Latin American Journal of Aquatic Mammals

ISSN: 2236-1057 | Vol. 19 No. 1, April 2024

Antillean manatees feed on floating *Halophila baillonii* in Placencia Lagoon, Belize

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The West Indian manatee (*Trichechus manatus*) is an herbivorous aquatic mammal classified as Endangered by the International Union for Conservation of Nature (IUCN) due to anthropogenic threats including habitat loss, hunting, and bycatch (Deutsch et al., 2008). The Antillean manatee (*T. m. manatus*) subspecies is classified as Endangered (Self-Sullivan & Mignucci-Giannoni, 2008) and distributed across the Gulf of Mexico and the Caribbean Sea, and as far south as Brazil (Lefebvre et al., 2001; Alves-Stanley et al., 2010). Although manatees are protected by law in Belize, they continue to face numerous threats, such as collisions with boats and entanglement in fishing gear (Auil, 2004; Galves et al., 2023a, b). Understanding their feeding ecology, including their diet, and feeding habits, is crucial for their effective management and conservation (Wirsing et al., 2022).

Unlike the seagrass-eating dugongs (Marsh et al., 1982), manatees are generalist and opportunistic feeders, consuming submersed, floating, and riparian vegetation (Hartman, 1979; Best, 1981). The composition of their diet is heavily influenced by the availability, distribution, and abundance of primary producers (Etheridge et al., 1985). Due to the large variety of habitats where manatees occur (Lefebvre et al., 2001), they display high variability in their foraging habits, reflected in their diet composition (Wirsing et al., 2022). Among manatees, the Antillean manatee is probably the most plastic species regarding habitat, feeding in freshwater, estuarine, and marine environments (Castelblanco-Martínez et al., 2021). In coastal areas, they consume parts of mangroves, algae, and a variety of seagrass species, with the most commonly reported being *Thalassia testudinum, Syringodium filiforme*, and *Halodule wrightii* (*e.g.,* Castelblanco-Martínez et al., 2009; Allen et al., 2018; see Table 1 for a review). However, their diet can vary depending on the seagrass species available in their habitat; for example, Florida manatees in the Indian River Lagoon in Florida, USA were shown to shift their dietary composition from seagrasses to algae following major seagrass decline associated with harmful algal blooms (Allen et al., 2022). The feeding habits and diet of Antillean manatees play a critical role in their survival and population dynamics, highlighting the importance of maintaining healthy seagrass ecosystems in their habitats.

Halophila baillonii is a species of seagrass found in several places throughout the Caribbean Sea (Samper-Villarreal et al., 2014; Caviedes & Carrasco, 2016; Samper-Villarreal & Cortes, 2020; van Dijk et al., 2023), including in Placencia Lagoon in southern Belize (Short et al., 2006a). It has a distinctive appearance with four petal-shaped leaves and a long, distinct leaf petiole (Short et al., 2006a; Figs 1A, 1B). *Halophila baillonii* beds can be found to be mixed with other seagrass species such *Halodule wrightii* and *Halophila decipiens* (Magalhães et al., 2015). In Placencia Lagoon, *Halophila baillonii* was found to occupy large monospecies meadows, extending from the mouth of the lagoon to the upper end of the estuary and dominating the substrate throughout most of the lagoon (Short et al., 2006a). The lagoon also hosts a variety of other seagrass species including *T. testudinum, S. filiforme, Halodule wrightii,* and *Halophila decipiens* (Short et al., 2006b). The extent of the meadow is estimated to cover almost half the area of the lagoon, which is approximately 3,000 hectares (Short

Keywords:
clover grass, foraging, seagrass,*Trichechus manatus manatus*

ARTICLE INFO

Manuscript type: Note

Article History
Received: 03 September 2023
Received in revised form: 01 November 2023
Accepted: 06 November 2023
Available online: 29 February 2024

Handling Editor: Ana Carolina Meirelles

Citation:
Ramos, E. A., Tellez, M., Castelblanco-Martínez, N., & May-Collado, L. (2024). Antillean manatees feed on floating *Halophila baillonii* in Placencia Lagoon, Belize. *Latin American Journal of Aquatic Mammals, 19*(1), 133-140. https://doi.org/10.5597/lajam00322

