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PILOT AERIAL STUDY OF THE MARINE MEGAFAUNA IN NORTHERN COAST ALAGOAS, BRAZIL.

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ABSTRACT

This study aimed to investigate the feasibility of strip-transect aerial survey for the study of the marine megafauna in northern coast of Alagoas, chosen as the pilot area due to the better water clarity and the occurrence of the Antillean manatee. It was sighted 15 dolphins, 13 sea turtles and 10 manatees. From five aspects tested on the experimental flight, three adjustments were necessary on the methodology as following: 1) reduction of the transect angle to 40º to increase the sampling area; 2) constant transects of 1.5 nautical miles from shore to standardize the area of coverage; and 3) transects restricted to the mouths of estuaries due to low visibility in turbid waters. This study demonstrated the effectiveness of aerial surveys for the detection of marine megafauna. However, the adjustments proposed are necessary to minimize the characteristic limitations of each species and/or habitat.

Keywords: aerial method, manatees, dolphins, sea turtles, limitations.

RESUMO

O estudo objetivou investigar a viabilidade do censo aéreo no estudo da megafauna marinha no norte de Alagoas, escolhida como área piloto devido à melhor transparência da água e presença de peixes-bois marinhos. Foram avistados 15 golfinhos, 13 tartarugas e 10 peixes-bois. Dentre os cinco parâmetros testados no voo piloto, três sofreram ajustes metodológicos: 1) redução do ângulo de abertura das transecções aéreas para 40°, aumentando a área amostrada; 2) transecções constantes a 1,5 milhas náuticas da costa, padronizando-se a área de cobertura; e 3) transecções restritas às desembocaduras dos estuários, devido à impossibilidade de detecções de animais dentro dos estuários, onde há águas muito turvas. Os resultados mostraram a eficácia metodológica das pesquisas aéreas na detecção da megafauna marinha. No entanto, os ajustes propostos são necessários para minimizar as limitações características de cada táxon e/ou habitat.

Palavras-chave: método aéreo, peixe-boi marinho, golfinhos, tartarugas, limitações.

INTRODUCTION

Aerial surveys have been used throughout the world to estimate the distribution and abundance of aquatic animals, the most studied of which are sea turtles and marine mammals (MCCLELLAN, 1996; PREEN et al., 1997; ROOS et al., 2005; LANGTIMM et al., 2011). However, such surveys are rare in Brazil and mainly restricted to the southern region of the country (SECCHI et al., 2001; DANILEWICZ et al., 2010; ZERBINI et al., 2010; ZERBINI et al., 2011). Indeed, published studies have been carried out in the northeastern region, addressing the humpback whale [*Megaptera novaeangliae* (Borowski, 1781)] (ANDRIOLO et al., 2006; 2010; WEDEKIN, 2011) and Antillean manatee (*Trichechus manatus manatus* LINNAEUS, 1758) (COSTA, 2006). Other studies in the region have relied mainly on data from stranded animals and the reports of fishermen (MARCOVALDI; MARCOVALDI, 1999; PARENTE; VERGARA-PARENTE; LIMA, 2004; LUNA et al., 2008; MEIRELLES et al., 2009; LIMA et al., 2011).

The perception and availability bias regarding the sighting of marine animals are the main limiting factors to aerial surveys (MARSH; SINCLAIR, 1989; KATSANEVAKIS et al., 2012). According to COSTA (2006), the high cost of aircraft rental and the difficulty sighting specimens in turbid coastal waters at particular times of the year limit the use of this method in northeastern Brazil. Sampling difficulties can render the identification of species and the precise count of individuals in a population impossible. However, this method is useful in understanding population tendencies (REYNOLDS, 1999), especially among species vulnerable to extinction, such as the manatee, which is considered the most endangered aquatic mammal in Brazil (ICMBIO, 2011).

