Analyzing Hurricanes Irma and Maria Impacts on Bird Abundance Using Remote Sensing

A STUDY OF PUNTA CUCHARAS NATURAL RESERVE IN PONCE, PUERTO RICO WITH IMPLICATIONS FOR CONSERVATION

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INTRODUCTION

Two significant tropical cyclones crossed near or over Puerto Rico during September 2017. The first, Hurricane Irma, a Category 5 passed ~80 km north of the island on 6 September. The second, Hurricane Maria, made landfall on Puerto Rico on 20 September. Field observations and remotely sensed data revealed that both storms caused significant defoliation of island's forest cover, with Irma causing damage in the northwest corner of the island and Maria defoliating forests and toppling trees across the island (Beusekom et al. 2018, Feng et al. 2018, Liu et al. 2018).

Caribbean marine and terrestrial structure and composition communities are strongly influenced by hurricanes (Connell 1978, Boucher 1990) Even though, little is known about how the 2017 hurricanes impacted Puerto Rico's birdlife (Wunderle 2018). It has been well documented that costal climate change due to atmospheric events will rise sea levels and increase frequency and intensity of tropical storms (Walker et al. 2019). Predictions about response of coastal birds to effects of hurricanes will be essential for anticipating and countering environmental impacts (Wilson, 2017).

Tropical hurricanes can reduce the density of migratory breeding birds. For example, seabirds and coastal birds have no places to hide during a hurricane. After a tropical cyclone some birds may perish because their altered habitats no longer provide the necessities they need, among them food, water or nesting sites (Wilson, 2017). Understanding ecological impacts is important in order to manage viable populations.

Here, we attempt to address how hurricanes Irma and Maria, as a whole, impacted birds abundance in correlation to forest loss before (January – December 2016) and after (January – December 2017) the events by validating the results of an extensive survey on coastal birds conducted across the coastal zone of Punta Cucharas Natural Reserve (PCNR) by Llegus-Santiago et al. (2019), using remote sensing methodologies. With this study we want to address the implications for conservation in terms of the natural reserve management. Although we assumed that any changes in the bird assemblage from 2016 to 2017 reflected direct or indirect effects of the storms, we acknowledge that variation in bird occupancy between years may reflect other, unmeasured processes for which we lack adequate experimental controls.

SCIENTIFIC QUESTION

The scientific question in which our research project was based on was: is there a correlation between the reduction of bird's abundance and the impacts on bird habitats made by hurricanes Irma and Maria?

OBJECTIVES

Objectives for this research project were three, among them were (1) study how hurricanes Irma and Maria impacted the PCNR birds abundance before and after the events, (2) perform an impact assessment analysis between bird abundance and Simpson's diversity index, (3) and asses the implications for bird conservation in the PCNR and the scope of biodiversity assessments generally. As an outcome for this project we will validate what Llegus-Santiago et al. (2018) did on their research paper applying geospatial analysis.

METHODOLOGY

STUDY SITE

Research was conducted on the Punta Cucharas Natural Reserve (PCNR), located in the south coastal plain of municipality of Ponce, in the island of Puerto Rico. This natural reserve is considered an important bird area (IBA) by the Department of Natural and Environmental Resources (DRNA). It covers a total area of 35 hectares and possess a rich variety of ecosystems, among them mangrove and dry, a fine sandy beach, salty flock surfaces, a lagoon and a coastal beach (**Fig 1**).

