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Antillean manatee (*Trichechus manatus manatus*) occurrence and grazing spots in three protected areas of Costa Rica

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Abstract

The Antillean manatee is a poorly studied marine mammal in Costa Rica. Its distribution covers the entire Caribbean coast, but sighting reports are scarce. This research was conducted in three protected areas (PA) where the species is primarily observed. The objectives were to determine the density patterns of sightings and grazing spots; to explore the relationship between grazing spots and sightings with geographic and temporal variables, for PA separately; to study the frequency of sightings and grazing spots according to season, month, and period of the day, for PA together; and to determine the pertinence of using a marine ecology application MarEco to register manatee sightings by the public. Data on manatee sightings and grazing spots gathered with the MarEco app, under a citizen science mechanism, were complemented with data obtained by the Tortuguero Conservation Area Administration (TCAA) through other means. The number of sighting records registered through MarEco during nine months was alike to the number of records reported to the TCAA over six years in two of the PA studied. The areas with the highest density of grazing spots and sightings matched with studies conducted 10 to 20 years ago. In two of the PA, sightings were most often associated with the rainy season, while fresh grazing spots were specially counted from 6:00 h to 8:59 h. The results suggest that manatees exhibit high site fidelity in the three PA, that their increased presence during the rainy season is likely due to increased availability of food, and that they perform feeding activity predominantly at night.

Keywords:
citizen science, conservation, ecology, marine mammals

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Introduction

The Antillean manatee (*Trichechus manatus manatus*) is classified under a Vulnerable conservation status by the Red List of the International Union for Conservation of Nature, indicating a decreasing trend throughout its whole habitat range from the Caribbean to Brazil, and the species is reported as extinct in 18 specific locations along that extent (Deutsch et al., 2008). It is also included in Appendix I of the Convention on International Trade in Endangered Species (CITES, 2023).

In Costa Rica, the conservation status of the manatee has not been officially defined and its population size is unknown, but it is presumed to be small. In 2017, the National System of Conservation Areas (SINAC, by its Spanish acronym) indicated that only 17 manatee encounters had been reported by locals for the entire northeast Caribbean coast of Costa Rica since 2012. The last dead (stranded) animal was registered in March 2022. To give priority to this species for conservation and management purposes, a Declaration for Natural Sanctuaries for the Conservation of the Antillean Manatee, led by local communities surrounding the protected areas (PA), was signed by the government on 8 June, 2016. The species was also declared a symbol of the marine fauna of the country by Law N° 9264 (La Gaceta N° 183; 24 September, 2014).

Studies on the manatee in Costa Rica started in the 1980s. Today, the general distribution extent and threats against the species are known, and its population is recognized as fragmented and ecologically unstable. Also, the feeding resources preferred by the species and specific highly used zones in three protected areas have been identified (Reynolds et al., 1995; Jiménez, 1999; Smethurst & Nietschmann, 1999; Gómez Lépiz, 2010; Espinoza Marín & Gonzalez-Socoloske, 2013; Vargas Ramírez, 2015). So far, feeding grounds and high-fidelity sites have not officially been defined.

In general, surveying marine mammals is difficult (King & Heinen, 2004; Taylor et al., 2007). Monitoring manatees in Costa Rica is particularly challenging because they are shy and inhabit murky estuarine environments and deep coastal canals with limited visibility (de Thoisy et al., 2003). Consequently, the use of traditional methods to monitor the species has proven to be ineffective or unfeasible in practical and financial terms. To date, research has been based on surveys of residents to understand where manatees are found. In a two-year effort to radio-track the animals, experts from the US were unable to catch any manatees (FUNDAR & FMSCR, 2007), and the use of sonars to find the animals did not generate determinant results (Villate, 2010).

In addition to the former, manatees have important adaptations for their life in the water that allow them to minimally expose themselves to risk situations and minimize the probability to be preyed upon (Mercadillo-Elguero et al., 2014); they can quickly exchange large amounts of air from their lungs, having to emerge relatively little to ventilate (Davis, 2019), which considerably reduces the time they spend at the surface.

Given those difficulties with detection, we developed a mobile phone app (MarEco) for Android and iOS systems (downloadable for free from online stores) that collects georeferenced ecological data, along with imagery, as a tool to register manatee sightings and grazing spots in Costa Rica with the support of local inhabitants. The app is linked to a web administration platform that receives the data and imagery and automatically organizes them in databases for download.

