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Nota científica

FIRST NATIONAL PHOTO-IDENTIFICATION CATALOG OF THE GREATER CARIBBEAN MANATEE (*TRICHECHUS MANATUS MANATUS*) IN THE DOMINICAN REPUBLIC USING UAV SURVEYS

Primer catálogo nacional de fotoidentificación del manatí del gran Caribe (*Trichechus manatus manatus*) en la República Dominicana mediante censos con drones

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ABSTRACT

Between May 2023 and December 2025, a total of 611 unmanned aerial vehicle (UAV) flights were conducted across eleven coastal sites in the Dominican Republic with the objective of developing the first standardized photo-identification catalog of the Greater Caribbean manatee (*Trichechus manatus manatus*). The analysis was based on a combined photographic dataset, structured from systematic UAV surveys (2023–2025) as the primary source, complemented with supplementary records collected between 2021 and 2023 from the national drone census, opportunistic flights, and photographs provided by divers. A total of 225 images were pre-selected based on the visibility of diagnostic anatomical marks, of which 66 met the minimum criteria for quality and distinctiveness, allowing the identification of 48 individuals, of which 45 were incorporated into the final catalog. Diagnostic marks were primarily located in the caudal region (73%), followed by the dorsal region (10%) and dorsal–caudal combinations (8%), with tail mutilations being the most frequent mark type (33%). Environmental conditions, particularly water turbidity, affected detection probability and image quality, highlighting the need for site-specific sampling protocols within a standardized national framework. This catalog represents the first baseline for individual-based monitoring of manatees in the Dominican Republic and demonstrates that protocol standardization reduces the amount of usable material while substantially increasing identification reliability.

Keywords: sirenians, unmanned aerial vehicles, diagnostic features, individual recognition, catalog development, population monitoring.

RESUMEN

Entre mayo de 2023 y diciembre de 2025 se realizaron 611 vuelos con vehículos aéreos no tripulados (UAV) en once sitios costeros de la República Dominicana con el objetivo de desarrollar el primer catálogo estandarizado de foto identificación del manatí del Gran Caribe (*Trichechus manatus manatus*). El análisis se basó en un archivo fotográfico combinado, construido a partir de un muestreo UAV sistemático (2023–2025) como fuente principal, complementado con registros suplementarios obtenidos entre 2021 y 2023 a partir del censo nacional con drones, vuelos oportunistas y fotografías aportadas por buzos. Se preseleccionaron 225 imágenes según la visibilidad de marcas anatómicas diagnósticas, de las cuales 66 cumplieron los criterios mínimos de calidad y distintividad, permitiendo la identificación de 48 individuos, de los cuales, 45 fueron incorporados al catálogo final. Las marcas diagnósticas se localizaron principalmente en la región caudal (73%), seguidas por el dorso (10%) y combinaciones dorso–caudales (8%), siendo las mutilaciones en la cola el tipo de marca más frecuente (33%). Las condiciones ambientales, particularmente la turbidez del agua, afectaron la probabilidad de detección y la calidad de las imágenes, evidenciando la necesidad de protocolos de muestreo específicos por sitio dentro de un marco nacional estandarizado. Este catálogo constituye la primera línea base para el monitoreo individual de manatíes en la República Dominicana y demuestra que la estandarización del protocolo reduce el material utilizable, pero incrementa la confiabilidad de las identificaciones.

Palabras clave: sirénidos, vehículos aéreos no tripulados, características diagnósticas, reconocimiento individual, desarrollo de catálogo, monitoreo poblacional.

The Greater Caribbean manatee (*Trichechus manatus manatus*), previously known as the Antillean manatee (Mignucci-Giannoni et al., 2024), is a large herbivorous sirenian inhabiting coastal, estuarine, and freshwater-associated environments throughout the Wider Caribbean region. The subspecies is currently listed as Endangered on the IUCN Red List (Morales-Vela et al., 2024) and as Critically Endangered in the Dominican Republic (MIMARENA, 2011; MIMARENA, 2018) due to multiple anthropogenic pressures across its range, such as habitat degradation, vessel collisions, entanglement in fishing gear, and coastal development (Domínguez-Tejo, 2021). Although the species is known to occur along several sectors of the Dominican coastline, published information on population size, structure, and dynamics remains limited (Belitsky & Belitsky, 1980; Domínguez-Tejo, 2021). To date, the country lacks systematic, long-term monitoring programs capable of tracking individuals through space and time, which constrains assessments of population trends, site fidelity, and connectivity among areas of recurrent use. In data-limited regions, standardized monitoring tools are essential for establishing conservation baselines.

