Chapter 11
West Indian Manatee *Trichechus manatus* in South America: Distribution, Ecology and Health Assessment

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Abstract The West Indian manatee inhabits exclusively tropical waters of Atlantic Ocean, from Virginia, in United States, to Alagoas, in Northeastern Brazil, in a fragmented way. In South America, low species density and difficulty to detect the animals that inhabit areas with murky waters, associated with a lower financial investment in research in the past, lead to a delay in manatee research. However, in the last decade, an increase in manatee research could be noted in the continent. Nevertheless, a significant part of this information is available only on theses, conference abstracts, reports, etc. Thus, this chapter aims to gather and update important information on the species, mainly on distribution, spatial ecology, feeding habits, genetics and health.

Keywords Sirenia • Abundance • Spatial ecology

11.1 Introduction

The West Indian manatee, *Trichechus manatus*, is one of the four only extant species of the Sirenia order. The IUCN Red list considers the species as Vulnerable, with a decreasing population, due to habitat loss and anthropogenic causes (Deutsch et al. 2008). Many authors and the Society for Marine Mammalogy accept the existence of two subspecies (Committee on Taxonomy 2016): Florida manatee, *T. m. latirostris,* corresponding to animals in the United States.; and Antillean

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manatee, *T. m. manatus,* including manatees that inhabit the tropical and subtropical western Atlantic coasts, from Bahamas to Brazil, including the Caribbean Sea and Gulf of Mexico. However genetic (García-Rodríguez et al. 1998; Vianna et al. 2006; Santos et al. 2016), skull morphology and cytogenetic (Barros 2013; Barros et al. 2017) studies indicate the necessity to revisit this taxonomic classification. Therefore, in this chapter we chose not to use the subspecific classification.

The species inhabits exclusively tropical waters of Atlantic Ocean, from Virginia (37° N, 76° W), in United States, to Alagoas (10° S, 36° W), in Northeastern Brazil, in a fragmented way. In the United States, West Indian manatee is concentrated in Florida, due to warm water temperature. During summer months, some animals disperse to other states and can be found in Georgia, South Carolina, North Carolina, Virginia and rarely in New Jersey. In tropical countries, the species range is not totally understood, however it seems more related to displacements from resting areas to foraging and freshwater sites.

As an exclusively herbivore taxa, manatees occur in rivers, estuaries, lagoons, channels and coastal shallow waters, where animals can feed on a variety of submerged, floating or emergent plants (Marsh et al. 2011). In the United States, during winter, animals concentrate in warm water refuges, natural or artificial, with clear waters. These two factors propitiated early studies with the species there. In other countries, mainly in South America, low species density and difficulty to detect the species, that inhabits areas with murky waters, associated with a lower financial investment in research in the past, lead to a delay in manatee research. In the last decade, an increase in manatee research could be noted in South America. Nevertheless, a significant part of this information is available only in theses, conference abstracts, reports, etc. Thus, in this chapter we present a review on the research conducted with West Indian manatee in South America, discussing its importance to species conservation and management.

11.2 Distribution

In South America, *T. manatus* inhabits rivers, swamps, coastal lagoons, estuaries and coastal areas. Dark waters in these habitats hamper manatee detection, rendering aerial surveys an ineffective method to identify the species distribution. Thus, indirect evidences, such as interviews, feeding traces and presence of feces are the most used approaches to study manatees in the region, associated with direct observations. Aerial surveys were only used with good results in Brazil (Alves et al. 2013, 2016). More recently, the side scan sonar (SSS) emerged as an important detection tool to study manatees (Gonzalez-Socoloske et al. 2009; Gonzalez-Socoloske and Olivera-Gomez 2012). Detection of manatees using sonars initially aimed to avoid collision with boats, the main cause of manatee mortality in U.S.A. (eg, Bowles et al. 2004). However, as demonstrated by Gonzalez-Socoloske et al. (op. cit.) through tests in clear waters of Florida and in the dark waters of a lagoon in Mexico, SSS is a cost-effective option to detect manatees in turbid and dark waters. In South

Fig. 11.1 West Indian manatee distribution (in dark *blue*) in South America, including main rivers, bays and estuaries. *Blue dots* are isolated records of the species

America, this tool is already being used in some countries, with encouraging results (eg, Colombia, Arévalo-González et al. 2014; Arévalo-González and Castelblanco-Martínez 2015; Brazil, Choi-Lima et al. 2014; FMA 2015).