Throughout its whole range, including Costa Rica, the manatee habitat has suffered significant deterioration mainly due to deforestation, water pollution, and human activities (Marsh et al., 2017). Historical reports of hunting in the northern Caribbean area of the country and in some adjoining sectors of Nicaragua (Jiménez, 2002) were an additional problem for the species. The last report of a hunted manatee was in December 2021 (M. Hernández, local boat driver, 2021, pers. comm.).

Determining key areas for manatees is crucial to conduct effective conservation efforts to mitigate the impacts of segmentation and habitat loss (Favero et al., 2020). The level of vulnerability of the manatee habitat can lead to mortality events if the appropriate precautions and management strategies are not addressed to guarantee the ecosystem's functionality and the survival of these animals (Bailey & Thompson, 2009). Habitat zoning and protection of primary food sources for manatees are key elements in their protection (Favero et al., 2020). Also, maintaining connectivity between areas commonly used by manatees is crucial to preserve genetic diversity and population health (Tucker et al., 2012).

Therefore, analyses are developed in the Tortuguero National Park (TNP), the Barra del Colorado Wildlife Refuge (BCR), and the Gandoca Lagoon, at the Gandoca-Manzanillo National Mixed Wildlife Refuge (GMR), under the following objectives: (1) to determine density patterns of manatee sightings and grazing spots, seeking to identify the most important areas for the manatee and its feeding grounds; (2) to explore the relationship between grazing spots and manatee sightings with location (lat*long), period of the day, month, and year (for each PA separately), with the purpose of understanding spatial-temporal aspects addressing habitat use by the manatee; (3) to study the

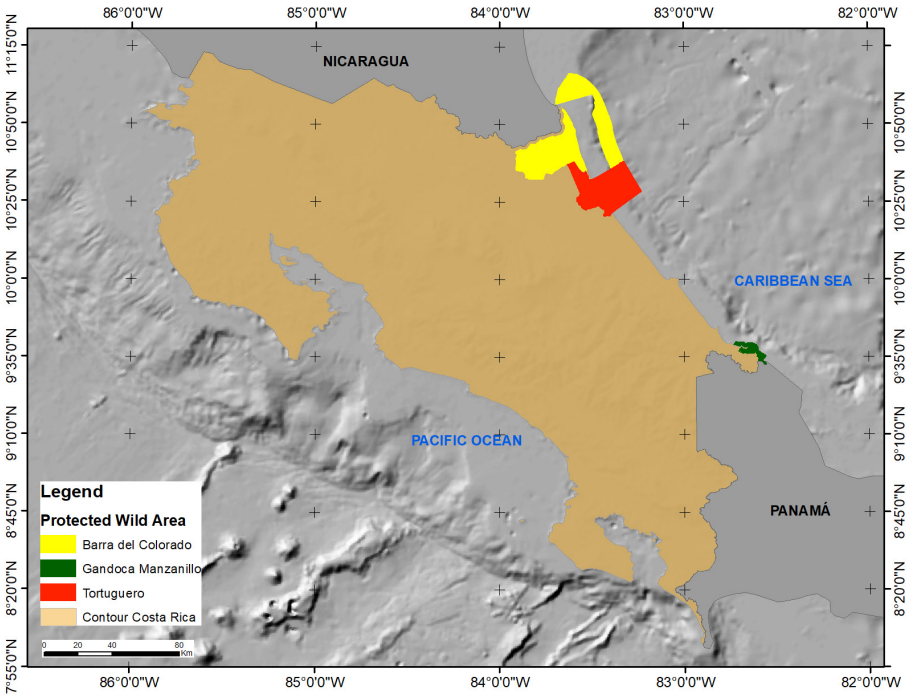

Figure 1. Map of Costa Rica showing the three protected areas in the Caribbean where this study was conducted, 2015 - 2022.

frequency of manatee sightings and grazing spots according to season, month, and period of the day, for the TNP and the BCR together, in order to explore their association with those three temporal scales; and (4) to determine the pertinence of basing the use of the MarEco App under citizen science to generate manatee sighting records in the three PA.

Material and Methods

Sampling areas

This study analyzes manatee data obtained with the MarEco app in the Tortuguero National Park (TNP), the Barra del Colorado Wildlife Refuge (BCR), and the Gandoca Lagoon (GL), at the Gandoca-Manzanillo National Wildlife Refuge (GMR), three PAs with important manatee habitats in the Caribbean of Costa Rica (Fig. 1). Data collected by the Tortuguero Conservation Area Administration (TCAA) before the existence of the app is also included in this study.