Individual identification is a cornerstone of marine mammal research and conservation, as it enables the longitudinal study of animals and populations. Photo-identification (photo-ID), based on naturally occurring external features, has become a well-established research approach across a wide range of marine mammal taxa, avoiding the need for invasive marking techniques. In cetaceans, individual-based catalogs constitute the foundation for population monitoring programs and incorporate procedures for image selection, individual distinctiveness, and data validation as well as analytical tools to assess catalog completeness (Giacomo & Ott, 2016; Riou et al., 2024; Urian et al., 2015). These catalogs provide an objective framework for detecting population changes and informing conservation management decisions.

For sirenians, photo-identification has proven particularly valuable given the logistical and ethical constraints associated with capture-mark-recapture methods. Long-term photo-identification programs developed for the Florida manatee demonstrate that individual-based catalogs can elucidate key population traits, including survival, reproduction, and movement patterns, when sustained through time and supported by rigorous methodological standards (Beck, 2022; Beck & Reid, 1995; Reynolds et al., 2008). These studies emphasize that the construction of a reliable catalog is a prerequisite for demographic inference and long-term population assessment.

Recent advances in small unmanned aerial vehicles (UAVs or drones) have expanded the applicability of photo-identification for manatees by enabling the acquisition of high-resolution imagery over shallow and turbid waters with minimal disturbance to animals. Experimental and operational studies indicate that small multi-rotor UAVs elicit limited behavioral responses in manatees under appropriate flight conditions (Ramos et al., 2018). Building upon these technological advances, Landeo-Yauri et al. (2020) proposed the first standardized UAV-based photo-identification protocol for the Greater Caribbean manatee.

Here, we implement and evaluate a standardized UAV-based photo-identification workflow adapted from Landeo-Yauri et al. (2020) to initiate the first standardized national catalog of individually recognizable manatees in the Dominican Republic and evaluate its performance as a baseline monitoring tool for future demographic and conservation applications.

Between May 2023 and December 2025, a total of 611 UAV surveys were conducted across eleven coastal sites in the Dominican Republic (Fig. 1), previously identified as areas of recurrent manatee occurrence (Belitsky & Belitsky, 1980; Domínguez-Tejo, 2021) and complemented by previous aerial and drone-based census efforts conducted by the authors (unpublished data). This systematic UAV effort constituted the primary source of the combined photographic dataset used for catalog construction. Survey sites and their corresponding provinces were as follows: Bahía de Manzanillo (Monte Cristi); Estero Hondo, Luperón, and La Isabela (Puerto Plata); Las Terrenas (Samaná); Sabana de la Mar (Hato Mayor); Miches (El Seibo); Bayahíbe (La Altagracia); Puerto Viejo (Azua); Club Náutico (Barahona); and Playa Pedernales (Pedernales). All sites share the presence of essential resources that reflect habitat suitability requirements for the species, including shallow waters, seagrass meadows, mangroves, and access to freshwater sources (Herrera, 2024).

Surveys followed a targeted, site-based design intended to locate and photograph manatees using small rotary-wing UAVs (DJI Mavic 3), equipped with integrated high-resolution camera suitable for photo-identification. Flights were conducted at altitudes between 100 and 120 m from sunrise to sunset (approximately 06:00–18:00) and were suspended between approximately 11:00 and 15:00 when high solar zenith angles increased surface glare and reduced detectability. Surveys were conducted under conditions that allowed visual detection, although flights were occasionally conducted under moderate wind conditions depending on operational constraints. To improve detection, a dual-observer approach was implemented, in which a second observer monitored the live video feed via an external HDMI display, complementing the pilot's field of view.