The megafauna on the northeastern coast of Brazil is represented by a single species from the order Sirenia, the Antillean manatee (*T. m. manatus*) (LIMA et al., 2011), 19 species of cetaceans (ALVITE et al., 2004), the most frequent of which is the Guiana dolphin [*Sotalia guianensis* (VAN BÉNÉDEN, 1864)], and five of the seven living species of sea turtles: green sea turtle [*Chelonia mydas* (LINNAEUS, 1758)], loggerhead sea turtle [*Caretta caretta* (LINNAEUS, 1758)], hawksbill sea turtle [*Eretmochelys imbricata* (LINNAEUS, 1766)], olive Ridley sea turtle [*Lepidochelys olivacea* (ESCHSCHOLTZ, 1829)] and leatherback sea turtle [*Dermochelys coriacea* (VANDELLI, 1761)] (GOMES; SANTOS; HENRY, 2006). The Antillean manatee has particular characteristics of occurrence in comparison to other species, such as warm, shallow waters (OLIVERA-GÓMEZ; MELLINK, 2005), abundant aquatic vegetation (PALUDO; LANGGUTH, 2002; COSTA, 2006) and human activities (PARENTE; VERGARA-PARENTE; LIMA, 2004; BORGES et al., 2007). Therefore, estuaries are essential habitats as foraging, breeding and resting grounds for the manatee (REYNOLDS; POWELL, 2002; LIMA et al., 2011).

The aim of the present study was to investigate the applicability of aerial surveys using strip-transect for studies of distribution and abundance of marine megafauna in northeastern Brazil, using the northern coast of the state of Alagoas as a pilot area.

STUDY AREA

The geographic limits of the sampling area on the northern coast of the state of Alagoas were Peroba Beach [northernmost portion of the state (08°07'52"S/34°55'33"W)] to Ponta Verde Beach in the capital city Maceió (09°30'39"S/35°47'56"W), totaling approximately 114 km of coastline (Fig. 1). This area was chosen mainly due to its higher water transparency in comparison to other areas of northeastern Brazil as well as the constant occurrence of manatees of either native populations or reintroduced specimens (LIMA, 2008; LIMA et al., 2011). This ideal conditions were decisive for validate the aerial sampling.

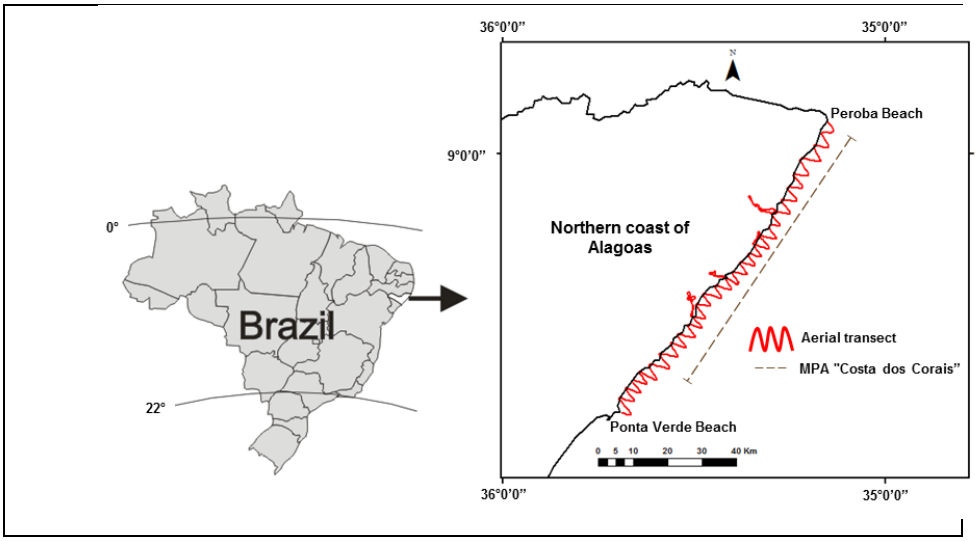

Figure 1 – Northern coast of Alagoas showing the aerial transects (zigzag) between Peroba Beach and Ponta Verde Beach. Highlight for the coverage area of the Marine Protected Area (MPA) "Costa dos Corais" within the study area (dotted line).