The TNP was declared in 1970. It has 76,732.30 hectares of which 26,455.80 are terrestrial, with different uses, and 50,276.50 are marine, 100% dedicated to conservation. It is formed by an extensive network of rivers and canals, accessible only by boat (Law 5680). The BCR was created in 1985 with an area of 81,177 hectares composed by coastal areas, lagoons, rivers, swamps, and flooded forests. Human communities live inside the PA and, for that reason, 61% of its area is destined for sustainable use, while 35% is declared for absolute protection; the remaining 4% is dedicated for special use and public use (E.D. 16358-MAG). The GMR was created in 1985 with an area of 10,489.50 hectares. It includes the GL, surrounded by dense mangrove forests (E.D. 16614-MAG).

Data collection

Data were collected using a non-invasive technology developed by the PRIAS Laboratory, at the National Center for High Technology (CeNAT) to monitor the manatee in Costa Rica: the application MarEco for mobile devices, for use with Android and iOS systems, is downloadable for free from online stores. Data on manatee sightings and grazing spots provided by the TCCA referring to the TNP and the BCR were also considered for analysis.

Due to the difficulties in seeing manatees in Costa Rica derived from habitat conditions and the species' fragmented population (Reynolds et al., 1995; Smethurst & Nietschmann, 1999; de Thoisy et al., 2003), a data collection system based on citizen science was implemented using the MarEco app, under the support of park rangers and locals to register specifically manatee sightings. The app automatically records coordinates, date, and time. In addition, the collector indicates the behavior, social structure, number of individuals, and human activity close to the manatees, and obtains photos and video by accessing the device's camera. A user's guide is included in the app. The data collected through the application is automatically sent to an online data management platform for download (https://mareco.cenat.ac.cr/). In addition to receiving live records through the app, the platform also allows users to add records manually.

The use of the app by locals and park rangers was chosen as part of the sampling methods following a recommendation from a recent academic thesis, which indicated that manatees are seen most frequently by local inhabitants. Therefore, involving them to report sightings of the species as part of a participative monitoring program enables systematized information to be collected into a database (Vargas Ramírez, 2015). The app was promoted through 17 formal presentations that explained its use, reaching 250 people among the three PAs.

Table 1. Sampling sites in manatee (*Trichechus manatus manatus*) habitats located in three protected areas on the Caribbean coast of Costa Rica.

Protected Area	Manatee sightings	Years	Sites sampled for grazing spots	Grazing spots
Tortuguero National Park	17	2015-2022	1. Caño Sérvulo 2. Laguna Jalova 3. Cuatro Esquinas	345
Barra del Colorado Wildlife Refuge	11	2016-2022	1. Agua Dulce 2. Laguna del Medio 3. Laguna de Atrás 4. Río Colorado 5. Laguna Samay 6. Dos Bocas 7. La Boca del Mono	46
Gandoca Lagoon-Gandoca-Manzanillo National Mixed Refuge	6	2021-2022	-	-

Fresh grazing spots (recognized by groups of bitten leaves and stems without tender sprouts or dark scars on them) were registered by researchers and park rangers using either the MarEco app (BCR) or a GPS (TNP). For this, both shores in canals and lagoons used by the manatee were surveyed from the beginning to the end using a boat at a speed of one knot (BCR) or by kayak or canoe (TNP). No grazing spots were searched for in the GL, at the GMR. Manatee sightings were reported for the three PAs through the app.

Both single grazing spots (located more than 25 m away from any other grazing spot at both sides along the shore) and multiple grazing spots (two or more grazing spots located less than 25 m between each other) were considered. Following that classification, in the TNP, park rangers and volunteers registered grazing spots in three specific canals: Caño Sérvulo, Laguna Jalova, and Cuatro Esquinas. Likewise, in the BCR, researchers in charge of this study registered grazing spots in canals where manatees are usually seen, and monitored canals where the species is not seen, covering areas at the north and south of the Colorado River (Fig. 2, Table 1).

Analysis: t-Student and ANOVA

To analyze the average number of manatees per sighting, a t-Student test was applied for the three PAs together, and Analyses of Variance were used to compare between the three PAs, as well as between seasons (rainy: November to January and May to August; dry: February to March and September-October; transition: April, https://www.imn.ac.cr/documents/10179/31165/clima-regiones-climat.pdf/cb3b55c3-f358-495a-b66c-90e677e35f57).

