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Is the West Indian Manatee (*Trichechus manatus*) at the Brink of Extinction in the State of Veracruz, Mexico?

Arturo Serrano,[1] Iliana del Carmen Daniel-Rentería,[1] Tania Hernández-Cabrera,[1] Gerardo Sánchez-Rojas,[2] Liliana Cuervo-López,[1] and Agustín Basáñez-Muñoz[1]

[1] *Laboratorio de Mamíferos Marinos, Universidad Veracruzana, Km 7.5 Carretera Tuxpan-Tampico, CP 92850, Tuxpan, Veracruz, México*
E-mail: arserrano@uv.mx
[2] *Centro de Investigaciones Biológicas, Universidad Autónoma del Estado de Hidalgo, Km 4.5 Carretera Pachuca Tulancingo, Pachuca, Hidalgo, CP 42184, México*

Abstract

The West Indian manatee (*Trichechus manatus*) is distributed from the Atlantic coast of the United States to the center of Brazil along the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. The species' current distribution is more fragmented than in the past, and manatee populations are generally less abundant than they were during the last century. In Mexico, there is no specific information about the size of the manatee populations. Hence, the objective of this study was to estimate the density and abundance of manatees in the Alvarado Lagoon System (ALS) in Veracruz using distance sampling. In total, 959 systematic line transects were surveyed using a small boat. These surveys covered 90% of the ALS. Manatee density and abundance for the entire ALS was estimated at 0.23 animals/km^2 (CV 34.48%) and 121 manatees (CV 34.48%), respectively. These are the first density and abundance estimates for this lagoon system and for the State of Veracruz. The extremely low number of manatees supports the urgent implementation of effective conservation measures for the species to prevent extinction of this species in Veracruz.

Key Words: West Indian manatee, *Trichechus manatus manatus*, abundance, density, Veracruz, conservation, coastal management, Gulf of Mexico, Sirenia

Introduction

The West Indian manatee (*Trichechus manatus*) is distributed from the Atlantic coast of the United States to the center of Brazil along the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico (Lefebvre et al., 2001). Water temperature is one of the key factors influencing the distribution of this species, which is often associated with habitats warmer than 24° C (Whitehead, 1977; Edwards, 2013; Kleen & Breland, 2014). The current distribution of West Indian manatees is fragmented, and the species is less abundant than in the past century. This decline in abundance is mainly due to uncontrolled hunting and habitat loss (Powell, 1996). This species is designated as threatened with extinction by the Convention on International Trade in Endangered Species (CITES) (2008), vulnerable by the International Union for Conservation of Nature and Natural Resources (IUCN) (2008), and threatened with extinction by the Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT) (2010).

The overall status of manatees in Mexico is unknown (United Nations Environment Programme [UNEP], 2010). Based on empirical data, some authors have suggested that there are about 1,000 to 2,000 manatees in Mexico (UNEP, 2010). A few local populations have been studied—for example, approximately 250 manatees have been estimated for the State of Quintana Roo (Colmenero & Zárate, 1990; Morales-Vela et al., 2000). The other states with manatee populations have no precise data on the abundance of this species.

Manatees have been reported along the entire coast of the State of Veracruz (Colmenero & Hoz, 1986); however, recent studies proved that the species has disappeared from the north of the state (Serrano et al., 2007). The largest and most preserved manatee population in Veracruz may be in the Alvarado Lagoon System (ALS) (Ortega-Argueta et al., 2003). Therefore, the purpose of this study was to estimate the density and abundance of manatees in the ALS to obtain baseline data which can be compared to other manatee populations in Mexico and allow for long-term assessments of this population in Veracruz.

Methods

Study Area

The ALS is located in the center of Veracruz between 18° 53' N, 95° 34' W and 18° 25' N, 96° 08' W (Figure 1). The ALS is a floodplain made up of coastal lagoons, over 100 inland lakes, and several rivers. This lagoon system has an extension of 56,500 ha. It is inhabited by 45 phytoplankton genera, nine zooplankton species, 38 mollusk species, 26 crustacean families, 44 fish species, more than five amphibians, 24 reptile species, 346 bird species (Cruz, 1999), and more than 15 mammal species (Montejo-Díaz, 2003).