This area has different coastal ecosystems, such as estuaries and lagoons with mangroves positioned transversally to the coastline as well as coral and sandstone reefs occurring from the coastline to several meters in depth (CORREIA; SOVIERZOSKI, 2005). A large part of the study area is located within the Marine Protected Area (MPA) "Costa dos Corais" (Fig. 1), considered the largest marine protected area in Brazil. This MPA was established to protect the reef ecosystems, maintain the integrity of the mangroves and preserve the manatee population (FERREIRA; CAVA, 2001; LIMA 2008).

The present study was designed as a pilot plan for a subsequent study from the coast of the state of Piauí to the state of Alagoas, initially focusing on *T. m. manatus*, with the subsequent inclusion of dolphins and sea turtles.

MATERIAL AND METHODS

The main analyzed factors for the detection success of animals were as follows: (1) strip transect methodology, using zigzag transects perpendicular to the coast; (2) the largest angle measure for sighting marine animals and a subsequent calculation of the threshold area scanned; (3) conditions of the flight altitude, speed and visualization of the sea surface (bubbles windows); (4) morphology and behavior of each taxon as influential factors in the detection and identification of species; and (5) environmental conditions of the Beaufort scale and transparency of water (coastal and estuarine) for the ideal aerial survey.

The present study was carried out in January 2010, a month of dry season, with a sampling effort of two hours of flight. The total area covered was 264 km^2, with more than 312 km of distance travelled in a zigzag pattern.

Identification of animals

The identification of the species was based on the diagnostic morphological and behavioral characteristics of each species. In cases of dubious sightings or imprecise counts of individuals, recounts were performed (LANGTIMM et al., 2011) through circular flights over the location of the sight and imprecise records were discarded. A group was defined as two or more animals (MORALES-VELA et al., 2000).

The main morphological characteristics used for the aerial identification of *T. m. manatus* were brownish-gray coloration, robust fusiform body shape, flat oar-shaped caudal fin (HUSAR, 1978) and slow movement (HARTMAN, 1979). A calf was a specimen measuring 1/3 of the adult animal by its side (HARTMAN op. cit.). The distinctive characteristics of dolphins were the fusiform shape, body coloration, morphology of the head and dorsal fin (JEFFERSON; LEATHERWOOD; WEBBER, 1993) and fast swimming with occasional leaps. The references for sea turtles were the greenish-brown (Cheloniidae) or black (Dermochelydae) shell, circular body shape (with fusiform and curvilinear carapace composed of plates) and oar-shaped pectoral fins used simultaneously for swimming (WYNEKEN, 2001).

Aerial survey

"Strip transect" was the sampling method, which is defined by monitoring a strip of predetermined width in which each observer records all sightings. This method allows acquiring data on distribution and estimating the representative density in the area samples, thereby allowing the estimation of abundance (JOLLY, 1969). To conduct this method is recommended initially a pilot sample, according to the particular characteristics of each environment and species, never assuming their application *a priori* (KATSANEVAKIS et al., 2012). The sampling area (strip) was demarcated from the tip of the wing of the aircraft to the strip directly below the wings (Fig. 5). Clinometers were used to determine the largest angle measure for sighting marine animals and a subsequent calculation of the threshold area scanned.

Sampling was performed in systematic zigzag transects (Fig. 1) with a 60º open angle perpendicular to the coast, accompanying the width of the continental shelf. This transects were designed to better cover the area and to maximize flying effort (ANDRIOLO et al., 2006; 2010). Estuaries were also sampled, as these sites are habitats for manatees (LIMA et al., 2011). Flights over these ecosystems occurred parallel to the margins of river, traveling approximately 1 km inland (Fig. 1 and 2).