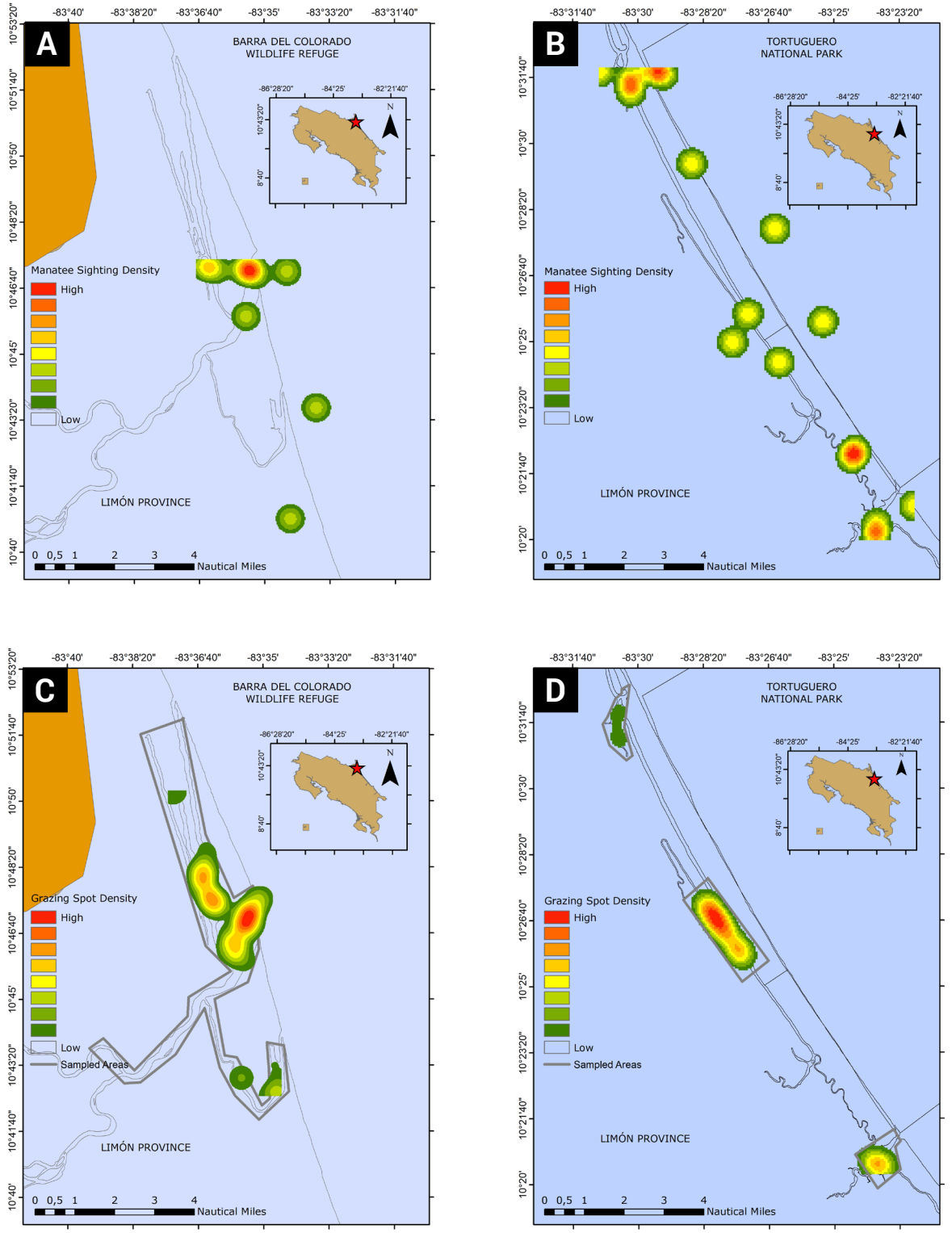

Figure 2. Antillean manatee (*Trichechus manatus manatus*) core areas in Costa Rica, 2015-2022. Manatee sightings in A) Barra del Colorado Wildlife Refuge and B) Tortuguero National Park. Grazing spot density in C) Barra del Colorado Wildlife Refuge and D) Tortuguero National Park.

