia edward*	Amazilia de pecho blanco	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Unknown	13	High PS-g; High BD-g; High ND-g.
	Rufous-tailed hummingbird	*Amazilia tzacatl*	Colibrí colirufa	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Unknown	9	
	Sapphire-throated hummingbird	*Lepidopyga coeruleogularis*	Colibrí gorgizafiro	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Unknown	12	High PS-g; High BD-g; High ND-g.
	Scaly-breasted hummingbird	*Phaeochroa cuvierii*	Colibrí de cuvier	Mangrove, Tropical Dry Forest, Dunes	N/A	N/A	13	High PS-g; High BD-g; High ND-g.
Troglodytidae	House wren	*Troglodytes aedon*	Ratona común	Mangrove, Tropical Dry Forest	Least Concern	Increasing	5	
Tyrannidae	Western wood-pewee	*Contopus sordidulus*	Pibí occidental	Tropical Dry Forest	Least Concern	Decreasing	11	High PT-c; Loss of 47% of the population since 1970
	Panama flycatcher	*Myiarchus panamensis*	Copetón colipardo	Tropical Dry Forest	Least Concern	Stable	12	Mid scores in all categories. PBH : Forests, Mangroves
	Streaked flycatcher	*Myiodynastes maculatus*	Bienteveo rayado	Mangrove	Least Concern	Stable	9	
	Great kiskadee	*Pitangus sulphuratus*	Bienteveo grande	Mangrove, Tropical Dry Forest, Dunes	Least Concern	Increasing	5	
	Scissor-tailed flycatcher (O.R.)	*Tyrannus forficatus*	Tirano tijereta rosado	Tropical Dry Forest	Least Concern	Decreasing	11	High PT-c ; Loss of 27% of the population since 1970 ; BBS half-life: 37 years
	Tropical kingbird	*Tyrannus melancholicus*	Tirano tropical	Tropical Dry Forest, Dunes	Least Concern	Increasing	4	
	Fork-tailed flycatcher	*Tyrannus savana*	Tijereta sabanera	Tropical Dry Forest, Dunes	Least Concern	Stable	7	

Glossary

O.R. = Out of Range - Bird whose range does not extend to the area researched (based on the *The Birds of Panama, 2010* book).

PIF Score: Conservation assessment done by the Partners in Flight organization. Each species is assigned scores for 6 factors, assessing largely independent aspects of vulnerability: Population Size (PS), Breeding (BD) and Non-breeding Distribution (ND), Threats for Breeding (TB) and Non-breeding (TN) seasons, and Population Trend (PT). Each score reflects the degree of vulnerability for the species (i.e., risk of significant population decline, major extirpation or extinction) due to that factor, ranging from "1" for low to "5" for high vulnerability. Scores are combined in various ways to produce an overall assessment of vulnerability, determine Watch List status and identify other categories of concern.

PIF Assessment: Noteworthy attributes and additional aspects of the score for each bird.

- **PBH**: Primary Breeding Habitat.
- **PS-g** = Population Size (Global) - Indicates vulnerability due to the total number of breeding-aged adult individuals in the global population. Evaluation of population size is based on the assumption that species with small breeding populations are more vulnerable to extirpation or extinction than species with large breeding populations.
- **TB-c** = Threats to breeding (Continental) - Vulnerability due to the effects of current and probable future extrinsic conditions that threaten the ability of populations to survive and successfully reproduce during the breeding season within their breeding range in North America.
- **PT-c** = Population Trend (Continental) - Population trend indicates vulnerability due to the direction and magnitude of recent changes in population size. Like the threats scores, population trend scores reflect trends for North American populations only, even for species with ranges that extend beyond the continent.
- **BD-g** = Breeding distributions (Global) - Indicate a species' vulnerability due to the geographic extent of its range in the breeding season. The underlying assumption is that species with narrowly distributed populations are more vulnerable to individual risks and threats than species with widely distributed populations, and that this vulnerability can vary seasonally as migratory populations re-distribute.
- **ND-g** = Non-breeding distributions (Global) - Indicate a species' vulnerability due to the geographic extent of its range in the non-breeding season. The underlying assumption is that species with narrowly distributed populations are more vulnerable to individual risks and threats than species with widely distributed populations, and that this vulnerability can vary seasonally as migratory populations re-distribute.
- **BBS half-life** = Estimated number of years until 50% of the remaining population is lost based on 10 year Breeding Bird Survey (BBS) trends.