The aircraft used was a single-engine high-wing Cessna 172 A, with bubble windows adapted in the posterior portion (ZERBINI et al., 2011), ideal for the observers to view the ocean surface. Flyovers standardized occurred at an altitude of 150 m and a velocity of 140 $km.h^{-1}$ (coast and estuaries), which is within the minimum range recorded in previous studies (MORALES-VELA et al., 2000; WRIGHT et al., 2002; COSTA, 2006) and corresponds to the minimum safety conditions of the crew during the study. The flyover crew was composed of a pilot, positioned on the left of the plane, two independent observers laterally covering each sampling strip (detection bias) in the rear portion of the plane and an annotator alongside the pilot. The observers were equipped with clinometers to measure the width of the strip sampled.

The annotator was equipped with a GPS to register the location of the sightings as well as the GPS of the plane for recording the flight path, two photographic cameras, nautical charts of the study area and standardized charts to record data on the flight conditions (altitude in feet and velocity in $km.h^{-1}$), environmental conditions (visibility, Beaufort Sea state and tide), human activities and sightings of marine megafauna (species, abundance, social structure, time and geographic position). The flight took place in the dry season (summer) during the rising tide, which allowed an increase in the spatial use of the animals, especially those with coastal habits and those that use estuaries. Data collection involved the identification of the specimens, sighting number, size of group, composition of group (presence of offspring), geographic position of sighting within the transect), habitat location/type, time and geographic position of takeoff and landing, time and geographic position of sampling.

The ideal environmental conditions expected for aerial survey were Beaufort Sea state 2 or less, absence of rain or mist (PREEN, 2004; LANYON, 2003), and water transparency "excellent" (animals clearly visible even underwater).

Data analysis

The survey design and locations of the sightings were transferred to the "GPS TrackMaker Pro" program (ANDRIOLO et al., 2010) for subsequent spatialization using the Arcmap program (version 9.3), identified nominally and by two coordinates (lat/long), to determine the spatial pattern of species occurrence.

RESULTS

A total of 16 sightings and 38 specimens of manatees, dolphins and sea turtles were recorded (Tab. 1), with higher occurrence number in the southern portion of the sampling area (Fig. 2).

Table 1 – Summary of sightings of Antillean manatees (*Trichechus manatus manatus*), dolphins and sea turtles during aerial survey on northern coast of Alagoas, northeastern Brazil.

	Manatee	Dolphin	Sea Turtle
Number of sighting	7	4	5
Total animals	10	15	13
Mean animals/sighting	1.4	3.75	2.6
Maximum animals/sighting	3	7	4