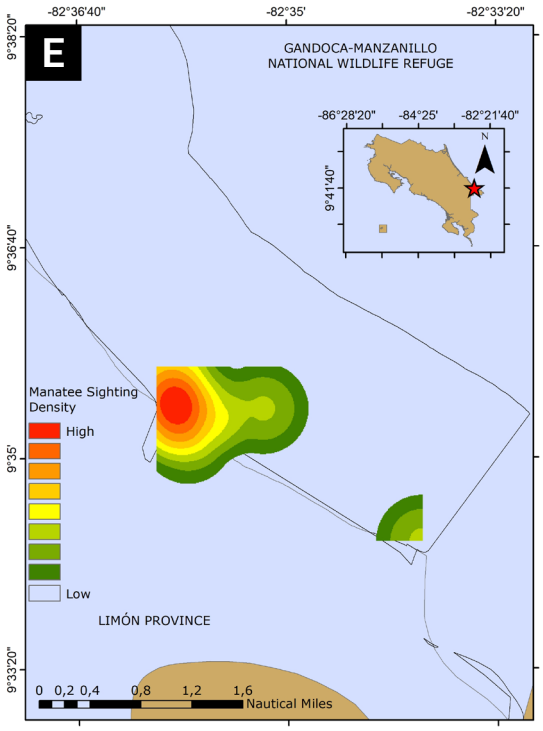

Figure 2. cont. Antillean manatee (*Trichechus manatus manatus*) core areas in Costa Rica, 2015-2022. Manatee sightings in E) Gandoca-Manzanillo National Mixed Refuge.

Kernel Analysis

This test was used to obtain estimates of the probability density functions. Core density areas of both manatee sightings and grazing spots were identified, considering an output cell size by default between 10 to 20 km^2, a planar method, and a search radius of 1 km. Manatee sightings were analyzed based on the sightings *per se* instead of the number of individuals and, in multiple grazing spots, only the first and last ones along the corresponding section where they were found were considered for the analyses.

Principal Component Analysis

It was applied to explore the most representative variables related to grazing spots and manatee sightings, separately, considering location (lat*long), PA, period of the day, month, and year, using 50 m^2 grids as analysis units.

Correspondence Analysis

This test was used to identify the relationships between number of manatee sightings and grazing spots, with the season, the month, and the period of the day (06:00 h to 08:59 h, morning; 09:00 h to 11:59 h, late morning; 12:00 h to 14:59 h, afternoon; 15:00 h to 17:59 h, late afternoon; 18:00 h to 05:59 h, night), as six separate analyses. Also, the relationship between behavior (feeding, traveling, resting, and mating) with the period of the day, the season, the month, and the PA was addressed, as four separate analyses.

Table 2. Eigenvalues, proportion of explained variance, and variable coefficients for manatee (*Trichechus manatus manatus*) sightings and grazing spots in three protected areas of the Caribbean of Costa Rica. PC = Principal Component.

Protected Area			PC1	PC2
TortugueroNational Park	Manatee sightings	Eigenvalue	2.3632898	0.8213960
		Proportion of explained variance	0.5908	0.2054
		Latitude	-0.5682763	0.06940001
		Longitude	0.5239963	-0.30256975
		Period of the day	0.5269122	-0.24091335
		Season	-0.3533461	-0.91956291
	Grazing spots	Eigenvalue	2.2386955	0.9964113
		Proportion of explained variance	0.5597	0.2491
		Latitude	-0.6453243	0.1195572
		Longitude	-0.6451477	0.1229459
		Period of the day	-0.1018365	-0.9745391
		Season	-0.3961947	-0.1444436
Barra del Colorado Refuge	Manatee sightings	Eigenvalue	2.1173848	1.0437192
		Proportion of explained variance	0.5293	0.2609
		Latitude	0.6621698	-0.2491076
		Longitude	-0.6688705	0.1694637
		Period of the day	0.2977861	0.4991850
		Season	-0.1595836	-0.8124296
	Grazing spots	Eigenvalue	2.3366379	0.9750935
		Proportion of explained variance	0.5842	0.2438
		Latitude	0.5958887	-0.02990057
		Longitude	-0.5798267	-0.03407015
		Period of the day	-0.3963723	-0.69756264
		Season	0.3893670	-0.71508849

Results

A total of 34 manatee sighting records, from years 2015 to 2022, were obtained (17 in the TNP, 11 in the BCR, and six in the GMR). Of those, 15 records were gathered through the MarEco app between September 2021 and May 2022, and 19 corresponded to historical georeferenced records from 2015 to 2017 and 2019 to 2021, provided by the TCAA.

A total of 391 fresh grazing spots were registered both in the TNP and the BCR. Sampling effort in the TNP was conducted in 2021, in February, April, June, August, and October, during three days per month, especially in the morning and late afternoon, for a total of 15 surveys. Sampling efforts in the BCR included November 2021, and January and March 2022, especially in the late morning, in six surveys. A total of 46 records of grazing spots were registered with the MarEco app at the BCR (2021, n = 11; 2022, n = 35), and 345 records of grazing spots were provided by the TNP Administration for 2021, for that PA.