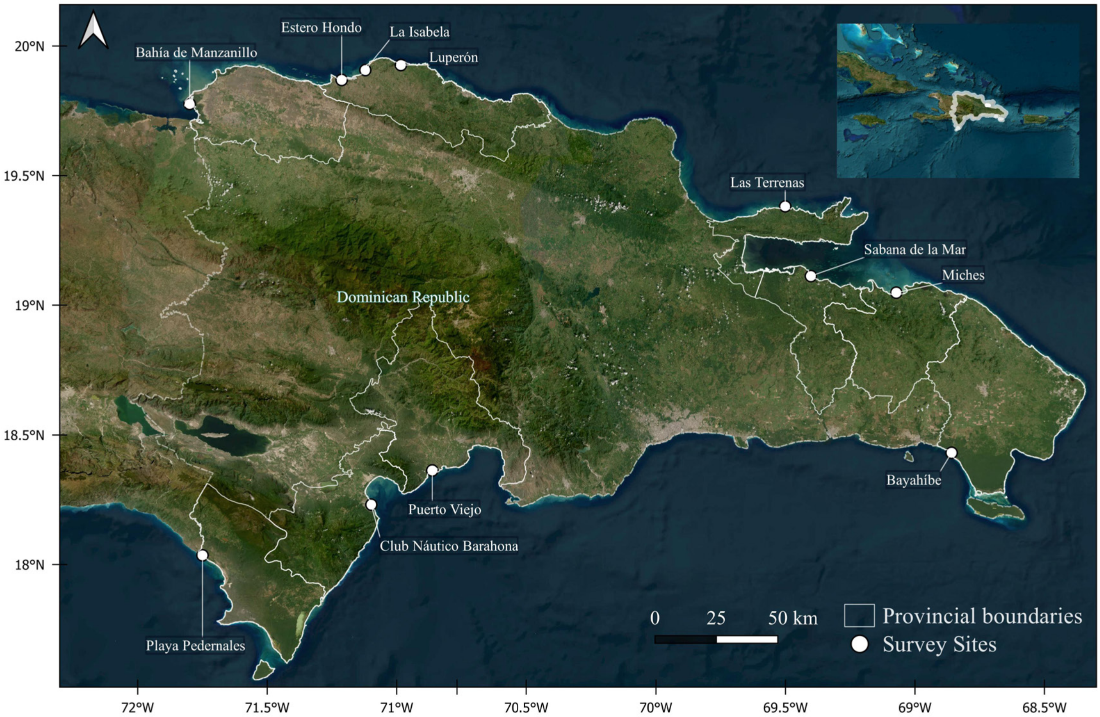

Figure 1. Coastal survey sites used for UAV-based photo-identification of the Greater Caribbean manatee (*Trichechus manatus manatus*) in the Dominican Republic (May 2023–December 2025). White circles indicate survey sites; provincial boundaries are shown in light lines. Inset shows location within the Greater Antilles.

Upon detection, the UAV descended to a typical photo-ID altitude of 30–40 m to balance image resolution and disturbance minimization, as flight altitude has been shown to influence both image quality and animal response to UAVs (Ramos et al., 2018). Operator procedure prioritized gentle hovering and slow passes to obtain high-quality oblique and near-vertical images, maintaining visual contact with the animal and anticipating diving behavior to capture image sequences when the caudal region became visible. Images were acquired in short bursts (5 frames per second) to increase the likelihood of capturing diagnostic features. When multiple individuals were present, operators prioritized a single individual and attempted to obtain repeated image sequences across successive surfacing cycles. For each flight, the following variables were recorded: date, time, province, site name, flight duration (min), flight distance (km), maximum altitude (m), geographic coordinates (latitude/longitude), and environmental conditions (Beaufort Sea state and cloud cover), with flight path files saved and stored.

In addition to images obtained during the standardized UAV surveys described above, the photographic dataset used for catalog construction incorporated complementary records collected between 2021 and 2023. These included photographs obtained during the national drone census, opportunistic UAV flights, and externally contributed images from diver observations. These supplementary records expanded the geographic coverage beyond the systematically surveyed sites and were included only when image quality allowed the assessment of diagnostic features under the same standardized evaluation criteria applied throughout this study. Although integrated into the same workflow, these sources were not considered equivalent in sampling effort to the systematic UAV surveys and were used to complement the catalog rather than to represent standardized survey effort.