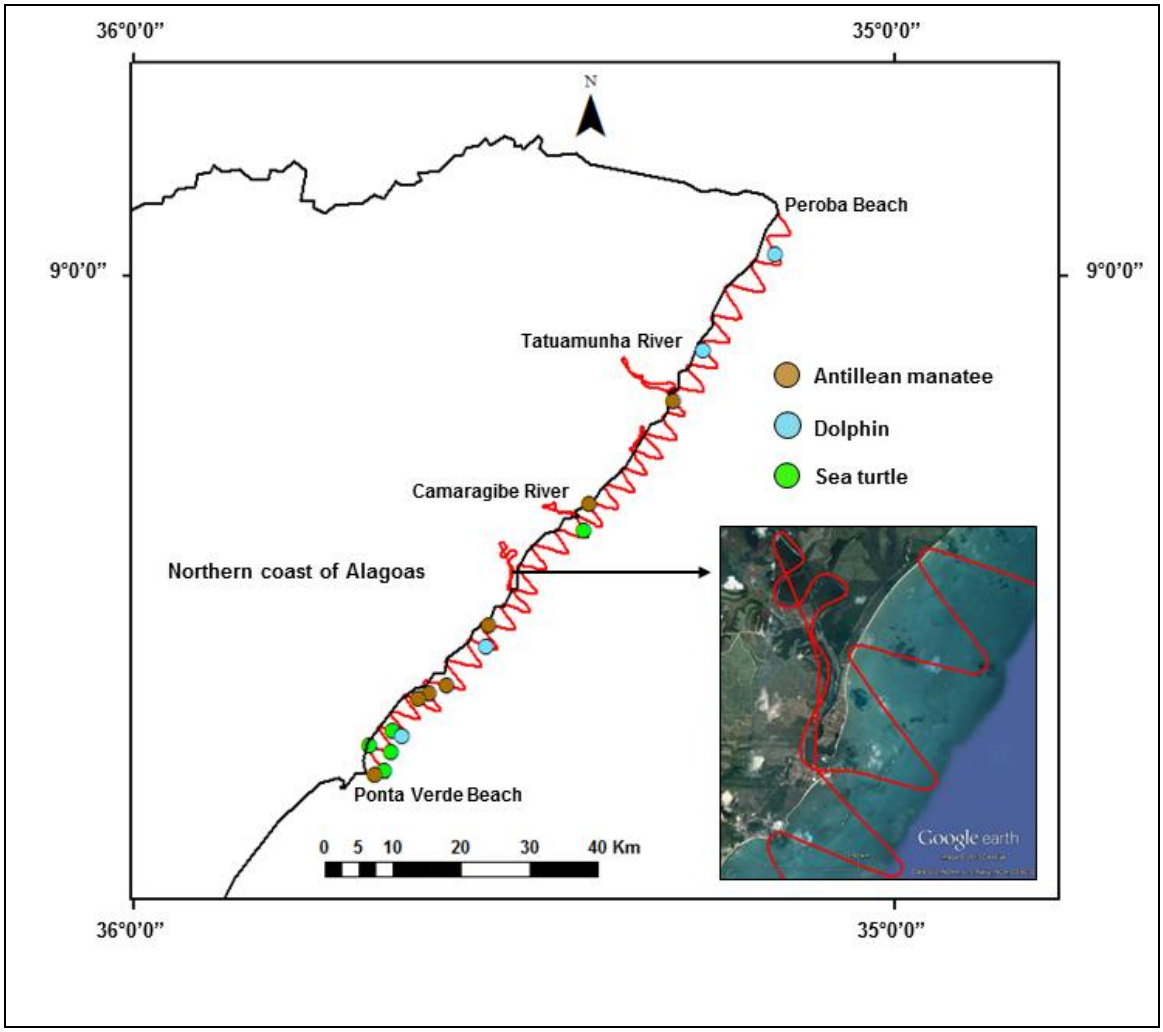

Figure 2 – Spatial distribution of Antillean manatees, dolphins and sea turtles during aerial survey with zigzag trajectory on northern coast of Alagoas, northeastern Brazil. Highlighting the transect sampling irregular-shaped in estuary of "Barra de Santo Antônio", and sightings of manatees near Tatuamunha and Camaragibe Rivers.

The environmental conditions were favorable to the detection of marine megafauna from the air, with optimal water transparency and the absence of clouds and strong winds, which that corresponds Beaufort Sea state 1 (Fig. 3).

Figure 3 – Aerial photo showing favorable conditions (optimal water transparency and calm sea - Beaufort Sea state 1) for sightings of marine mammals and sea turtles during flyover on northern coast of Alagoas.

The behavior of Antillean manatees, with little exposure at the water surface and its predominantly solitary habits (unlike the other taxa studied) did not hamper detection due to the high water transparency, which allowed the visualization of submerged individuals. However, the sightings of some manatees and sea turtles became more confusing when flying over areas located above reefs or in very turbid waters due to the cryptic brownish coloration of these animals. In five of these cases, we performed the recount effort, two of them being discarded.

The detection of manatees within four estuaries was not possible due to the high water turbidity, the difficulty of flying over narrow, twisting channels (e.g. estuary of Barra de Santo Antônio; Fig. 2) and abundant vegetation on the banks of the rivers. To validate the efficiency of aerial detection under such conditions, a flyover was performed on the estuary of the Tatuamunha River (09°12'83.00"S/35°16'11.29"W), where three manatees are kept in natural captivity (1050 m²) and none were sighted from the airplane (Fig. 4). However, manatees were sighted at the mouths of the Tatuamunha and Camaragibe Rivers (09°18'30.37"S e 35°23'42.19"W) (Fig. 2).