Between 2015 to 2022 the number of manatee sightings recorded increased (Fig. 3A). Records analyzed referred to feeding activity (n = 7), mating (n = 2), resting (n = 14), and traveling (n = 6). One record referred to a dead stranded manatee. In five cases, the activity was not identified (Fig. 3B). Nine encounters involved groups between three to eight manatees and, one time, a mother-and-calf pair was seen. Pairs were found three times, and 21 sightings involved only one manatee (Fig. 3C).

For the three PAs together, the average number of manatees per sighting was 2.11 ± 1.937 ($t = 6.458$, $df = 34$, $p < 0.001$); comparing between seasons, the transition month (April) reached a higher average number of manatees per sighting (3.00 ± 2.828, n = 2) compared to the dry season (1.67 ± 1.397, n = 15) and the rainy season (2.39 ± 2.253, n = 18), but differences were not significant ($F = 0.780$, $df = 2$, $p = 0.467$). Between PAs, there was a non-significant higher average of manatees per sighting in the GMR (3.33 ± 1.966, n = 6) compared to the TNP (1.94 ± 2.304, n = 17) and the BCR (1.82 ± 1.079, n = 11) ($F = 1.037$, $df = 3$, $p = 0.390$).

Kernel analysis revealed core areas for manatee sightings in the three PA, and for grazing spots in the TNP and the BCR. Core areas in the BCR for both manatee sightings and grazing spots were located primarily north of the Colorado River. In the TNP, manatee sighting patterns were very dispersed along the whole PA, while grazing spots were concentrated in Caño Sérvulo, Laguna Jalova, and Cuatro Esquinas due to sampling effort being restricted to those canals. For the GMR, a core area for manatee sightings was identified in the surroundings of the GL mouth, both inside the lagoon and in the sea (Fig. 2).

Through Principal Component Analysis (PCA) it was found that, for the TNP, grazing spots were strongly associated with the location (lat*long) and that, for the BCR, both grazing spots and manatee sightings were strongly associated with that variable. Also, manatee sightings were associated with the rainy season in the two PAs, while grazing spots were associated with the period of the day (morning) in the TNP, and with the season (rainy) and the period of the day (morning), in the BCR (Table 2).

The rainy season and the morning were assigned to reclassification code 1 and, in each case, the coefficient values in the principal components reached the lowest negatives. The GMR was not analyzed through PCA as the number of analysis units was too low.