Figure 1. Images of the seagrass *Halophila baillonii* found in the northern end of Placencia Lagoon in southern Belize. A) Various pieces of *H. baillonii* collected at the water's surface in Placencia Lagoon with a ruler for scale. B) *H. baillonii* was regularly documented to bloom in large quantities, creating masses of floating mats and large deposits of seagrasses along the lagoon's shores. Photo credit: Eric A. Ramos.

et al., 2006a). In many regions of Placencia Lagoon, seagrass meadows stretch from within the mangrove prop roots to the barrier peninsula (Short et al., 2006a). The lagoon's sediments are fairly uniform mud and sand, and *H. baillonii* is found in shallow, sheltered areas up to a depth of 30 meters (Short et al., 2006a). Lower shoot and density of *H. baillonii* have been reported during the rainy season in Costa Rica (Samper-Villarreal et al., 2022) and Brazil (Magalhães et al., 2015), due to a decrease in water transparency. Similar seasonality can be expected in Belize but, to our knowledge, this has not been described.

Manatees in Placencia Lagoon were previously reported to consume *H. baillonii* (Short et al., 2006a), but no direct observations or sightings supported these claims. To the best of our knowledge, no other information is available on the diet of local manatees in the lagoon. Here, we present direct surface observations of Antillean manatees consuming floating *H. baillonii* in the northern sections of Placencia Lagoon. Drone footage and surface observations of manatees from a kayak provided visual confirmation of manatees directly feeding on *H. baillonii,* sometimes with numerous manatees feeding simultaneously on floating mats composed primarily of *H. baillonii*. Additionally, in Table 1 we briefly review the known food items of Antillean manatees in the region to contextualize our report.

From December 2022 to June 2023, data on manatees were collected in the shallow waters of the northern section of Placencia Lagoon, directly east of Maya Beach in the Stann Creek district of southern Belize (Fig. 2). Data were captured in one of two ways: with surface observations from a kayak or using a small aerial drone. Opportunistic manatee sightings from a double kayak were done sporadically throughout the study period for 2–3 hours, from 05:00 h to 18:30 h. Manatee observations from the kayak were filmed with a Canon EOS 80D digital SLR camera equipped with a 100–400 m telephoto lens or filmed with an iPhone 13 (Apple Inc.). We flew two different small drone models over areas with manatees. The drone was flown at altitudes of 20 to 100 m with the objective of enabling detection of manatees and imaging of animals and their behavior. A single pilot (ER) launched a DJI Phantom 4 or a DJI Mavic 3 Mini from land and piloted the aircraft with the DJI Fly app on its remote controller. Flights took place primarily in the morning (06:00 h–10:00 h) and afternoon (15:00 h–18:00 h) to avoid the high levels of glare from the sun from 10:00 h to 14:00 h, and only in non-rainy conditions with low wind speed (0–20 kts). The gimbal-stabilized camera was pointed or angled (60-90°) to image manatee activity. The camera filmed in 4 K (for both drones 3840 X 2640 dpi) at 30 fps, storing the data on a microSD card. The aircraft was flown for nine to 18 min until the battery had 30% power remaining, then returned to land. The live view was transmitted to the remote control and helped to maintain the animals in the field-of-view of the camera.

All videos were later reviewed by EAR using QuickTime Media Player on a desktop computer to identify all instances of manatee foraging at the surface (all event sampling; Mann, 1999). To ensure there was no impact on manatee behavior, videos were also reviewed to identify possible disturbance behaviors in response to the drone (*e.g.,* fleeing, clustering together; Ramos et al., 2018; Landeo-Yauri et al., 2021).

A total of 327 flights were conducted over 83 days resulting in the capture of 117.2 hours of video aerial observations. No disturbance responses were observed. On four days (15, 16, 17, and 18 January 2023), one to nine Antillean manatees were observed consuming floating *H. baillonii* while in proximity or immersed in mats floating at the surface. These mats were composed primarily of *H. baillonii* interspersed with detritus and vegetation (*e.g.* mangrove leaves).