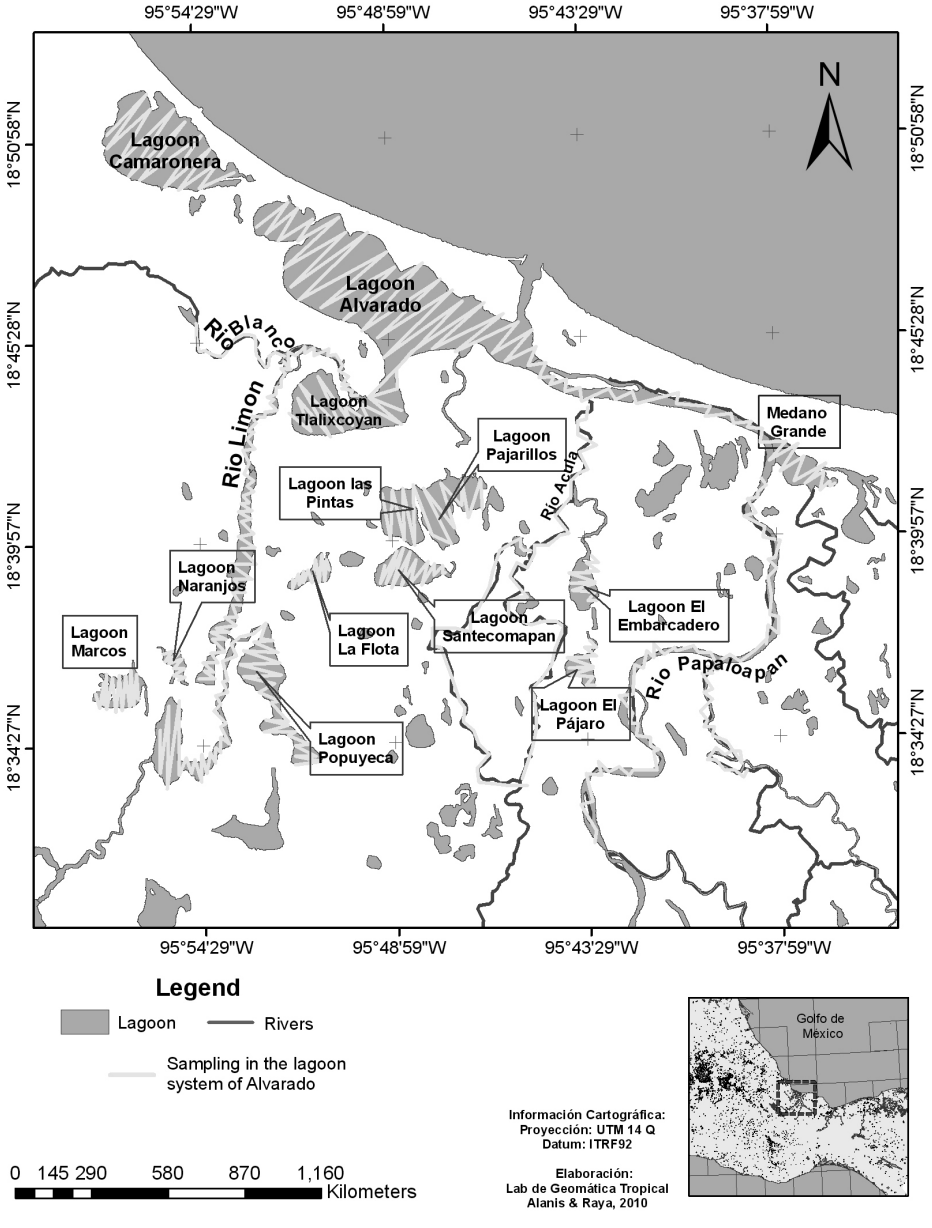

Figure 1. Geographic locations of the study area and of line transects carried out in the Alvarado Lagoon System (ALS), achieving 94% coverage of the site

Data Collection

To estimate the density and abundance of manatees, a distance sampling methodology was employed (Buckland et al., 2001). Systematic line transects were carried out covering the entire study area. The transects were designed using the methodology presented by Thomas et al. (2007) and Buckland et al. (2008) for complex systems using the software *Distance*, Version 5.0, Release 2 (Thomas et al., 2006). The program was used to design equally spaced zigzag line transects over the entire study area. New random transects were generated for each biweekly survey to maximize spatial coverage of the study area. Transects were completed biweekly using a boat 7 m in length with a 2-m beam and one 115-hp outboard engine. The surveys were carried out at 15 km/h, and the following data were collected: date, sighting time, and general environmental conditions.