- **CBSD** = Common Bird in Steep Decline - PIF also highlights a list of Common Birds in Steep Decline. While these birds do not exhibit broad levels of vulnerability warranting Watch List designation, their populations have declined continentally by an estimated 50% or more since 1970. Together these Common Birds in Steep Decline have lost close to a billion or more breeding birds during this period, raising concern for the vital ecosystem services that they provide.
- **Watch List Yellow-R** = Range restricted and small populations in need of constant care. The Watch List are species of greatest conservation concern and includes those most vulnerable due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges. Species were included in the Watch List if they had a Maximum Combined Score >14, or 13 in combination with PT-c = 5.
- **Watch List Yellow-D** = Steep declines and major threats. The Watch List are species of greatest conservation concern and includes those most vulnerable due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges. Species were included in the Watch List if they had a Maximum Combined Score >14, or 13 in combination with PT-c = 5.

*Descriptions from PIF website. For more information on PIF score, visit http://pif.birdconservancy.org/ACAD/

Informative Pamphlet "Las aves del Refugio de Vida Silvestre Pablo Arturo Barrios"

Ostrero Americano
American Oystercatcher
Haematopus palliatus

Playa & costa
Beach & coast

Playero Manchado
Spotted Sandpiper
Actitis macularius

Manglar, playa y costa
Mangrove, beach & coast

Playero Trinador
Whimbrel
Numenius phaeopus

Manglar, playa y costa
Mangrove, beach & coast

Garza-Tigre Cuellinuda
Bare-Throated Tiger-Heron
Tigrisoma mexicanum

Manglar
Mangrove

Garza Blanca
Great Egret
Ardea alba

Manglar & costa
Mangrove & beach

Tántalo americano
Wood stork
Mycteria Americana

Manglar
Mangrove

Amazona Real
Yellow-Crowned Parrot
Amazona ochrocephala

Manglar y bosque seco tropical
Mangrove & tropical dry forest

Annelise Geisterfer y Aurélie Guisnet, estudiantes de la Universidad McGill en Canadá, identificaron 51 especies de aves en el R.V.S. Pablo A. Barrios utilizando el libro *Birds of Panama* (2010) para identificarlas. Como parte de su pasantía en la ONG local Proyecto Ecológico Azuero, produjeron este folleto informativo con sus propias fotografías y las del fotógrafo de naturaleza Matt Stirn. Para más información, visite proecoazuero.org

Annelise Geisterfer & Aurélie Guisnet, students from McGill University in Canada, created a list of 51 bird species of the Pablo A. Barrios Wildlife Refuge using the book *Birds of Panama* (2010) for identification. As part of their internship with the local NGO Azuero Earth Project, they produced this informative pamphlet with their own photographs and those of the nature photographer Matt Stirn. For more information, visit proecoazuero.org

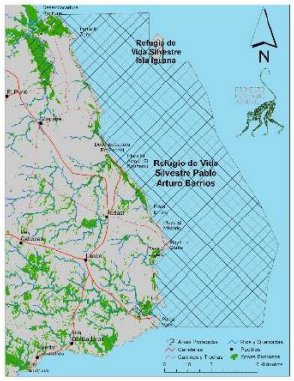
McGill

PROYECTO ECOLÓGICO AZUERO

Las aves del Refugio de Vida Silvestre Pablo Arturo Barrios

El Refugio de Vida Silvestre Pablo Arturo Barrios, fundado en 2009, cubre un área de más de 15 mil hectáreas a lo largo de la costa Este de la península de Azuero frente al Golfo de Panamá. Este refugio tiene una rica diversidad de ecosistemas, incluidos manglares, dunas y bosques tropicales secos, cada uno de los cuales contribuye de forma única a la biodiversidad del refugio y las regiones adyacentes. Entre otros, sirve como hábitat para muchas especies diferentes de aves. Aquellos enmarcados en amarillo son, además, parte de la Watchlist Yellow de Compañeros en Vuelo (CEV) que incluye aves que requieren atención de conservación.

The Pablo Arturo Barrios Wildlife Refuge, founded in 2009, covers an area of more than 15 thousand hectares along the Eastern coast of the Azuero peninsula facing the Golf of Panama. This refuge holds a rich diversity of ecosystems, including mangroves, dunes and dry tropical forests, each uniquely contributing to the biodiversity of the refuge and adjacent regions. Among others, it serves as a host to many different species of birds. Those framed in yellow are additionally part of the Partners in Flight (PIF) Watchlist Yellow which includes birds requiring conservation attention.