Images from all sources were incorporated into a unified curation workflow. For UAV-derived data, photographic material was reviewed directly, and externally contributed photographs (e.g., diver observations) were evaluated under the same criteria. All images were recorded in RAW format (.dng) to preserve image quality and allow subsequent adjustment of contrast, color, and exposure during post-processing using Adobe Lightroom. An initial review identified potential manatee detections, and a first-stage filtering process was applied to remove images that did not meet minimum criteria for photo-identification. Post-processing included image orientation and cropping when necessary to optimize the visibility of diagnostic marks. Each candidate image was assigned a unique ID and linked to available metadata (e.g., date, location, source). This first-stage depuration eliminated approximately 18 052 images, resulting in a curated subset from which 225 images were preselected as candidates for detailed evaluation.

Each preselected image was evaluated using a standardized workflow that assessed image quality (Q) and individual distinctiveness (D), following criteria adapted from established photo-identification protocols (Landeo-Yauri et al., 2020; Ramos et al., 2018) and refined for this study. Individuals were considered for catalog inclusion only if: (1) at least one persistent diagnostic feature was visible (e.g., scars, mutilations, natural skin pigmentation patterns, or distinctive natural features such as tail notches or bifurcations); (2) the feature was clearly depicted in images of sufficient quality; and (3) had minimal occlusion caused by turbidity, glare, or surface foam.

Image quality scoring incorporated resolution, contrast, distortion, body coverage, and angle. Scores were summed and classified into three quality categories: excellent (Q1: 6–8), average (Q2: 9–12), and poor (Q3: >12). Quality scoring followed the criteria proposed by Landeo-Yauri et al. (2020) and are detailed in Table SI (Supporting Information).

Distinctiveness scoring classified images into four categories: D1 (very distinctive), D2 (moderately distinctive), D3 (weakly distinctive), and D4 (not distinctive; Fig. 2). Distinctiveness was assigned at the image level; therefore, multiple images of the same individual could receive different classifications. For catalog purposes, individuals were classified based on the image showing the highest quality and most distinctive features. Category definitions were adapted from Landeo-Yauri et al. (2020) and are provided in Table SII (Supporting Information).

Each individual considered for the catalog was assigned a unique alphanumeric code following the scheme TMRD[NNN], where ‘TM’ = *Trichechus manatus*, ‘RD’ = Dominican Republic, and [NNN] is a sequential number. For each catalog entry, the following information was recorded: code, observation site, date of observation, description of diagnostic features, image file reference (ID), and reviewers.