The total number of manatees sighted was recorded in addition to information on manatee movements in relation to the boat, and the distance and angle to the manatee from the boat. The distance and angle to the animals were obtained with a hand-held rangefinder (Bushnell model Scout 1000 ARC Laser [range: 4.5 to 914 m]). Since ALS waters are extremely murky, a side-scan sonar and a hydrophone array that detects low-frequency mammal vocalizations (Tyack & Clark, 2000) were used to detect manatees. The side-scan sonar was a Hummingbird model 734c[2] (depth capability = 330 m; operating frequency = 200 kHz single beam; area of coverage = 20° @ -10 dB in 200 kHz; target separation = 63.5 mm), which was used as recommended by Gonzalez-Socoloske et al. (2009). The side-scan sonar provided distance and angle to manatees that were detected but not sighted visually above the water surface. The hydrophone array contained two hydrophones (Cetacean Research Technology model C54XRS [frequency response 1 Hz to 200 kHz]) with an interface model M-Audio Fast Track PRO (24-bit/96 kHz) and a laptop. The distance of manatees to the boat was estimated using the difference of time of arrival of the manatee sounds between the hydrophones.

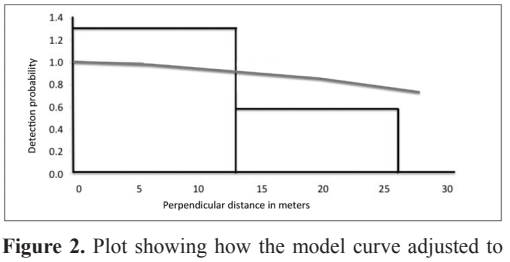

Figure 2. Plot showing how the model curve adjusted to the data; the Half-Normal model was used.

Data Analysis

Distance sampling was used to estimate manatee density and abundance in the ALS (Buckland et al., 2001). Density and abundance estimates were generated using the software *Distance*, Version 5, Release 2 (Thomas et al., 2006). A Half-Normal key function was used to analyze the data as it yielded the best fit to the data (Figure 2). With this methodology, an estimate of abundance based on sightings during travel was achieved. A sighting was considered to be a manatee detection by any one method (e.g., visual, acoustic, or sonar). The basic parameters of the estimate are (Thomas et al., 2010)

$$\hat{N} = \sum_{i=1}^{n} \frac{1}{\hat{P}_i}$$

where $\hat{N}$ = total population size, $\hat{P}$ = estimated inclusion probability for animal i, n = number of observations, and $\hat{P}_i$ (has two components): (1) probability that animal i falls within the sampled plots and (2) an estimate of its probability of detection. Data were obtained by searching for manatees along the default transect lines.

Results

The total search effort covered 332.36 h with an average of 7.38 h/d. A total of 959 transects covering 46,764 ha (83% of the ALS) were surveyed (Figure 1). From October 2008 to January 2011, 13 manatees were detected in the ALS (seven by direct sight, three by hydrophone array, and one by side-scan sonar). These animals were detected in the Tlalixcoyan Lagoon (four animals, 31%), Medano Grande Lagoon (four, 31%), Limón River (two, 15%), Culebrilla Lagoon (one, 8%), Camaronera Lagoon (one, 8%), and Alvarado Lagoon (one, 8%) (Figure 3).

A relative abundance of 0.39 animals/h was estimated for the entire ALS when we pooled all data. The efficiency of each manatee detection tool was estimated: 0.021 animals/h by direct sightings, 0.015 animals/h using the hydrophone array, and 0.003 animals/h using side-scan sonar (Figure 4).

The relative number of detections per season was calculated as well. For this analysis, no distinctions between detection methods were made. The season with the most manatee detections was the rainy season (July through October) with 0.05 animals/h, followed by the dry season (March through June) with 0.028 animals/h. The season with the least animals was the cold front season (November through February) with 0.022 animals/h (Figure 5). Similarly, the relative

abundance by year was estimated: the year with the most manatee detections was 2008 with 0.022 animals/h, followed by 2010 with 0.017 animals/h. The year with the fewest animals was 2009 with 0.0042 animals/h (Figure 6). The total manatee abundance for the ALS was 121 individuals (CV 34.48%), with a density of 0.23 animals/km^2 (CV 34.48%) (Table 1).