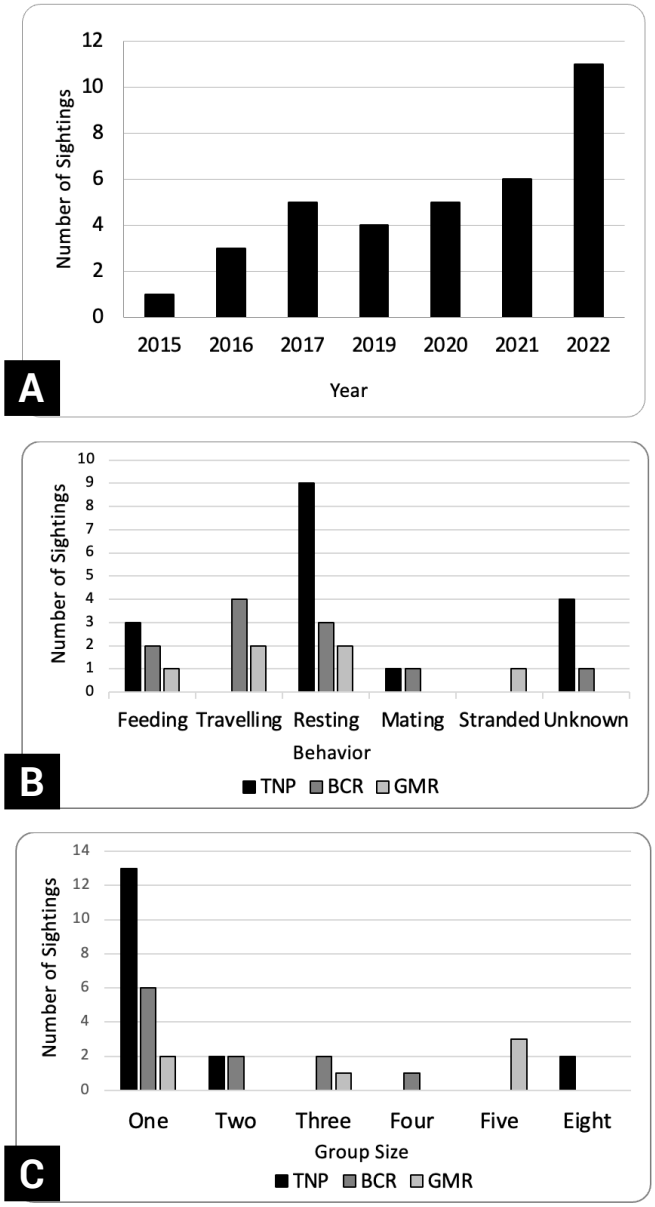

Figure 3. Antillean manatee (*Trichechus manatus manatus*) number of sightings per year in the Tortuguero National Park, the Barra del Colorado Wildlife Refuge, and the Gandoca Lagoon, at the Gandoca-Manzanillo National Mixed Refuge, Caribbean of Costa Rica, together (A), and according to behavior (B) and group size (C) for each protected area, separately.

For the TNP and the BCR together, according to Correspondence Analysis, there were no significant differences in the number of manatee sightings or in the number of grazing spots between seasons ($\chi^2 = 2.090$, $df = 2$, $p = 0.352$), despite grazing spots being more frequently recorded during the rainy season. When comparing between months, however, sightings in the two PAs were more frequent in December, January, and March, while grazing spots were counted in higher numbers during June, August (more often), and October ($\chi^2 = 235.193$, $df = 11$, $p < 0.001$). In the two PAs, grazing spots were counted in a higher frequency during the morning and the late afternoon, while frequency of manatee sightings was higher during the morning, late morning, and late afternoon ($\chi^2 = 27.509$, $df = 4$, $p < 0.001$).

Due to the low amount of data, no statistical differences were found regarding behavior in relation to period of the day, season, month or between the TNP and the BCR through Correspondence Analysis. However, specific relationships were seen. In the morning, and during September and November, traveling was common and, in the dry season, manatees were seen mostly resting, especially in the TNP.

Discussion

The manatee has been studied in Costa Rica since 1981 (O'Donnell, 1981; Reynolds et al., 1995; Jiménez, 1999, 2000, 2002; Gonzalez-Socoloske et al., 2009; Gómez Lépiz, 2010). Research to date has allowed the government to establish measurements to protect the species (Law N° 9264, La Gaceta N° 183; 24 September, 2014). Previous studies focused on specific spots inside PAs (Reynolds et al., 1995; Jiménez, 1999; Vargas Ramírez, 2015), but it has been revealed that the manatee habitat range in Costa Rica extends from border to border (Sánchez Godínez, 2013).

This study gathered manatee data in three PAs, simultaneously, for the first time in the country: TNP, BCR, and GMR. Citizen science was used to collect manatee sighting data with the use of the MarEco application for mobile devices.

Even though a sustained effort was made during the nine months dedicated to intensive field work, specific challenges were faced regarding the promotion and use of the MarEco app. Those challenges included limited local residents attending meetings to receive training about its use; misinterpretations of the intent of the study by some dwellers, due to non-accurate locally spread information beyond official communications provided by the study; interest by some locals in getting paid to gather data with the app; and explicit lack of disposition by specific people to register the manatee with the app. Gathering records on manatee sightings with the tool reached a low number due to these challenges.

Citizen science inherently involves challenges specially related to logistical limitations regarding time, space, and staff available to provide significant educational bases beyond the training required to do citizen science, as well as the goodwill and disposition of people to participate voluntarily; timing and budgetary limitations in projects conducting the studies are also part of the challenges faced (Weber et al., 2019; Roche et al., 2020). All of the former were obstacles encountered in the present study.

Even so, efforts to promote the MarEco app should continue because the tool allows anyone to generate manatee records not only inside the three PAs, but along the whole Costa Rican Caribbean coast. Social media are a key ally for such continued promotion. Two one-day paid posts per week in social media for the last two months of the study reached 232,000 inhabitants along the Caribbean coast of Costa Rica, with a great response from people wanting to record the manatee with the MarEco app.

Data analysis revealed an increasing trend in the number of records of manatee sightings from 2015 to 2022 with the highest number of reports in that last year, due to the use of the MarEco app. This indicates that if the effort to motivate locals continues, it will be possible to keep increasing the number of records in time. Long-term citizen science efforts have allowed the collection of 14,076 koala (*Phascolarctos cinereus*) sighting records and refinement of koala distribution and population estimates derived from active surveying (Dissanayake et al., 2019). They also have allowed the assessment of the causal factors underpinning the distribution and abundance of wildlife road-induced mortality in the cassowary (*Casuarius casuarius johnsonii*) (Dwyer et al., 2016). Monitoring of the American black bear (*Ursus americanus*) was possible through a long-term citizen science effort with a twofold spatial and temporal coverage compared to systematic sampling based on the use of camera traps (Sun et al., 2021).