In aerial drone observations on 15 and 17 January 2023, numerous manatees were sighted feeding near the edges of these large mats floating at the water's surface (Figs 3A, 3B; Supplementary Video S1). Using manatees as a course scale for size, the mats were estimated to be approximately several meters wide, and one meter to tens of meters long (Figs 3A, 3B). When first sighted at 07:14 h on 17 January 2023, four manatees fed on floating seagrass at the surface, clustered less than a meter apart (Figs 3A, 3B). The manatees fed at the edge of the floating mat, following the mat as it drifted at the water's surface (Fig. 3B). The animals took breaths regularly but continued to consume floating vegetation after each surfacing. In flying the drone

Table 1. Primary producers reported as items in the diet of Antillean manatees (*Trichechus manatus manatus*).

Species	Location	References
Aeschynomene rudis	Mexico	1
Amansia multifida	Brazil	2, 3
Anadyomene stellata	Brazil	2
Avicennia germinans	Brazil	2, 3, 4, 5, 6
Bacopa egensis	Mexico	1
Batophora sp.	Mexico	Pers. obs. DNC-M
Blutaparon portulacoides	Brazil	2, 3
Bryothamnion seaforthii	Brazil	2
Cabomba aquatica	Guyana	7
Caperonia castaneifolia	Mexico	1
Caulerpa cupressoides	Brazil	2, 3
Caulerpa mexicana	Brazil	2, 3
Caulerpa prolifera	Brazil, Puerto Rico	2, 3, 8
Caulerpa racemosa	Brazil	2, 3
Caulerpa sertularioides	Brazil	2, 3
Caulerpa sp.	Cuba	9
Chara sp.	Belize, Guatemala, Mexico	10, 11, 12
Cryptonemia crenulata	Brazil	2, 3
Cyperus digitatus	Mexico	1
Cyperus spp.	Mexico	1
Cyperus imbricatus	Mexico	1
Dalbergia glabra	Mexico	1
Dictyopteris deliculata	Brazil	2, 3
Dictyota deliculata	Brazil	2, 3
Dictyota mertensii	Brazil	2, 3
Echinochloa polystachya	Mexico	1
Eichhornia crassipes	Brazil, Mexico	1, 4, 5, 6
Eichhornia spp.	Brazil	2, 3
Eragrostis contrerasii	Mexico	1
Eriochloa punctata	Mexico	1
Gelidiella acerosa	Brazil	2, 3
Gelidium sp.	Brazil	2, 3
Gracilaria caudata	Brazil	2, 3
Gracilaria domingensis	Brazil	2, 3
Gracilaria obtusata	Brazil	2, 3
Gracilaria sp.	Brazil	2, 3
Fimbristylis vahlii	Mexico	1
Halimeda sp.	Cuba	9
Halodule wrightii	Belize, Brazil, Mexico, Puerto Rico	2, 3, 8. 9, 10, 11, 13, 14, 15
Halophila baillonii	Belize	This study
Halophila sp.	Belize	11
Hydrocotyle umbellata	Trinidad	16
Hymenachne amplexicaule	Guyana	7
Hypnea musciformis	Brazil	2, 3
Hypnea spinella	Brazil	2, 3
Ipomoea aquatica	Trinidad	16
Laguncuaria racemosa	Brazil	9, 17
Laurencia sp.	Brazil	2, 3
Leersia hexandra	Trinidad	16
Leptochloa panicea	Mexico	1
Leptochloa panicoodes	Mexico	1
Ludwigia peploides	Mexico	1