Figure 4 – Aerial photo of validation of viability of aerial survey of estuaries performed in natural captivity of three Antillean manatees in estuary of Tatuamunha River, Alagoas; Image reveals non-viability of visual detection due to high water turbidity.

All dolphins sighted belonged to the family Delphinidae, with only one group of seven individuals at Peroba Beach (08°58'17''S/35°09'18''W) identified as *S. guianensis*. The social structure of the delphinids was predominantly gregarious, with groups of three to seven animals. Sea turtles, represented by the family Chellonidae, were the second most abundant taxon (Table 1), with groups of up to four specimens detected.

The clinometer readings regarding the some sightings determined the following angles: 30°, 40°, 45°, 50°, 55° and 65°. Considering the constant altitude of the flight (150 m) and the largest angle (65°), the scanning areas per researcher totalized 321.7 m, with 634.4 m of area covered (Fig. 5).

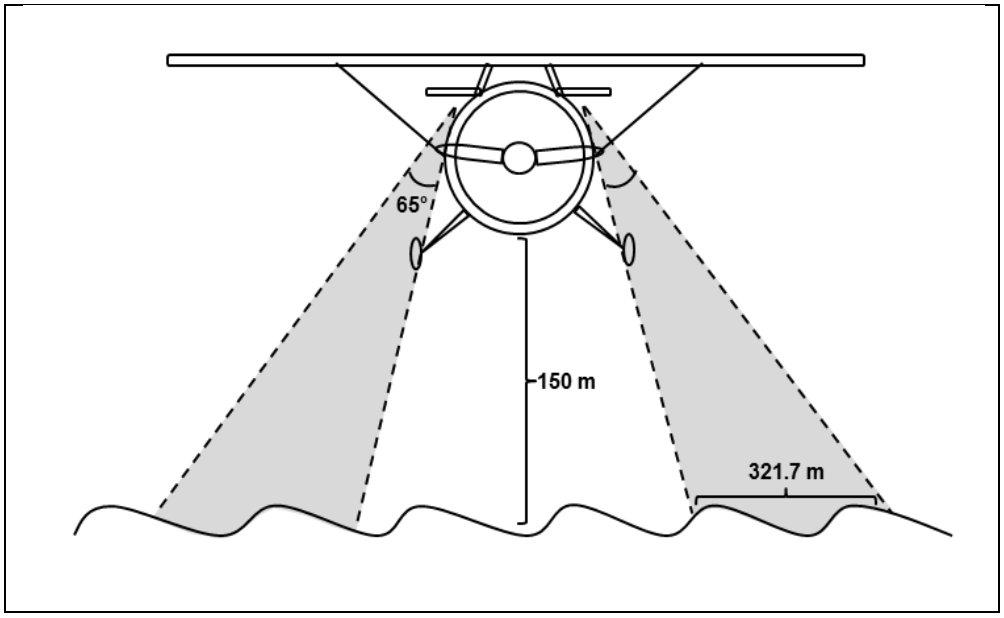

Figure 5 – Schematic of strip transect sampling method from aircraft indicating constant altitude, maximum sighting angle and length of base scanned (tread area) by each observer.

Three small methodological adjustments were necessary: (1) reduction of the open angle of the transects to 40° to increase the sampling area, (2) standardization of the transect lines to 1.5 nautical miles from the coast, corresponding to 2778 km (isobaths of 10 to 20 m), due to the considerable variation in the continental shelf in the area, and (3) replacement of the transects in estuaries with only a scan of the mouths of rivers, due the transparency bad this water in comparison with the sea coast water.

DISCUSSION

This pilot aerial study on the northern coast of the state of Alagoas for detection of marine megafauna attained satisfactory results regarding the flying and environmental conditions, except in water turbid estuaries where the transparency of the water was crucial for the successful detection of manatees. In contrast, COSTA (2006) reported methodological inefficacy regarding the identification and quantification of manatees to the east of the state of Ceará due to the turbidity of the sea water. In the present study, meteorological and environmental variables exerted a positive influence on the sighting of the animals and such favorable variables may be considered a priority to the feasibility of this type of survey in the Brazilian northeast coast.