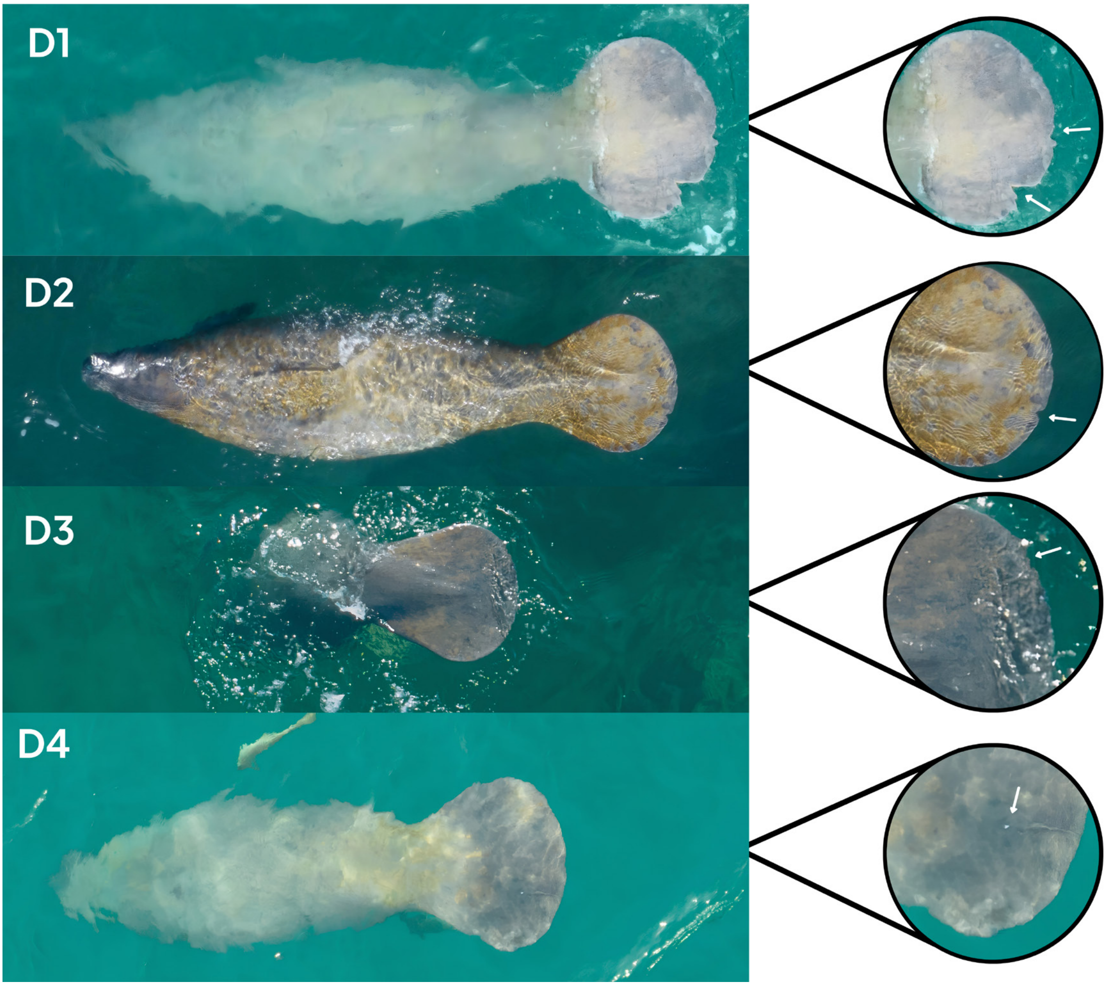

Figure 2. Representative examples of distinctiveness categories (D1–D4) used for photo-identification of the Greater Caribbean manatee (*Trichechus manatus manatus*). White arrows indicate diagnostic features. D1= very distinctive; D2= moderately distinctive; D3= weakly distinctive; and D4= not distinctive.

An initial technical review of candidate images was conducted during the screening phase. Images considered suitable for catalog inclusion were subsequently evaluated independently by at least two trained reviewers. Discrepancies in quality or distinctiveness scoring were resolved through joint review and consensus.

Individuals were considered identifiable when at least one image met the minimum criteria for both quality and distinctiveness. Individuals represented exclusively by images classified as D4 were flagged due to insufficient diagnostic value for reliable identification. Only individuals meeting these criteria were retained in the final catalog. All catalog images were georeferenced when GPS metadata were available and stored in a curated project repository.

A total of 611 UAV surveys conducted across eleven coastal sites resulted in 179 manatee sightings, distributed among all surveyed locations (Table I). Sightings were recorded in all sites, with the highest number observed in Las Terrenas, Puerto Viejo, Estero Hondo, and Club Náutico, whereas the remaining locations showed lower detection frequencies. These sightings represent the outcome of the systematic UAV survey effort and provide the primary source of photographic material for catalog construction.

Table I. Number and percentage of manatee sightings recorded during UAV surveys across 11 coastal sites in the Dominican Republic (n = 179). Percentages represent the proportion of sightings relative to the total number recorded. Values in bold indicate sites with the highest number of sightings.

Province	Site	Sightings (n)	% of total
Montecristi	Bahía de Manzanillo	10	6
Puerto Plata	Estero Hondo	**24**	13
	Luperón	4	2
	La Isabela	4	2
Samaná	Las Terrenas	**63**	35
El Seibo	Miches	7	4
Hato Mayor	Sabana de la Mar	3	2
La Altagracia	Bayahíbe	8	4
Azua	Puerto Viejo	**29**	16
Barahona	Club Náutico	**21**	12
Pedernales	Playa Pedernales	6	3
Total	—	179	100

For the development of the photo-identification catalog, a combined photographic dataset was assembled, integrating images obtained during the systematic UAV surveys (2023–2025) with supplementary records from 2021–2023, including the national drone census, opportunistic UAV flights, and diver-contributed photographs.