Pelícano Alcatraz
Brown Pelican
Pelecanus occidentalis

Mar y costa
Ocean & coast

Fragata Magnífica
Magnificent Frigatebird
Fregata magnificens

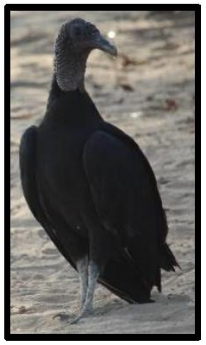
Mar y costa
Ocean & coast

Gaviota Reidora Americana
Laughing Gull
Leucophaeus atricilla

Mar y costa
Ocean & coast

Aura Gallipavo
Turkey Vulture
Cathartes aura

Manglar, playa y bosque seco tropical
Mangrove, beach & tropical dry forest



Oripopo Cabeza Negra
Black Vulture
Coragyps atratus

Manglar, playa y bosque seco tropical
Mangrove, beach & tropical dry forest

Bienteveo Rayado
Streaked Flycatcher
Myiodynastes maculatus

Manglar
Mangrove

Tirano Tropical
Tropical Kingbird
Tyrannus melancholicus

Manglar, playa y bosque seco tropical
Mangrove, beach & tropical dry forest

Bienteveo Grande
Great Kiskadee
Pitangus sulphuratus

Manglar, playa y bosque seco tropical
Mangrove, beach, tropical dry forest

Tirano Tijereta Rosado
Scissor-Tailed Flycatcher
Tyrannus forficatus

Bosque seco tropical
Tropical dry forest

Ratona Común
House Wren
Troglodytes aedon

Manglar y bosque seco tropical
Mangrove & tropical dry forest

Oropéndola de Baltimore
Baltimore oriole
Icterus galbula

Bosque seco tropical
Tropical dry forest

Oropéndola Cabecicastaña
Chestnut-Headed Oropendola
Psarocolius wagleri

Bosque seco tropical
Tropical dry forest

Zanate Mexicano
Great-Tailed Grackle
Quiscalus mexicanus

Manglar, playa y bosque seco tropical
Mangrove, beach & tropical dry forest

Chimachima
Yellow-Headed Caracara
Milvago chimachima

Manglar, playa y bosque seco tropical
Mangrove, beach & tropical dry forest

Busardo-Negro Norteño
Common Black Hawk
Buteogallus anthracinus

Manglar, playa y bosque seco tropical
Mangrove, beach & tropical dry forest

APPENDIX C – ***CORE Ethical Certification***

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Annelise Geisterfer

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **19 January, 2018**

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Aurélie Guisnet

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

Date of Issue: **24 January, 2018**

SUPPLEMENTAL TEXT: PRODUCTS FOR HOST ORGANIZATION

The product agreed upon with the Azuero Earth Project is a comprehensive species list of the birds found in the Pablo Arturo Barrios Wildlife Refuge including their English common name, scientific name, Spanish common name, area found, IUCN status, IUCN population trend and PIF score. In addition, we provided them with bird song recordings, pictures of birds and the refuge, designed the informative pamphlet "Las aves del Refugio de Vida Silvestre Pablo Arturo Barrios" in order to share some of the results of our research with the local community and facilitate birding in the area, held a bird watching activity for the children of the community, entered all our identified species in the eBird database, and finally guided the photographer Matt Stirn through the refuge for bird photography to support his making of a documentary and article on the Pablo Arturo Barrios Wildlife Refuge. Overall, we provided the Azuero Earth Project with any information or action regarding bird species that would aid the establishment of a management plan for the refuge.

Methodology for Bird Surveys

The methods to obtain a species list of the birds of the refuge was essentially similar to those used to survey mangroves, except that the walks were more informal and we stopped indiscriminately when birds were sighted (no point count). The refuge consists of roughly 25 km of coastline from Punta Tigre near Mariabé to Punta Mala near Limón. As well as mangroves, there are tropical dry forests, sand dunes with vegetation, and shorelines. Therefore, the informal walks were performed along coastlines, forests and dunes to sample birds from these other ecosystems. We additionally pooled the data collected in mangroves, and added as well species spotted between sampling points. We devoted a total of three extra days to this sampling. These periods took place similarly twice a day within the same hours as noted for our formal

investigation. Due to convenience and security reasons, we sampled areas close to Pedasí. Starting from Playa Arenal, both observers walked to Playa el Toro (~1:30 hour walk) along the coast taking the same types of notes as in mangrove surveys. On the second sampling day, observers walked from Playa el Toro, midway towards Playa Arenal this time investigating the dune areas. The third observation day took place in the dry tropical forest near Playa Arenal (morning: Playa Arenal to Fisherman Port; evening: informal road situated about 500m from Playa Arenal two-ways). Once again, recordings and photos were taken when possible. Birds sighted were further identified using the same methods as described before.