Below we review the manatee records in each country of South America (Fig. 11.1). This is not intended to provide an exhaustive review on manatee records in these countries; rather it aims to gather important and update information that not always is available in scientific articles.

11.2.1 Colombia

In Colombia, the West Indian manatee inhabits mainly riverine environments, preferring lower and medium courses of rivers Magdalena, Atrato, Sinú, Cauca, San Jorge, Meta, Orinoco; and marshes, like the Ciénaga (swamps) de Paredes, de Santa Helena and Grande de Santa Marta (Caicedo-Herrera et al. 2004; Montoya-Ospina et al. 2001). Some manatee captures and sightings were recorded in the mouth of Sinú and Magdalena rivers; however, the presence of the species in the Caribbean Sea is not common in the country (Montoya-Ospina and Caicedo-Herrera 1995). In 2004, Caicedo-Herrera et al. compiled important information on the species distribution in the "Programa Nacional de Manejo y Conservación de Manatíes en Colombia" (National Program for manatee conservation and management in Colombia). This is the most complete source of information on *T. manatus* records in the country.

One of the most important sites of manatee occurrence in the country is the Magdalena river basin, mainly the marsh known as Ciénaga de Paredes, in Santander state, indicated by Montoya-Ospina et al. (2001) as the largest available habitat for the species in Colombia. After this report, considerable efforts to study the species in this and other basins were initiated. In the middle Orinoco river, Castelblanco-Martínez et al. (2009) made an important effort to study the species from 2001 to 2005, through sightings and interviews with local people. Over 800 manatee sightings were recorded in 1003 h of direct observation. The study was conducted in Department of Vichada, in Orinoquía Region, in the border with Venezuela, approximately 1100 km from the Caribbean coast.

In addition, in the middle and lower Atrato river, Caicedo-Herrera et al. (2004) established the *T. manatus* distribution through sightings, interviews and indirect records, as feces observation and evidence of foraging. Most records were in *ciénagas* and in Atrato river. Only one sighting was recorded, in Ciénaga La Grande. Ninety evidences of foraging and 17 recent sightings reported by fishermen during interviews were used to identify most important occurrence sites.

11.2.2 Venezuela

In eastern Venezuela, *T. manatus* occurs in the Gulf of Paria, the middle Orinoco river and its tributaries, the Orionoco Delta and the Venezuelan Llanos (Boher and Porras 1991; Lefebvre et al. 2001; Mondolfi and Muller 1979; O'Shea et al. 1988). In the west of the country, the species occurs in the Maracaibo system, comprised of the Gulf of Venezuela, Tablazo Bay and the Maracaibo Strait, which connect Lake Maracaibo in the interior of the Maracaibo Basin, to the Caribbean Sea. Additionaly, there are records of manatees in Limón river and channels south of São Carlos Island, and Ciénaga Juan Manuel de Aguas Claras y Aguas Negras.

According to O'Shea et al. (1988) interviews in Venezuela indicated that a small manatee population exists in Maracaibo Lake and the swamps bordering the lake. Interviews also revealed the presence of manatees in Manatí Lake and rivers Escalate, Catumbo and Bravo. After this research, there was little effort to study manatee in the system. Manzanilla-Fuentes (2007) reported 27 sightings of manatee in Tablazo Bay, including solitary animals and groups of up to four animals. Some stranded and rescued animals were also reported for the area (Boede and Mujica-Jorquera 2016; Ramírez-Carroz and Manzanilla-Fuentes 2008).

O'Shea et al. (1988) indicated that the species did not occur in the Caribbean coast due to inadequate ecological characteristics, representing a major discontinuity in the species distribution (Lefebvre et al. 2001). However, some rare records were reported in the mouth of Neverí river (Ojeda et al. 1993) and in Puerto Cabello (Delgado 1995).