From this combined dataset, 225 images were preselected based on the visibility of diagnostic anatomical features following the initial filtering process. Of these, 66 images met the minimum criteria for both quality and distinctiveness, allowing the identification of 48 individuals. After applying the distinctiveness criteria for catalog inclusion, 45 individuals were retained in the final catalog, with the 3 D4 individuals set aside to assess possible IDs in future surveys.

Analysis of the anatomical location of diagnostic features showed that they were primarily located in the caudal region (73%), followed by the dorsal region (10%) and dorsal–caudal combinations (8%). A small number of features were classified as other, including marks located on the head or combined snout–tail features. One individual was recorded as not assigned because the location of the diagnostic mark could not be confidently determined during image reassessment (Table II).

Table II. Anatomical location of diagnostic features used for individual identification. Percentages represent the proportion of evaluated individuals (n = 48).

Body region	Individuals (n)	% of evaluated individuals	Typical diagnostic features
Tail	35	73	Mutilations, natural notches, pigmentation patterns
Dorsum	5	10	Scars and pigmentation patterns
Dorsum + tail	4	8	Combined dorsal and caudal marks
Other	3	6	Head marks or combined snout–tail features
Not assigned	1	2	Diagnostic feature location not determined
Total	48	100	

Classification by type of distinctive mark showed that the most frequent type of diagnostic mark was tail mutilations (33%), followed by natural tail morphology (21%), pigmentation patterns (19%), combinations of mark types (17%), and scars (6%) (Table III). In a small number of individuals (4%), no clearly diagnostic feature could be determined; these cases were later classified as D4 during the distinctiveness assessment.

Table III. Types of diagnostic marks recorded in evaluated individuals (n = 48). Percentages represent the proportion of individuals exhibiting each mark type.

Distinctive mark type	Individuals (n)	% of evaluated individuals
Tail mutilations (edge cuts)	16	33
Natural tail morphology (notches, bifurcations)	10	21
Pigmentation patterns	9	19
Combination of mark types	8	17
Scars	3	6
No diagnostic feature observed	2	4
Total	48	100

The distribution of image distinctiveness categories and individual identification is summarized in Table IV. A total of 67 photographs were evaluated, representing 48 individuals. Most evaluated photographs corresponded to D1 and D2 categories, indicating the presence of clear diagnostic features. A smaller number of photographs were classified as D3, reflecting subtler marks. Photographs classified as D4 lacked reliable diagnostic features and were flagged and set aside as unreliable, pending potential reassessment in future surveys.

Because distinctiveness was assigned at the image level, some individuals were represented by images with different distinctiveness categories.

Table IV. Distribution of evaluated photographs and identified individuals across distinctiveness categories (D1–D4). Distinctiveness was assigned at the image level; therefore, individuals may be represented in more than one category.

Distinctiveness category	Photographs (n)	Individuals (n)
D1 (very distinctive)	27	16
D2 (moderately distinctive)	29	23
D3 (weakly distinctive)	8	8
D4 (color pattern only)	3	3
Total	**67**	**48***

* Individuals may be represented in more than one distinctiveness category due to multiple images.

The spatial distribution of individuals included in the catalog is presented in Table V. A total of 48 individuals were identified across provinces represented in the combined photographic dataset, including sites not covered by the systematic UAV surveys (e.g., Peravia). After applying catalog inclusion criteria, 45 individuals remained in the final catalog. Las Terrenas (Samaná) presented the highest number of individuals identified, followed by Bayahíbe (La Altagracia). Fewer individuals were recorded in coastal waters of Barahona, Puerto Plata, and Azua provinces.

Most individuals classified as D4 were recorded in sites located in El Seibo. No individuals suitable for photo-identification were recorded in Montecristi, Hato Mayor, or Pedernales during the study period.

Representative photographic examples illustrating diagnostic categories are provided herein. The complete photo-identification catalog is publicly available through the FUNDEMAR website (https://www.fundemardr.org/acciones/foto-id). The online catalog reflects the full photographic archive currently available for the project and therefore includes records from multiple sources and capture dates spanning 2021–2025.