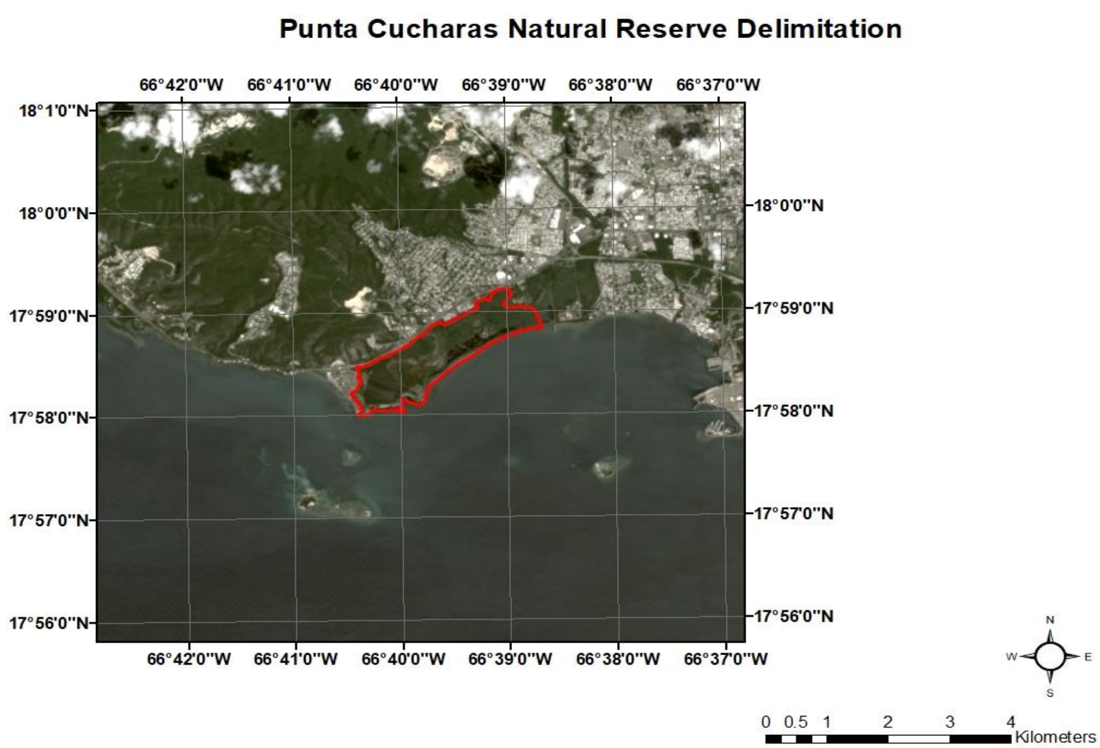

Fig 1. A map showing the delimitations of the Punta Cucharas Natural Reserves. It covers a total of 35 hectares and has a wide variety of ecosystems.

DATA SOURCES

For accomplishing our objectives, a total of 6 study sites were used as the interpretation of their respective ecosystems, these habitats were: dry forest, lagoon, mangrove forest, muddy bottom, salty flock and sandy beach (**Fig 2**). This were in accordance to study, this for the purpose of being consistent in validation process. Two Landsat-8 satellite OLI images (panchromatic sharpened to 15m resolution) were used, one before the hurricanes from October 16, 2016 and one after them from October 3, 2017 respectively. Bird abundance from 2016 and 2017 was provided by previous work on the PCNR (**Table 1**) for performing our statistical analysis. This bird abundance was calculated using the Simpson Biodiversity Index based on bird abundance.

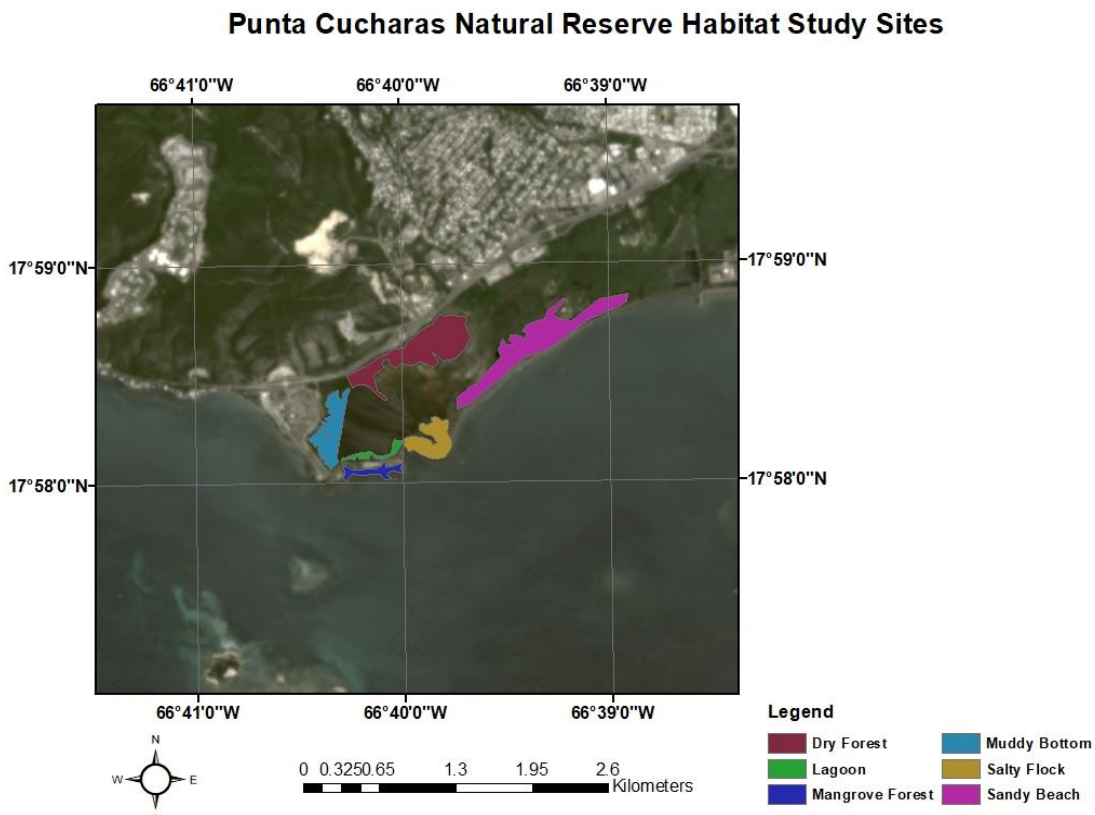

Fig 2. A map representing the six habitats used for this study.