Two databases were used to assess the conservation potential of the bird species. The first is the well-known IUCN red list of threatened species whose objective is in highlighting species that are at a high risk of extinction (IUCN, 2018). The list is highly comprehensive and thoroughly researched, therefore providing a strong basis for focus of conservation efforts. Nonetheless, groups targeted are those that have been classified as vulnerable (VU), endangered (EN) or critically endangered (CR) (IUCN, 2018). However, if we are working with many least concern species, it is good to know how vulnerable these species may be to risk factors such as breeding habitat or population size for example. This enables us to apply conservation efforts prior to the species even making the IUCN red list. In this way, the Partners in Flight (PIF) avian conservation assessment database provides valuable complementary information, creating its own watchlist based on different vulnerability factors (Partners in Flight Watch List, n.d.). The six factors that the PIF database concerns itself over are the global population size, the distribution of the bird both breeding and non-breeding, the threats to the breeding and non-breeding seasons, and the population trend (Partners in Flight Watch List, n.d.). Based on these scores some may be categorized into a watchlist and are deemed of high conservation concern:

red watchlist species are those that are highly vulnerable to a multitude of factors and thus should be given special attention; Yellow- R watchlist species have a restricted range and so their populations should be given extra care as they may be vulnerable to sudden changes in their environment; finally the Yellow - D are those who have been experiencing steep population declines and major threats (Partners in Flight Watch List, n.d.).

Products

Following visits to the various habitats of the PABWR, a comprehensive list of 51 species could be compiled, and provided to our host institution (Appendix B). Of these 51 species, there are 7 of them which we cannot confirm their identification with certainty. These are: Ruddy ground dove (*Columbina talpacoti*), Mangrove cuckoo (*Coccyzus minor*), Groove-billed ani (*Crotophaga sulcirostris*) (confirmed ani, but not species), Southern rough-winged swallow (*Stelgidopteryx ruficollis*) (believed to be Northern, but out of range), Snowy-bellied hummingbird (*Amazilia edward*), Rufous-tailed hummingbird (*Amazilia tzacatl*) and Western wood-pewee (*Contopus sordidulus*). All the identified birds were classified as Least Concern by the IUCN redlist of threatened species (IUCN, 2018), and four, namely the Magnificent Frigatebird (*Fregata magnificens*), the American Oystercatcher (*Haematopus palliatus*), the Yellow-Crowned Parrot (*Amazona ochrocephala*) and the Mangrove Cuckoo (*Coccyzus minor*), are part of the Partners in Flight (PIF) Watchlist Yellow (Partners in Flight Watch List, n.d.). Also, the Green Heron (*Butorides virescens*) was recognized in the Partners in Flight list of Common Bird in Steep Decline which includes birds that have lost more than 50% of their worldwide population since 1970 (Partners in Flight Watch List, n.d.).

In addition, we are providing the Azuero Earth Project with a total of 101 bird pictures, 124 other pictures of the refuge, and 20 bird song recordings, all of which we have collected ourselves

during our surveys.

Further, we leave our host organization with our informative pamphlet “Las aves del Refugio de Vida Silvestre Pablo Arturio Barrios” that we have designed to promote awareness to bird diversity in the community during the Earth day event held on April 21st (Appendix B)

Then, on April 20th, we organized a birding activity as part of the weekly activities for children held at the organization. With the help of other volunteers, we brought the children to Playa Arenal and walk with them on the beach until the nearest mangrove. Each pair of children had binoculars and a pamphlet guide, and we encouraged them to observe and identify the birds around them.

As an additional initiative, all the sightings were added to the eBird website developed by the Cornell Lab of Ornithology since no checklists had been recorded in the PABWR prior to our research. eBird is a form of crowd-sourced scientific data collection on avian diversity, the largest in the world (Sullivan et al., 2009). The website and/or app allows avid birders worldwide to enter any of their sightings, contributing to a global pool of data which is filtered and verified by experts in the field (Sullivan et al., 2009).

Finally, in the effort to create a video about the Pablo Arturo Barrios Wildlife Refuge and to write an article about the refuge as well, the nature photographer Matt Stirn visited the Azuero Earth Project (https://www.mattstirnphoto.com/). With the bird knowledge we had acquired through our surveys, we guided him through the refuge in the hope to obtain pictures and recordings of birds of the refuge. We were also interviewed for the documentary to comment on our work and the importance of the PABWR.