The development of the first standardized photo-identification catalog for the Greater Caribbean manatee in the Dominican Republic represents a significant step toward establishing individual-based monitoring tools for this endangered population. This study indicates the feasibility of implementing a UAV-based workflow for catalog construction under field conditions characterized by variable visibility and low detection rates.

Table V. Spatial distribution of evaluated and cataloged individuals by province of record. Distinctiveness categories (D1–D4) correspond to the highest-quality classification available for each individual.

Province	Individuals evaluated	Individuals retained	D1	D2	D3	D4
Montecristi	0	0	0	0	0	0
Puerto Plata	3	3	1	1	1	0
Samaná	23	22	7	13	2	1
Hato Mayor	0	0	0	0	0	0
El Seibo	3	1	0	0	1	2
La Altagracia	9	9	6	3	0	0
Azua	3	3	2	1	0	0
Barahona	6	6	0	4	2	0
Pedernales	0	0	0	0	0	0
Peravia	1	1	0	0	1	0
Total	48	45	16	22	7	3

Individuals are assigned to a single distinctiveness category corresponding to the highest-quality classification when multiple images were available.

A central outcome of this study is the use of a combined photographic dataset, structured around a systematic UAV survey effort and complemented by supplementary records. This approach allowed the integration of spatially and temporally heterogeneous data into a single standardized framework, increasing the likelihood of detecting and documenting individuals across the national coastline. However, as reflected in the filtering process, the application of standardized criteria resulted in a substantial reduction of usable material.

The marked reduction from 225 preselected images to 66 images meeting minimum quality and distinctiveness criteria underscores the importance of rigorous filtering in photo-identification studies. Similar patterns have been reported in marine megafauna, where strict image selection criteria improve identification reliability at the expense of sample size (Urian et al., 2015). This process ultimately enabled the identification of 48 individuals, of which 45 were retained in the final catalog after excluding those lacking sufficient diagnostic features. These results indicate that protocol standardization reduces the volume of usable data while substantially increasing the reliability of individual identifications.

The predominance of diagnostic marks in the caudal region is consistent with previous photo-identification studies on sirenians, where tail morphology and markings, such as mutilations, natural notches, and scars, provide key features for individual identification and constitute persistent and reliable traits for recognition (Beck, 2022). Although mutilations were the most frequent mark type, many consisted of small edge cuts that may be difficult to detect under suboptimal visibility conditions. In contrast, extensive scars, including those consistent with propeller strikes, were less common but highly conspicuous, facilitating rapid recognition even under moderate image quality conditions. Pigmentation patterns exhibited greater variability and dependence on visual quality and therefore required cautious evaluation. This hierarchy in diagnostic reliability is consistent with photo-identification approaches in other marine mammals, where individual recognition relies on persistent and distinctive external features documented under standardized quality criteria (Riou et al., 2024).

The classification of individuals based on distinctiveness categories provides an additional layer of interpretation for catalog reliability. Individuals classified as D1 and D2 represent the most robust component of the catalog, supported by clearly identifiable and persistent features. In contrast, D3 individuals should be considered provisional, as their identification relies on weaker or less consistent features that may require confirmation through future re-sightings. This pattern reflects the iterative nature of catalog development, where increased sampling effort and evaluator consistency can lead to the confirmation or reclassification of individuals over time. The flagging of D4 individuals reinforces the conservative nature of the catalog construction process, ensuring that only individuals with sufficient diagnostic value are prioritized.

Spatial differences in the number of individuals evaluated and cataloged should be interpreted with caution, as detectability is influenced by environmental conditions, particularly water turbidity, as well as variation in sampling effort, which were identified as key factors affecting both detection probability and image quality. UAV-based studies have shown that subsurface visibility, surface glare, and solar angle can limit the detection and evaluation of manatees, particularly in turbid or sediment-laden environments (Landeo-Yauri et al., 2020; Ramos et al., 2017; Ramos et al., 2018). Consequently, sites with clearer waters are more likely to yield high-quality diagnostic imagery, whereas turbid environments reduce the probability of successful individual identification. These constraints highlight the importance of incorporating environmental variability into survey design and support the implementation of site-specific and repeated sampling protocols within a standardized national framework to improve detectability, increase recapture rates, and enhance spatial comparability.