Por: Eduardo M. Llegus   Lugar: Reserva Natural Punta Cucharas, Ponce, Puerto Rico
Indices Diversidad   Datos colectados con proyecto, Reverdece y Educa tu Comunidad
Aves

Habitáculo	2016	2017
H1	0.7754	0.6683
H2	0.7039	0.4395
H3	0.90321	0.5781
H4	0.8991	0.4898
H5	0.7508	0.7796
H6	0.6079	0.6557

H1	Fondo lodoso	1	Agosto
H2	Laguna	2	Septiembre
H3	Bosque seco	3	Octubre
H4	Mangle	4	Noviembre
H5	Salitral	5	Diciembre
H6	Costa		

Promedio de Hábitaculos (H), por meses de 2016 con meses de 2017, respectivamente- Pre-huracán y Pos-huracán

	Habitáculo	1	2	3	4	5	**Promedio**
	H1	0.69697	0.84431	0.79557	0.79744	0.74265	0.7754
	H2	0.66670	0.64327	0.78095	0.619048	0.80952	0.7039
2016	H3	0.86462	0.92982	0.94947	0.90726	0.86486	0.9032
	H4	0.91026	0.87333	0.95333	0.92810	0.83041	0.8991
	H5	0.55556	0.85051	0.84615	0.68382	0.81818	0.7508
	H6	0.0000	0.80627	0.78182	0.61818	0.83330	0.6079

	Habitáculo	1	2	3	4	5	**Promedio**
	H1	0.0000	0.7000	0.80147	0.92898	0.91111	0.6683
	H2	0.48530	0.75213	0.0000	0.96026	0.00000	0.4395
2017	H3	0.41037	0.52286	0.67234	0.64121	0.64375	0.5781
	H4	0.0000	0.85238	0.0000	0.77821	0.81828	0.4898
	H5	0.52050	0.80714	0.77440	0.89852	0.89744	0.7796
	H6	0.66670	0.81333	0.88239	0.91594	0.0000	0.6557

Table 1. Simpson biodiversity index based on bird's abundance from the Punta Cucharas Natural Reserve for the years 2016 and 2017.

DATA ANALYSIS

To examine our study sites, computational data was processed using ESRI's ArcGIS 10.6 software. A normalized difference vegetation index (NDVI) was performed for both satellite images. NDVI mean pixel values for each habitat were extracted running a zonal statistics algorithm. To run our statistical analysis, NDVI mean values by habitats were added to Microsoft Office Excel software in order to correlation them with Simpson's biodiversity index.

RESULTS

A total of two maps with NDVI values were generated, one for the events before the hurricanes and one right after (**Fig 3, 4**). A Simpson biodiversity index distribution box plot graph by habitats before and after the hurricanes were created (**Fig 5,6**). A NDVI mean distribution by habitat study site graph before and after the events were created too (**Fig 7,8**). Finally, a Simpsons biodiversity index and a NDVI, both by habitat, from before and after the events comparison graphs were created (**Fig 9-12**).

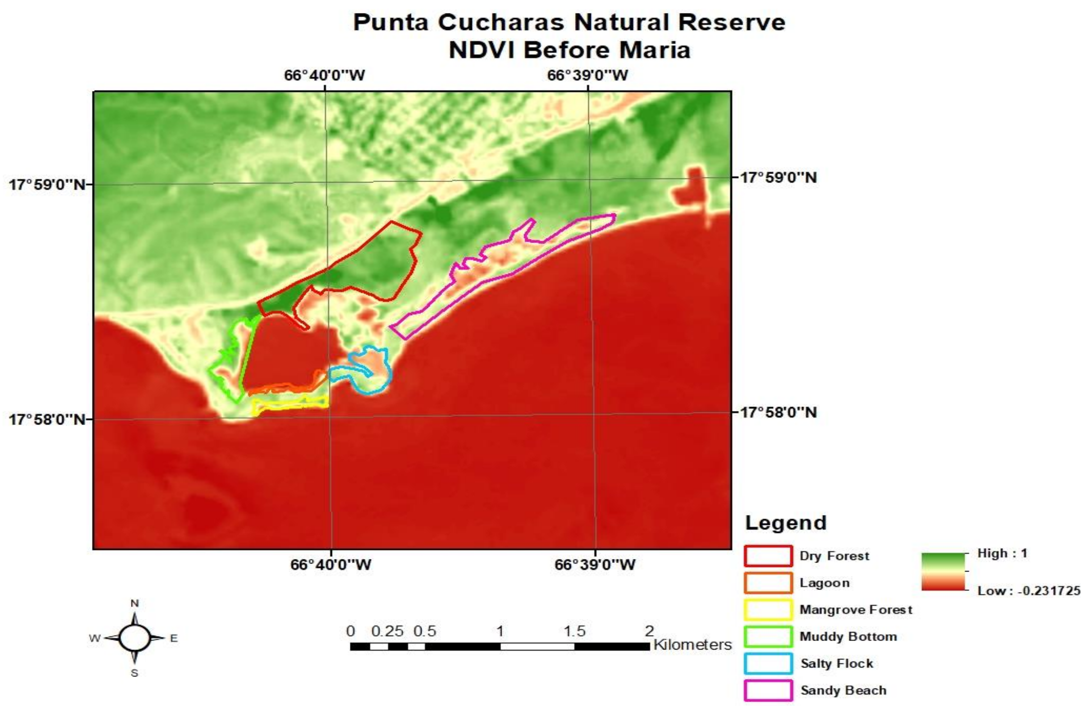

Fig 3. A map showing the NDVI values in the whole satellite image before the impacts of the two hurricanes from October 16, 2016. Habitat study sites are outline-colored to show NDVI dynamics inside each habitat.