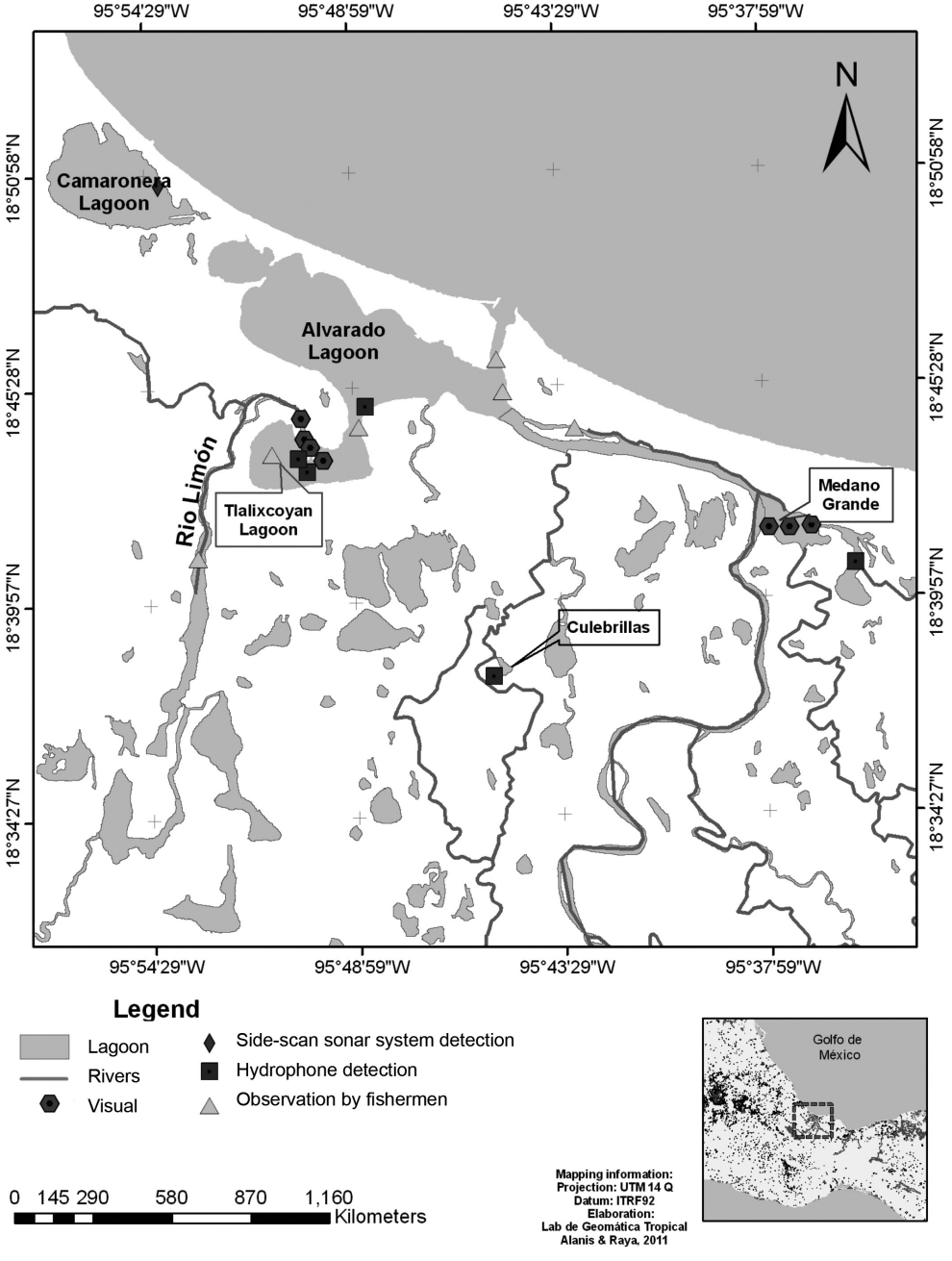

Figure 3. Map showing where manatees were detected and with which detection tool (side-scan sonar, hydrophones, or direct sight); the map also shows where the local fishermen have seen manatees.

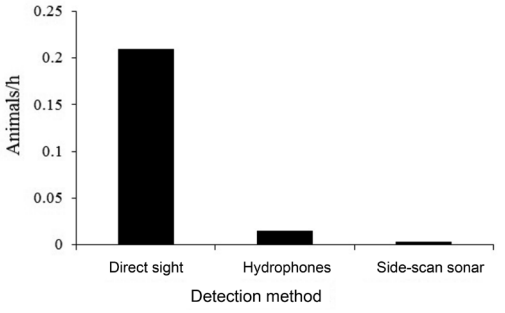

Figure 4. Relative manatee abundance according to the detection tool (direct sight, hydrophones, and side-scan sonar)