Regarding the sampling efforts implemented for the three data sources in this study, specific aspects define the results obtained: (1) manatee sighting records reached a wide spatial and temporal coverage because they involved reports by dwellers and park rangers, (2) sampling efforts to identify grazing spots in the TNP covered one year and referred to three specific canals, which biased the density spot identified for that PA, and (3) grazing spot sampling in the BCR covered specific months during the period of the study, but included a wide coverage of canals located to the north and to the south of the Colorado River and chosen at random, which avoided bias.

Differences in the number of sighting records obtained in the three PAs must be a resulting combination of the methods used to record those sightings and the intensity of use of each PA by people. On one hand, reporting a sighting to the TCAA required people to get a phone number, call, and describe the sighting, while the MarEco app required people to register the sighting in one or two minutes, under a pre-defined structure, while enjoying it. On the other hand, the TNP has the highest intensity of marine traffic, followed by the BCR, and the GMR. The more people navigate an area, the highest the probability manatees can be seen and reported.

The PCA revealed grazing spots in the TNP, and both grazing spots and manatee sightings in the BCR, to be mainly associated with location (lat*long). This indicated high fidelity to geographical areas. In the TNP, the core density area for grazing spots was determined by the specific locations sampled. In the BCR, the high-density areas found for manatee sightings and grazing spots at the north of the Colorado River coincided with reports made by dwellers almost one decade ago (Sánchez Godínez, 2013).

On the contrary, the PCA showed no strong association between manatee sightings and location in the TNP. This was corroborated by the widespread distribution of the species' density areas in this PA, which matched reports of two decades ago, when distribution of manatee presence was indicated for all the water bodies along the coast of this national park (Jiménez, 2000).

With reference to the core density area for manatee sightings in the GMR, in 2011 locals in the south Caribbean of Costa Rica indicated the surroundings of the mouth of the GL, both inside the lagoon and out into the sea, as the area where the manatee is frequently seen (Espinoza Marín, 2011). Our results, compared to previous information from the three PAs, indicate that the manatee has maintained its distribution patterns quite similar throughout the years. The PCA also revealed a positive correlation between manatee sightings and the rainy season for each of the two PAs, separately, and between the frequency of encounters of fresh grazing spots and the rainy season, specifically for the BCR.

The rainy season in the Costa Rican Caribbean spans seven months in the year. Gómez Lépiz (2010) exalts horsetail paspalum, *Paspalum repens*, as manatee's preferred feeding source in the TNP, followed by common water hyacinth, *Pontederia crassipes*, buffalo grass, *Urochloa* (*Brachiaria*) *mutica*, and floating pennywort, *Hydrocotyle ranunculoides*. In a lake complex, in northern Colombia, coverage by dense populations of horsetail paspalum, along with common water hyacinth, is determined by the inundation gradient caused by runoff water from heavy rains (Schmidt-Mumm & Janauer, 2014). Those two species of plants may also find favorable conditions in the TNP and the BCR during the rainy season, which would allow a higher availability as food sources for the manatee. This in turn would result in a greater presence of the species in these PAs, possibly explaining its stronger association with that time of the year. Correspondence Analysis revealed a higher occurrence of manatee sightings during December and January and of grazing spots during June and August, which corroborated the importance of the rainy months.

The correlation revealed by the PCA between the frequency of encounters of fresh grazing spots and the morning in the TNP and the BCR, could reflect that manatees feed during the night, and part of that activity extends during the first hours in the morning. Dwellers from the three PAs included in this study affirmed that manatees are hardly found eating after 9:00 h. Studies in Florida, USA, and the TNP, found that feeding activities were more frequent during the night, probably as a mechanism to avoid predators or even human activities (Jiménez, 2000; Ross, 2007). The Correspondence Analysis applied for the TNP and the BCR together corroborated the association between grazing spot frequency and the morning period, but also revealed an association with the late afternoon, and showed that manatee sightings occur mostly in those two periods of the day as well. The lack of significant results regarding the association between behavior and period of the day, season, and month, and between PAs in this study reinforces the need to continue monitoring the manatee to address and expand on this information, as it is extremely important for management and protection purposes.

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