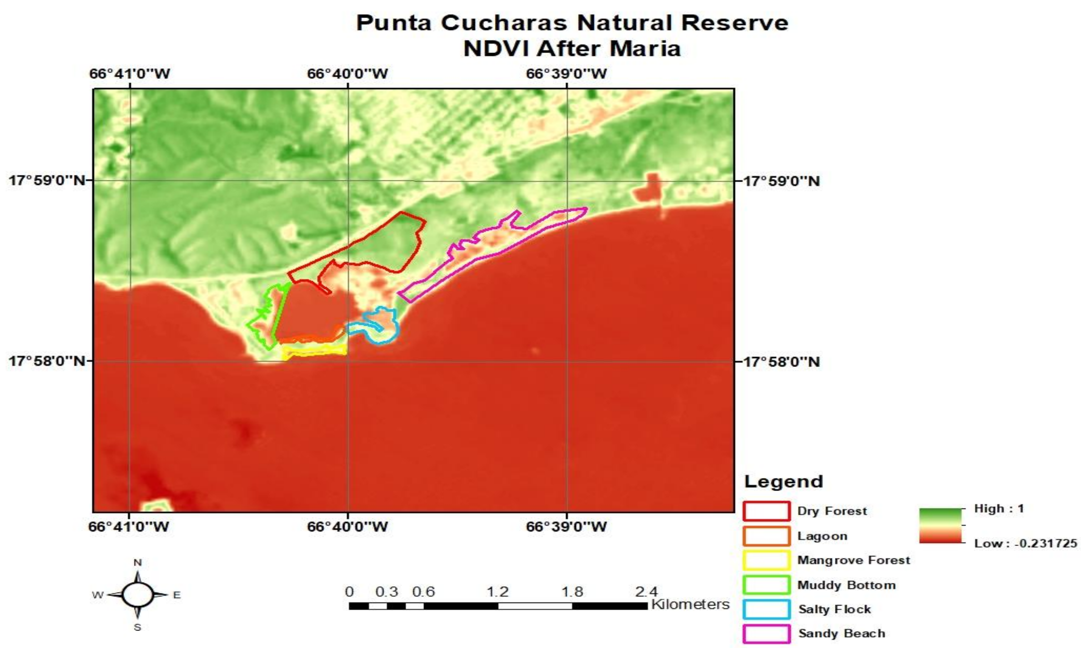

Fig 4. A map showing the NDVI values in the whole satellite image before the impacts of the two hurricanes from October 3, 2017. Habitat study sites are outline-colored to show NDVI dynamics inside each Habitat.

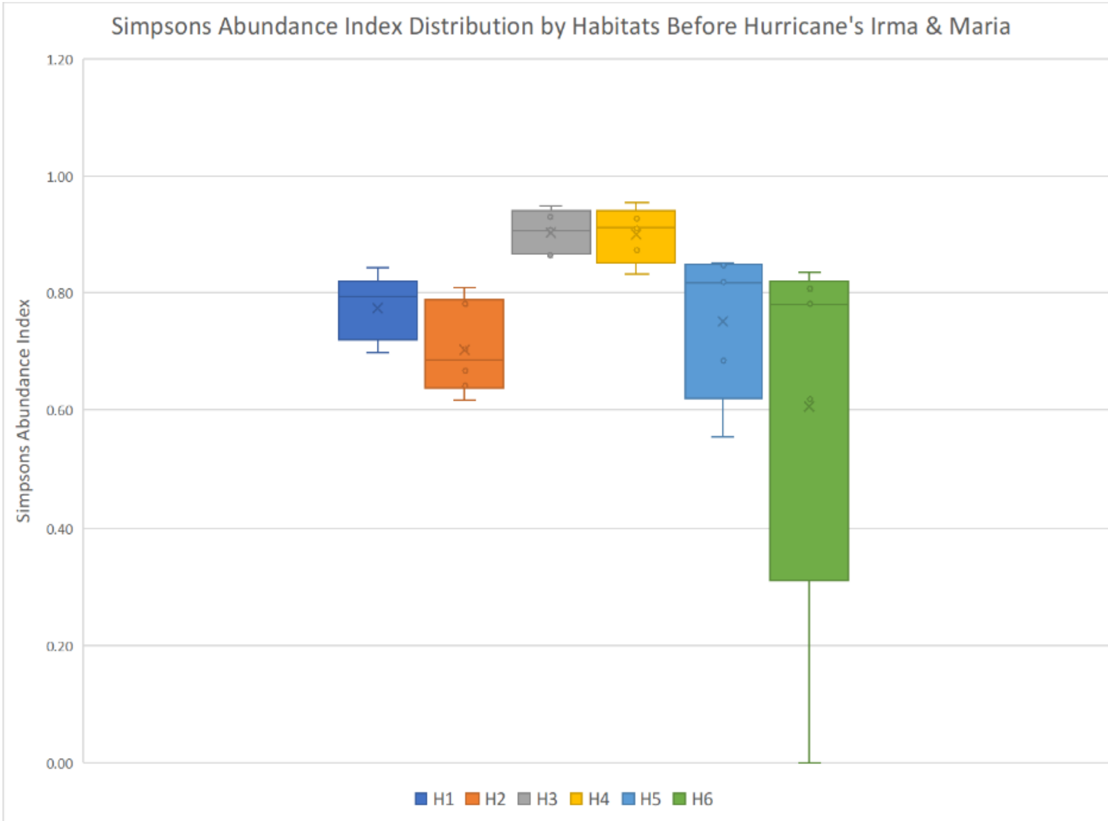

Fig 5. A box plot graphic showing Simpsons biodiversity index distribution by habitat before the hurricanes.