Species	Location	References
Luziola spruceana	*Guyana*	7
Lyngbya sp.	Belize	11
Machaerium lunatum	Suriname	17
Montrichardia arborescens	Brazil, Guyana, Suriname	4, 5, 6, 18
Najas sp.	Mexico	10
Nelumbo speciosa	Guyana	7
Neptunia natans	Mexico	1
Nymphaea ampla	Guatemala	12
Osmundaria obtusiloba	Brazil	2
Padina gymnospora	Brazil	2
Panicum sp.	Mexico, Suriname	1, 17
Paspalum fasciculatum	Mexico	1
Paspalum repens	Guyana, Mexico	1, 7
Paspalum vergatum	Guyana	7
Phyla strigulosa	Mexico	1
Pistia stratiotes	Guatemala, Trinidad	12, 16
Pontederia sagittata	Mexico	1
Rhabdadenia biflora	Brazil	4, 5
Rhizophora mangle	Belize, Brazil, Mexico	2, 3, 4, 5, 10, 11
Ruppia maritima	Belize, Mexico	10, 11
Sagittaria latifolia	Mexico	1
Sargassum sp.	Brazil	2, 3
Sesuvium portulacastrum	Brazil	2, 3
Setaria glauca	Mexico	1
Spartina brasiliensis	Brazil	4, 5
Syringodium filiforme	Belize, Cuba, Puerto Rico	8, 9, 11, 13, 14, 15, 19
Thalassia testudinum	Bahamas, Belize, Cuba, Dominican Republic, Mexico, Puerto Rico	4, 9, 11, 13, 14, 20
Typha domingensis	Mexico	1
Ulva lactuca	Puerto Rico	8
Ulva sp.	Belize, Brazil	2, 3, 11
Utricularia foliosa	Guyana	7

References: 1. Gonzalez-Socoloske & Olivera-Gomez (2019), 2. Borges et al. (2008), 3. Rodrigues et al. (2021), 4. Domning (1981), 5. Best & Teixeira (1982), 6. O'Shea et al. (1986), 7. Haigh (1991), 8. Mignucci-Giannoni & Beck (1998), 9. Navarro-Martínez et al. (2014), 10. Castelblanco-Martínez et al. (2009), 11. Allen et al. (2018), 12. Quintana-Rizzo (1993), 13. Hartman (1979), 14. LaCommare et al. (2008), 15. Powell et al. (1981), 16. Boyle & Khan (1993), 17. Husson (1978), 18. Duplaix & Reichart (1978), 19. Estrada & Ferrer (1987), 20. Odell et al. (1978).

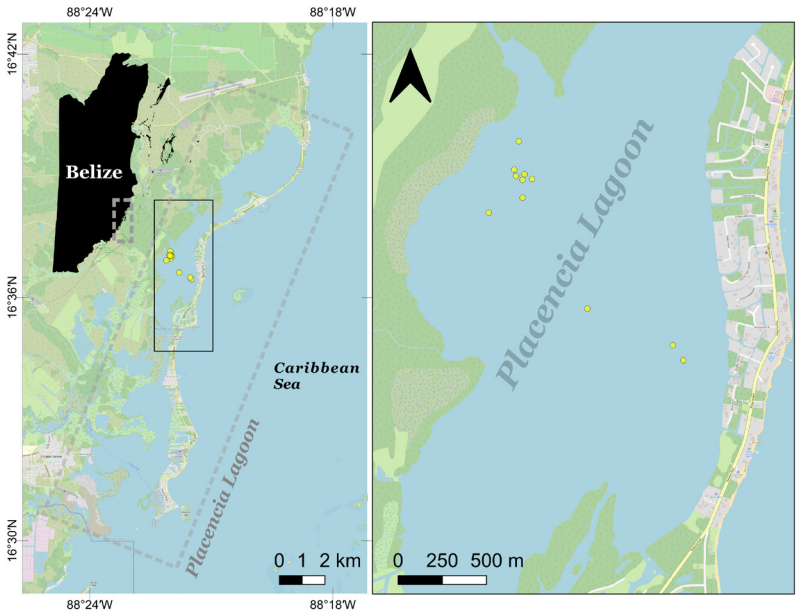

Figure 2. Map depicting sightings of Antillean manatees (*Trichechus manatus manatus*) in Placencia Lagoon in southern Belize. Locations of observations of manatees feeding on seagrass *Halophila baillonii* are denoted with a square.

Figure 3. Surface images of Antillean manatees (*Trichechus manatus manatus*) feeding on seagrass *Halophila baillonii* floating at the surface waters in Placencia Lagoon in southern Belize. A) Two manatees feeding at the surface on floating *H. baillonii* amidst seafoam and other detritus. Leaves and stems are visible on their snouts. B) A single manatee skimming the surface for seagrass before consuming floating seagrass. Images captured with a digital SLR from a kayak. Photo credit: Eric A. Ramos.