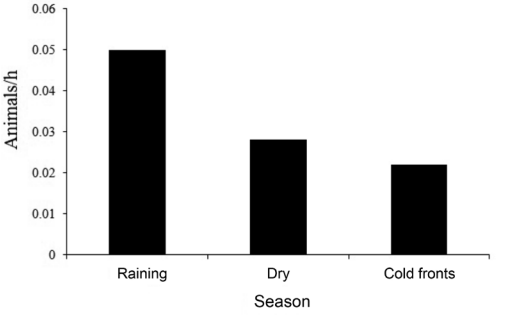

Figure 5. Relative manatee abundance by season

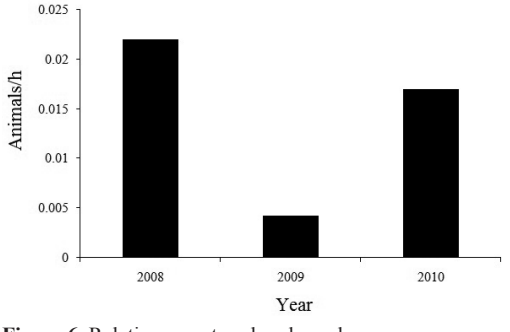

Figure 6. Relative manatee abundance by year

Discussion

The population status of manatees throughout their distribution is unknown in Latin America. Population sizes and trends are unknown, although they may be declining in many countries (UNEP, 2010). In the U.S. (the only country with reliable data), the manatee population size is estimated at 3,300 individuals (U.S. Fish and Wildlife Service [USFWS], 2007; UNEP, 2010). In Mexico, there is no overall manatee population estimate; however, there are some studies that give us an idea of the number of manatees left in the country. For example, in Quintana Roo, there is an estimated population of 250 manatees (Colmenero & Zárate, 1990; Morales-Vela et al., 2000). For the rest of the country, there are no precise manatee abundance data. For the northern region of the State of Veracruz, manatees have been reported as extinct (Serrano et al., 2007), although Ortega-Argueta et al. (2003) suggested that the ALS in Veracruz is the area where the largest manatee population is located. Still, these authors do not present an abundance estimation of the manatee population. In this study, the manatee population was estimated for the ALS as 121 (CV 34.48%). Therefore, this is the first study in Mexico to estimate manatee population abundance in the Gulf of Mexico, and, most importantly, we provide a coefficient of variation of the population estimate. Also, these data will serve as baseline information for future studies on manatee abundance.

Aerial surveys have been the most common method used to study manatee distribution in large areas—for example, in Florida (Reynolds & Wilcox, 1986), Puerto Rico (UNEP, 2010), Venezuela (O'Shea et al., 1988), Panamá (Mou-Sue et al., 1990), Nicaragua (Carr, 1994), and Quintana Roo, Mexico (Morales-Vela & Olivera-Gómez, 1997). Abundance estimation using aerial surveys has some limitations, including perception and availability bias, particularly since thick vegetation and murky waters often hinder visual detections of manatees, especially from a plane.

According to genetic studies, there are two main manatee populations in Mexico: one population distributed along the Gulf of Mexico coast and another on the Caribbean coast with a zone

Table 1. Manatee density and abundance estimation summary in Veracruz, Mexico, using a Half-Normal model

Description	Estimate	% CV	df	95%	Confidence interval
Density (km^2)	0.232	34.48	82.27	0.119	0.453
Abundance	121.00	34.48	82.27	62.00	235.00

Note: % CV = percentage of coefficient of variation; df = degrees of freedom

of mixing in between these two (Nourisson et al., 2011). Both populations show low genetic diversity, with lower genetic diversity present in the Gulf of Mexico population (Nourisson et al., 2011). Nourisson et al. (2011) found little gene flow from the Gulf of Mexico population to the Caribbean population, and no gene flow from the Caribbean to the Gulf of Mexico. Therefore, the loss of manatees from the ALS may have a severe impact on genetic variability since the ALS is the largest manatee population in this region of the Gulf of Mexico. Loss of genetic variation reduces survival, reproduction, and, ultimately, fitness and population persistence (Johnson et al., 2010). Population size, in addition to genetic diversity, is a critical parameter in conservation as it could help determine the rate of loss of heterozygosity (Tucker et al., 2012).

Is the Antillean manatee at the brink of extinction in the State of Veracruz, Mexico? Yes it is. Considering the reduced number of manatees surviving in the ALS and that manatee populations in the north of the state have disappeared (Serrano et al., 2007), the implementation of effective conservation measures is urgent so that this species will not become extinct in Mexico.

Acknowledgments

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