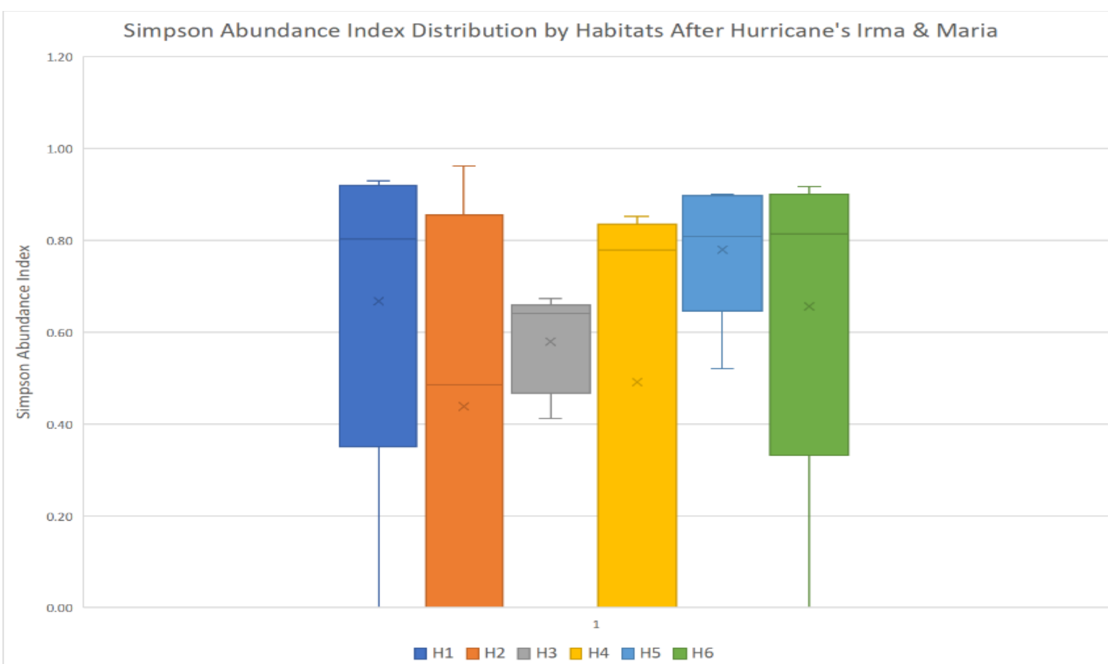

Fig 6. A box plot graphic showing Simpson's biodiversity index distribution by habitat after the hurricanes.

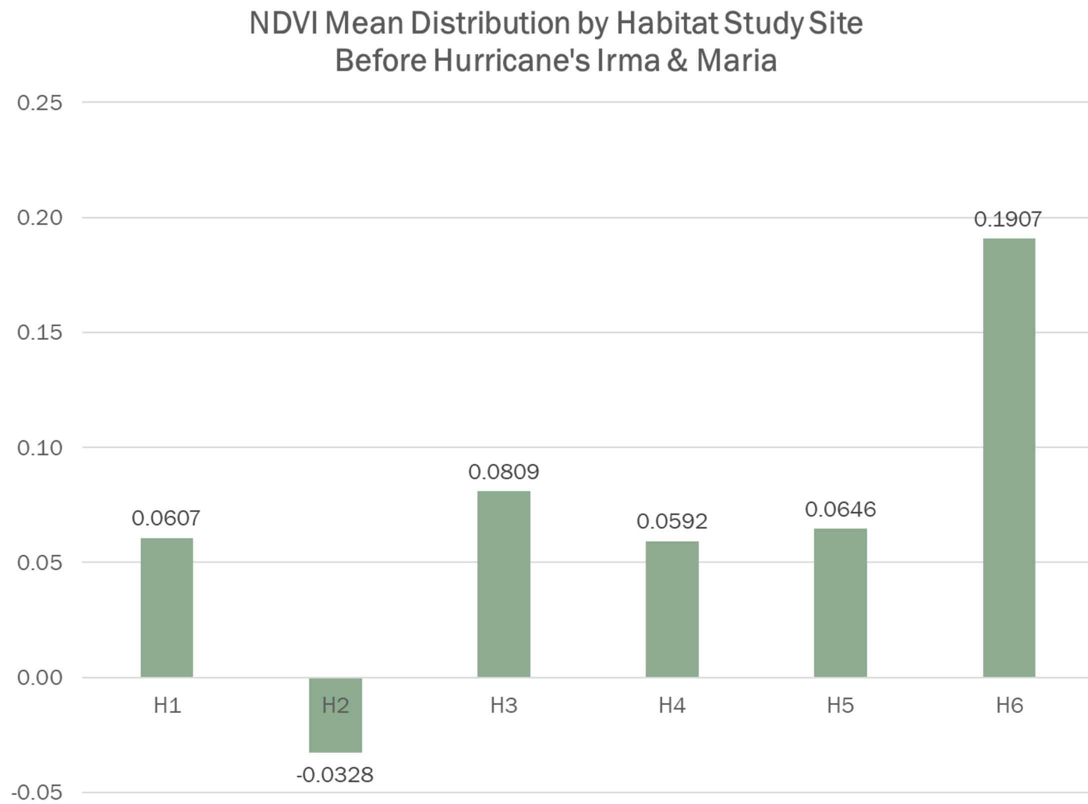

Fig 7. A bar graph showing NDVI mean distribution by habitat before the hurricanes.