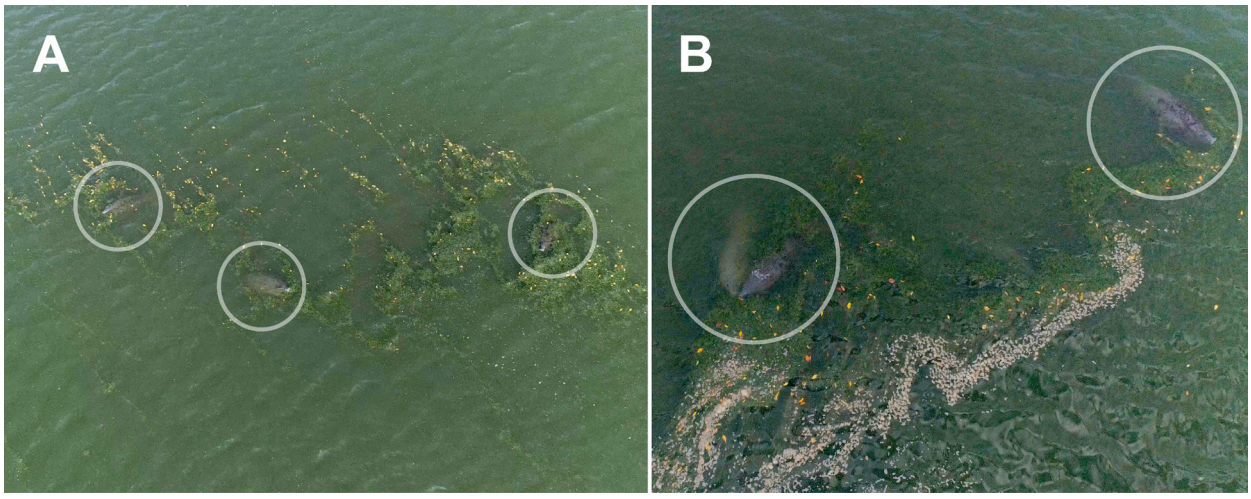

Figure 4. Aerial drone imagery of Antillean manatees (*Trichechus manatus manatus*) feeding at the surface on seagrass *Halophila baillonii* floating in large mats of vegetation in Placencia Lagoon, Belize. Manatees are encircled in white. A) Three manatees surface feeding while spread out in a floating mass of detritus composed primarily of *H. baillonii.* B) Three manatees feeding at the edge of the floating mat. Video and still imagery were captured with a DJI Phantom 4 Pro drone in the morning of 17 January 2023. Photo credit: Eric A. Ramos.

around the area, at least eight other manatees were identified at the edge of mats spread out over tens to hundreds of meters.

On 17 and 18 January 2023, manatee feeding appeared to be long in duration, with multiple manatees continuing to feed beyond the times of multiple drone flights to the same location for three to four hours in several locations throughout the northern section of Placencia Lagoon (Fig. 2). However, due to the limited underwater visibility and lack of identifying features on feeding manatees, it was unfeasible to identify how many manatees were feeding or track individual feeding times.

Similar to our drone observations, in surface observations filmed from a kayak on 16 January 2023, two to four manatees fed at the same time at the edges of the floating mats at the water's surface (Figs 4A, 4B; Supplementary Video S2). One manatee fed at the surface for at least four minutes and 22 seconds, continuously swimming while opening and closing its mouth around seagrasses (Figs 4A, 4B). Of the 15 kayak surveys conducted, surface feeding was also only observed on the single day we report here.