The spatial distribution of identified individuals reflects both ecological patterns and sampling design. Higher numbers of individuals were recorded in areas such as Bayahíbe, Samaná, and Puerto Plata, which are consistent with previously reported areas of recurrent occurrence (Belitsky & Belitsky, 1980; Domínguez-Tejo, 2021). Seven manatees were re-identified on different field trips at the same site. Only one manatee in Samaná province was recorded at Las Terrenas and later reported by community members at another site, Playa Fronton, 50 km away. However, these patterns should be interpreted cautiously, as differences in survey effort, detectability, and the inclusion of supplementary records limit direct comparisons among sites. The contribution of records from areas not included in the systematic survey design, such as Peravia, further emphasizes the value of integrating multiple data sources while acknowledging their limitations.

The progressive consolidation of the catalog will enable the investigation of key ecological and conservation questions, including site fidelity, spatial connectivity, individual survival, and identification of anthropogenic threats. Long-term manatee photo-identification programs have demonstrated their value for elucidating population structure, site fidelity, movement patterns, and life-history traits, thereby providing critical information for conservation and management (Beck & Reid, 1995; Reynolds et al., 2008). These approaches contribute to long-term datasets that have been fundamental for advancing the understanding of manatee population biology and informing conservation strategies (O'Shea et al., 1995). In this context, the documentation of scars consistent with vessel strikes in several localities further illustrates the catalog's capacity to detect spatial patterns of human-related risk.

UAV-based approaches represent an efficient and low-impact tool for acquiring diagnostic imagery in shallow and complex Caribbean habitats (Landeo-Yauri et al., 2020; Ramos et al., 2017), supporting their continued application within standardized monitoring frameworks. As recapture rates increase and sampling effort becomes more consistent, this catalog has the potential to evolve from a descriptive baseline to a robust monitoring tool for informing national conservation strategies. Ultimately, it will allow the evaluation of whether manatees in the Dominican Republic exhibit localized site fidelity or broader population connectivity, strengthening evidence-based conservation planning in the Wider Caribbean region.

Overall, this study establishes a standardized and reproducible framework for photo-identification of manatees in the Dominican Republic. While the current catalog represents an initial baseline, its structure allows for future expansion and refinement through continued monitoring, re-sightings, and integration of new records. By prioritizing diagnostic reliability over data volume within a unified national framework, this approach provides a robust foundation for long-term individual-based monitoring and contributes directly to the conservation and management of the species. Moreover, the methodology has strong potential for application in other regions where manatees are challenging to photograph or record due to environmental conditions, such as turbine riverine systems in the Amazon basin or brackish environments in Africa. As such, this framework offers a scalable and adaptable tool to support population monitoring and conservation efforts across the global range of sirenians.

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SUPPORTING INFORMATION

Table SI. Image quality scoring criteria adapted from Landeo-Yauri et al., (2020) and applied in this study.

Factor	Description	Scoring
Resolution / clarity	Sharpness of image	2 = excellent 4 = average (grainy) 9 = poor (blurred)
Contrast	Range of tones in the image	1 = ideal 2 = excessive or minimal
Distortion	Portion of manatee body distorted by water surface movement	1 = none to little 2 = partial 8 = complete
Partial	Portion of manatee body visible. Body parts can be covered by turbidity and/or light reflection	1 = all body visible 2 = body partially visible
Angle	Angle of dorsal view to camera	1 = perpendicular 2 = moderately angled

Table SII. Distinctiveness categories used for individual classification, adapted from Landeo-Yauri et al., (2020).

Category	Description	Identification reliability
D1 (very distinctive)	Prominent, permanent marks (e.g., deep tail mutilations, large scars) visible under all image quality conditions	High
D2 (moderately distinctive)	Clear and persistent marks visible in good-quality images (e.g., defined scars, stable tail notches)	Moderate
D3 (weakly distinctive)	Subtle or small marks visible only in high-quality images and potentially difficult to recognize in future encounters	Low (provisional)
D4 (not distinctive)	Color patterns or non-persistent features lacking long-term diagnostic value	Not reliable