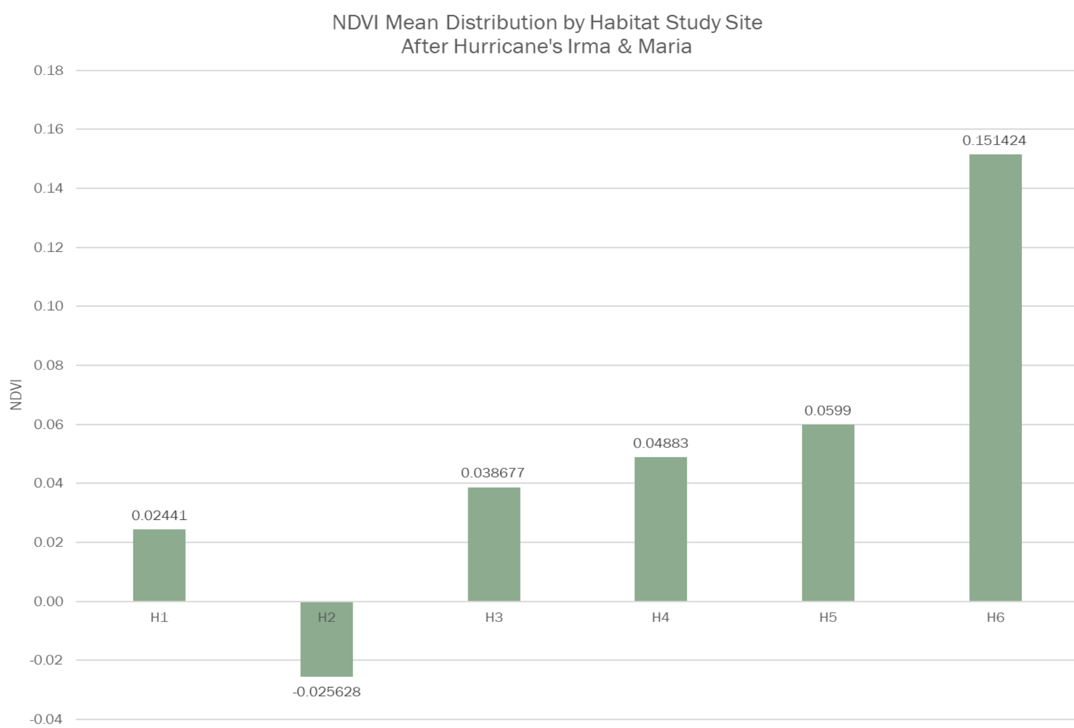

Fig 8. A bar graph showing NDVI mean distribution by habitat after the hurricanes.

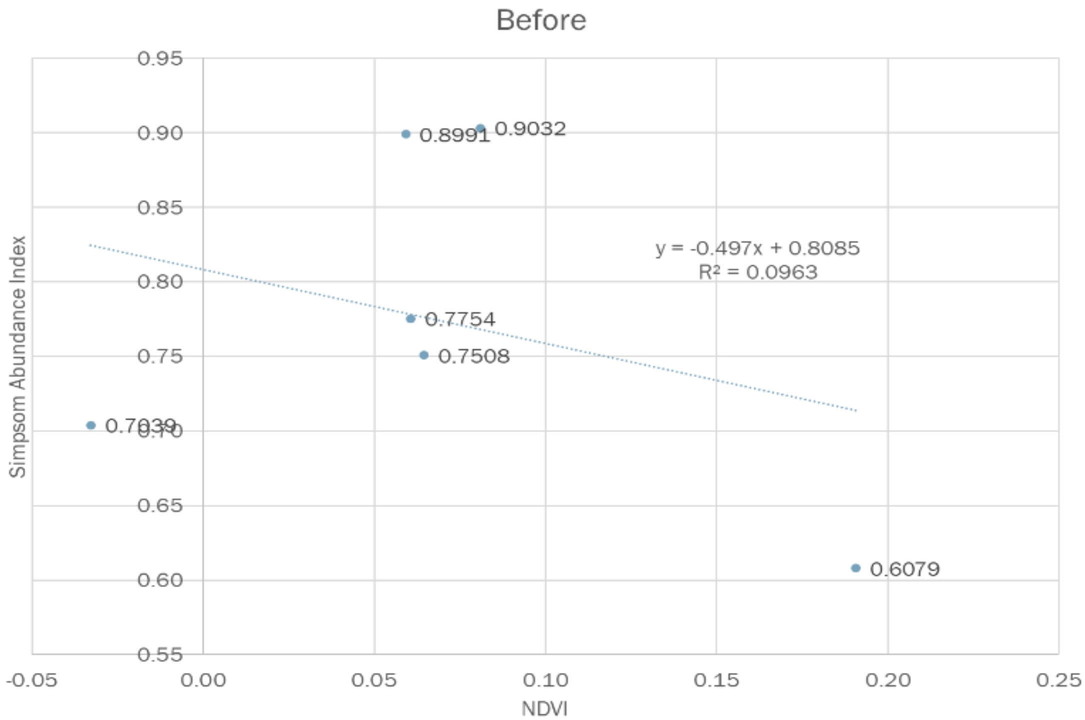

Fig 9. A point graph showing a correlational model analysis between the NDVI mean values and the Simpsons abundance index, by habitat, before the hurricanes.