The methodological inefficacy regarding the identification of species of dolphins (uncertainly of 65% sightings) and sea turtles, even in transparent waters, may be related to the agile movements of the animals, at the water surface and the speed of the aircraft, which did not allow ample time for the diagnosis of the specimens. The little experience of the observers in aerial record type may also have influenced in the diagnosis of the species. The uncertainty in the identification of delfinids is due to the fact that the species are differentiated by slight variations in coloration, morphology and behavioral patterns (JEFFERSON; LEATHERWOOD; WEBBER, 1993). The Guiana dolphin was identified due to the grayish coloration of the dorsum and the triangular shape of the dorsal fin (JEFFERSON et al., 1993).

Difficulties identifying sea turtles are also reported in previous studies, with the small size of the animals the most aggravating factor (EPPERLY; BRAUN; CHESTER, 1995; WYNEKEN, 2001; ROOS et al., 2005). A size threshold of approximately 75 cm in carapace length has been stipulated for optimal aerial detection (SHOOP; KENNEY, 1992). Moreover, fleeing behavior was recorded due to the noise of the aircraft, characterized by ripples caused on the surface of the water due to the rapid diving of the turtles. According to MCCLELLAN (1996), helicopters are more indicated for the identification of species in aerial surveys due to the lesser flight velocity. However, a comparative study found that the noise produced by such aircraft scare marine

animals off more than a single-engine high-wing plane (RATHBUN, 1988), as the one used in the present study.

The essentially solitary habits and subtle exposure at the water surface (HARTMAN, 1979) may exert a negative influence on the detection of manatees in turbid waters. Antillean manatees are difficult to sight due to the fact that these animals spent a large amount of time under water (REYNOLDS; POWELL 2002) and are therefore more easily detected when in groups, although the precise count of individuals is more difficult (LANGTIMM et al., 2011). Aerial surveys were used in Florida to estimate the quantity of *Trichechus manatus latirostris* (HARLAN, 1824) in the region. This was done during periods of cold weather, as the manatees gather in areas of warm water, which this facilitated counting the animals (ACKERMAN, 1995; LEFEBVRE et al., 2001). In Brazil, the constant temperature of the coastal waters turns this type of procedure unnecessary (LIMA et al., 2011).

Besides biological traits, degrees of turbidity and tide conditions may lead to detection errors, especially with regard to *T. m. manatus* and sea turtles. At low tide, rocky outcrops and reefs may be confused for these animals due to the similar color (ROOS et al., 2005). Therefore, flyovers during the rising tide, when these formations are submerged, may minimize this type of error. Moreover, the access of manatees to estuaries is facilitated, thereby allowing a greater chance of sighting these animals. Aerial surveys within estuaries are inefficacious due to frequent turns and circuitous flight, path required to sample the irregular-shaped estuarine water bodies, and mainly to the turbidity of the water. This irregular-shaped turns difficult to consistently maintain a formal transect protocol (LANGTIMM et al., 2011). However, there is a considerable need to monitor species that use these ecosystems, such as *T. m. manatus* (LIMA et al., 2011). The use of side-scan sonar in nautical studies is favorable to the detection of manatees in this type of environment (GONZALEZ-SOCOLOSKE; OLIVERA-GÓMEZ; FORD, 2009).

The corrected methodological parameters (reduction of the transect angle, constant zigzag transects of 1.5 nautical miles, and transects restricted to the mouths of estuaries) will minimize the limiting effects regarding the detection of marine mammals and sea turtles related mainly to the morphological and behavioral characteristics of the species in contrast to the conditions of the environment. Aerial surveys can also provide information for the development of management, conservation and recovery programs directed at habitats of ecological importance to the survival of marine mammals and sea turtles.

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