Our observations provide direct evidence of Antillean manatees surface feeding on floating *H. baillonii* in Placencia Lagoon, Belize. These findings confirm previous reports of manatees feeding on this seagrass in this area (Short et al., 2006a), and suggest this species could be an important food source for local manatees. Manatees were also regularly observed throughout the study period feeding on benthic seagrasses including this species (E. A. Ramos, unpub. data), supporting previous reports of the importance of this resource to local manatees (Short et al., 2006a). Over a five-month period, the presence of large volumes of *H. baillonii* was evident at the water's surface throughout the northern Placencia Lagoon and lining the eastern and western shorelines, clumping up on beaches and covering mangrove roots. Given the dominance of this seagrass within the lagoon, these were the most likely forage for manatees in the substrate and manatees were regularly observed feeding on the submerged seagrass beds at their critical habitats in the lagoon. Thus, floating *H. baillonii* may provide a sporadically available resource to manatees, consumed opportunistically when large masses of *H. baillonii* and other vegetation and detritus float across the surface of the lagoon. The drivers of these masses are unclear and could be the result of periodic blooms of seagrasses and/or weather associated with high winds and strong currents causing seagrass

to detach and uproot from the substrate (Oprandi et al., 2020). Additionally, while we directly observed manatees consuming *H. baillonii*, they may also consume other floating vegetation such as mangrove leaves or propagules (Allen et al., 2018).

Future research into *H. baillonii,* its nutritional value as an item of manatee's diet, and its ecology in Placencia Lagoon would enhance our understanding of local Antillean manatees in multiple ways. Firstly, seagrasses are a crucial food source for manatees in coastal areas of the Caribbean (Castelblanco-Martínez et al., 2009; Allen et al, 2018), and by studying the distribution and abundance of this and other seagrass species in the lagoon, we can gain a better understanding of the manatees' feeding habits and nutritional needs (Lefebvre et al., 2001). Secondly, seagrasses play a critical role in shaping the lagoon's physical environment, including water quality, sediment stability, and shoreline erosion. These factors can all affect the habitat suitability for manatees, and understanding how seagrasses influence these factors can aid in conservation efforts for the species (Fourqurean & Zieman, 2002), particularly considering future impacts to sirenians; for example, shifts in their distribution and reductions of feeding resources associated with human-driven habitat loss and climate change (Marsh et al., 2022). These issues already threaten manatees in the region as losses of numerous seagrass habitats of different species have been documented in Belize (Gaston et al., 2009). This includes Placencia Lagoon that underwent dramatic decline in seagrass coverage from 2003 to 2008 associated with eutrophication driven by effluent from shrimp farms and heavy coastal development (Short et al., 2006b). Finally, our observations highlight the strength of alternative monitoring techniques to traditional area surveys and animal captures for in-depth studies of Antillean manatee diets; for example, the power of small drones for non-invasively revealing critical components of the ecology and morphology manatees (Landeo-Yauri et al., 2020; Ramos et al., 2022) and for passive acoustic recording devices to detect manatee vocalizations and feeding sounds (Kikuchi et al., 2014; Ramos et al., 2020).

The results of this study can be used to inform conservation efforts aimed at protecting seagrass beds and preserving the habitat of Antillean manatees in the region. Placencia Lagoon is currently being considered for protection as a marine protected area or wildlife sanctuary (M. Tellez, Crocodile Research Coalition, 07 August 2023, pers. comm.) due to their high local manatee abundance and the high level of manatee mortalities they experience there (Galves et al., 2023a, b). Further studies on the feeding ecology of Antillean manatees, including their feeding rates and the potential impact of anthropogenic disturbances, will be essential for the effective management of these populations in the future.

Acknowledgments

We thank the residents of Placencia Lagoon for supporting the work of the Crocodile Research Coalition and our work with manatees. This research was permitted by the Belize Fisheries Department.

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SUPPLEMENTARY MATERIAL

Supplementary Video S1. Aerial drone observations of Antillean manatees *Trichechus manatus manatus* feeding on *Halophila baillonii* in Placencia Lagoon, southern Belize. Observations were made with a DJI Phantom 4 Pro on 17 January 2023. Photo credit: Eric A. Ramos. https://zenodo.org/doi/10.5281/zenodo.10070374

Supplementary Video S2. Surface observations of Antillean manatees *Trichechus manatus manatus* feeding on *Halophila baillonii* in Placencia Lagoon, southern Belize. Observations were filmed from a kayak on 16 January 2023 with a Canon EOS 80D SLR camera with a 100-400 m telephoto lens. Photo credit: Eric A. Ramos. https://zenodo.org/doi/10.5281/zenodo.10070374