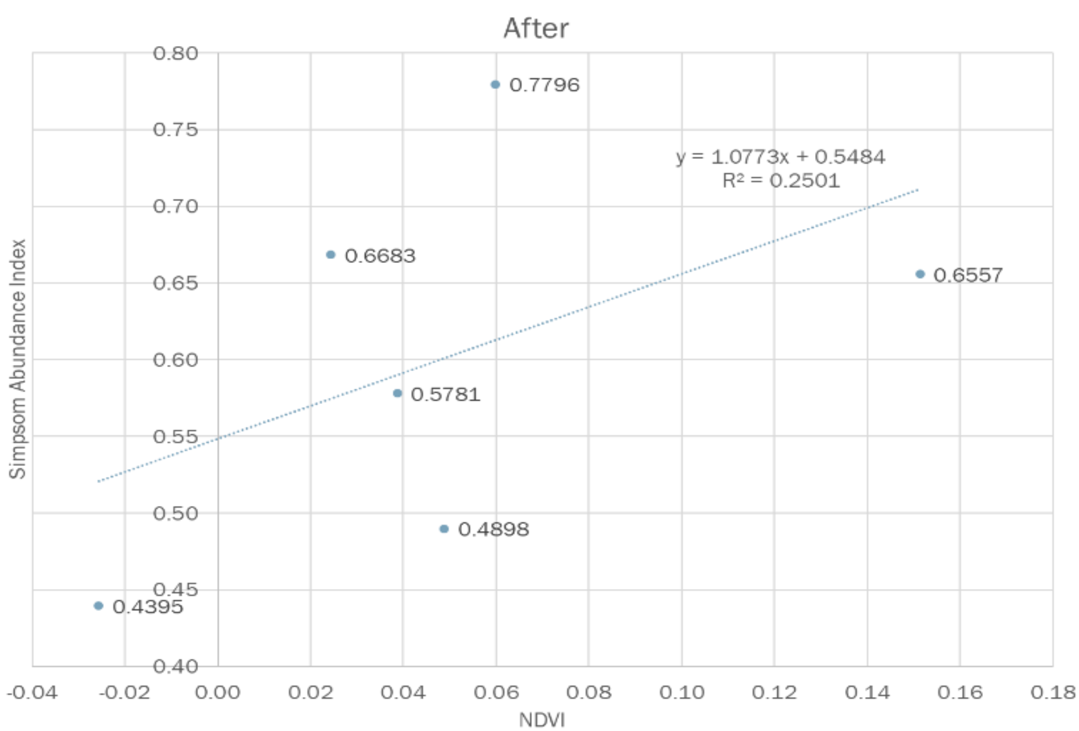

Fig 10. A point graph of correlational model analysis between the NDVI mean values and the Simpsons abundance index, by habitat, after the hurricanes.

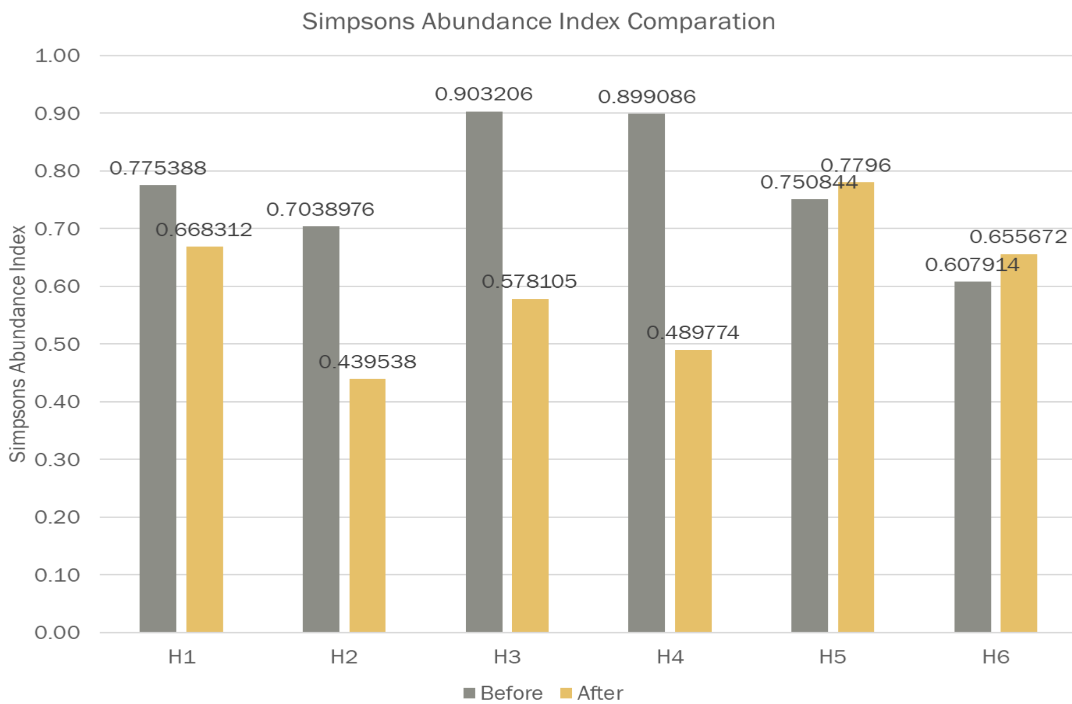

Fig 11. A bar graph comparing Simpson's biodiversity index values by habitats before and after the hurricanes.

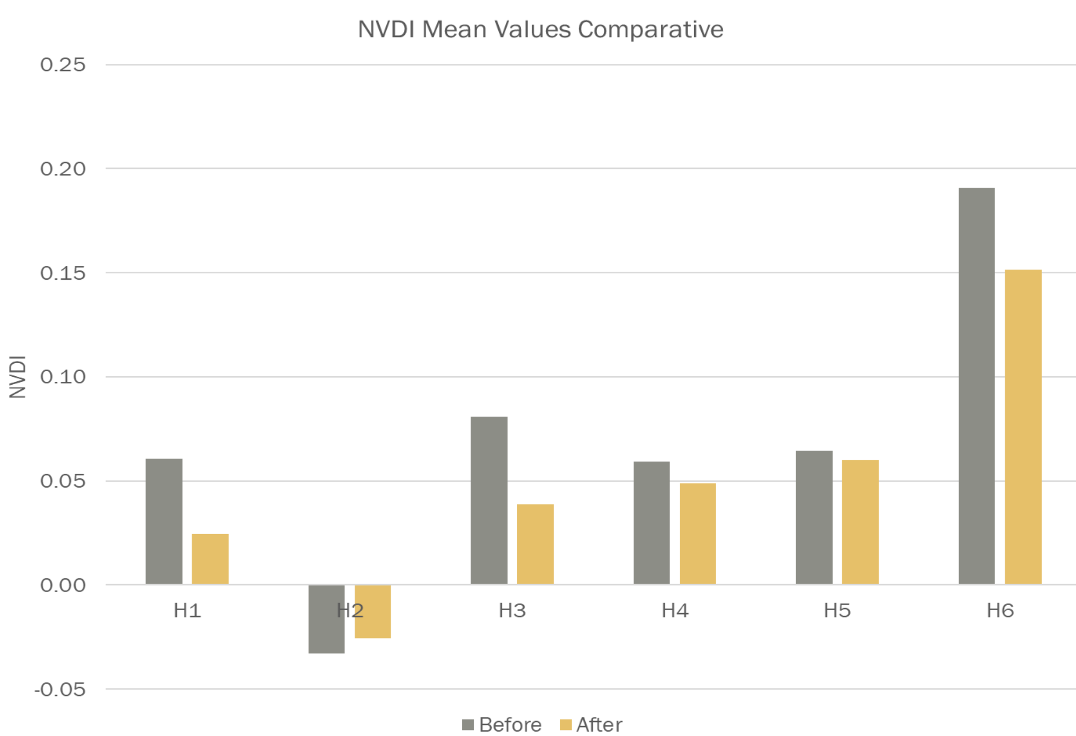

Fig 12. A bar graph comparing NDVI mean values by habitats before and after the hurricanes.

DISCUSSION

NDVI map values on study sites relatively decreased after the atmospheric events happened (**Fig 3,4**). By graph, NDVI values for each habitat relatively decreased too except lagoon habitat due to its nature, an aquatic area (**Fig 7,8,12**). On the other side, Simpson's biodiversity index was greatly reduced after the events except salty flock and coastal beach habitat zones (**Fig 5,6,11**). As Llegus-Santiago et al. (2018) concluded, it was validated on this study that Simpson's biodiversity index had a notable decrease right after the hurricanes.

Correlational models conclude that there was no correlation between NDVI habitat mean values and Simpson's biodiversity index for this study, neither before nor after the hurricanes (**Fig 9,10**). With these results, our hypothesis turned to be false. Even though, comparative models showed a decrease pattern in both NDVI habitat mean values and Simpson's biodiversity index in comparison to a year before the hurricanes (**Fig 11,12**). Delimitating habitat zones could be an alternative method for ensuring that zonal statistics were calculated inside of the boundaries used by Llegus-Santiago et al. (2018) study. Although it has been well documented that post-hurricane dispersal of individuals can contribute to changes in the composition and richness of local assemblages.

After running statistical analysis data, it is evident that other analysis should be made in order to avoid incongruence in analysis. On a side, surveys carried out over small geographic areas, like PCNR, are difficult in determining whether changes in observed numbers of individuals reflect changes in population size or simply dispersal away from the study area. On the other existing research effects of hurricanes on birds that considers abundance index methods do not necessarily address the potentially confounding effect of changes in detectability, this being a limiting factor when making this type of analysis. (Lloyd et al. 2019).

CONCLUSION

In this research project we have covered how an atmospheric event can affect forest NDVI values in correlation to bird habitat abundance. Even though hypothesis was wrong this methodology could be used for what was previously mentioned. It is evident that performing an impact assessment based on geospatial analysis techniques can be useful for making deeper analysis on study site were just terrestrial data could be a limitation sometimes. Developing this kind of assessments make a powerful decision tool in IBA's were coastal managers can scope their management plans. Finally, this will lead to the creation of good public policy at low mid and long term that will benefit at the very end whole ecosystems.

RECOMMENDATIONS

Some of the technical limitations that we found in the development of our research project were absence of field equipment for make real delimitations of study Habitat sites. To get better NDVI results, better resolution will be needed in the future. To make bigger and better statistical analyses a more advanced software than Excel could be used for this study too. These technical limitations are interpreted as recommendations for running a project that has by topic studying the forest structure and impact on bird diversity.

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