Manatees seem to be more abundant in eastern Venezuela. For this reason, there are more studies published for this region. In the middle Orinoco, in the border with Colombia, the species has been studied for several years by the Colombian

Fundación Omacha (Bermudez-Romero et al. 2004; Castelblanco-Martinez 2004; Castelblanco-Martínez et al. 2001, 2005). In the central lower Orinoco, Rivas-Rodríguez et al. (2012) studied the species in Caicara del Orinoco. In adition, an effort was initiated in 2007 in lower Orinoco, through interviews, sighting records and identification of feeding areas, between Las Bonitas and Mapire, including Caura river (Rivas-Rodriguez et al. 2012). The authors record the presence of manatee in 46 localities, expanding the knowledge of the species occurrence in the Orinoco river originally reported by Mondolfi and Müller (1979) and Correa-Viana et al. (1990). More recently, Rodulfo (2012) studied manatees in Caño Araguao, in the Delta of Orinoco, through interviews, indirect evidences of the species presence (e.g, foraging traces, feces), and sightings. Most records were in distributaries (caños), followed by the river mouth. Foraging areas were recorded in *canõ* Araguao, Río Grande de Araguao, confluence of Rio Grande with *caño* Anacasi, *canõ* Janeida, Canal Sorocobo, Barra de Araguao and Isla Jeocubanoco.

11.2.3 Guyana

Most information published on *T. manatus* in Guyana is from the 1960s and 1970s (eg, Bertram 1963; Bertram and Bertram 1963, 1973). The occurrence of the species on the coast seems to be associated to river mouths. Bertram (1963) suggested that the high water turbidity in the coast probably provided poor feeding grounds to the species. Most records in the country are from rivers, as Courantyne, Nanniekrek, Canje, Berbice, Demerara, Abary, Wuini, Barima, Sebai, Kiatuna, Essequibo, Arapiako, Pomeroon and Akawini. At that time, the species seemed to be more abundant in the Canje and Abary rivers, mainly in upper reaches, on the wet savannahs. In Abary river, manatees were caught by the Department of Drainage and Irrigation and released in channels to eat aquatic plants, as a weed control agent.

This practice started in Guyana after Allsop (1960) observed that the ornamental pools of the Botanic Gardens, in Georgetown, where manatees were kept since the 1880s, were always clear of aquatic plants. In 1916, manatees were used to maintain sugar-estate canals clear of aquatic plants and in 1952 four manatees were introduced in a canal of a water reservoir of the Georgetown Water and Sewage Works with the same purpose and were replaced by others through the years (National Science Research Council 1974). The same procedure was done in other canals from 1959 to 1962 by Drainage and Irrigation Department, when 80 manatees were used to control aquatic vegetation. In 1974, a Workshop to discuss “An International Centre for manatee research” was held in Georgetown. However, the meeting report discusses mainly the importance of using manatees to control “aquatic weeds” in the country, and recommends the species exploration for this purpose (National Science Research Council 1974). In 1991, Haigh published a review on the use of manatees as a means of biological control of aquatic weeds in Guyana. In the article, the author also proposed guidelines on the use of species.

Fig. 11.2 An adult West Indian manatee kept in Georgetown Sewerage and Water Commisioners, in French Guiana, to control aquatic vegetation. This practice started in the 1880s and hundreds of manatees were used in the country for this purpose (Photo: Nataly Castelblanco-Martínez)

There is no recent effort to identify the species distribution in Guyana and almost every report is related to the use of species to control aquatic vegetation. It seems the species is still used in the country to control the aquatic vegetation in water bodies. The Botanical Gardens still maintains manatees in the waterways, and although some articles (eg, Converse et al. 1994) indicated that the population that inhabits the pools is wild, historical information indicates that those animals were introduced in those facilities. Castelblanco-Martínez (2015) reported that in Georgetown at least 30 manatees are inadequate kept in artificial ponds in the Botanical Gardens, the Guyana National Park; and in the Georgetown Sewerage and Water Commissioners, a water treatment plant (Fig. 11.2).

11.2.4 Suriname

There is little information on West Indian manatee in Suriname. Most of published data indicate that the species occurs mainly in rivers and river mouths. Murie (1870) reported the capture of a young male in Maroni (or Marowijne) river, in the border between Suriname and French Guiana. The animal was transported to England, but died from exposure to cold weather. Husson (1978) published a review on the species records in the country indicating the presence of *T. manatus* in Saramacca river. In 1974, Dekker described his trips to Suriname in 1966 and 1971 to capture manatees for a zoo in Amsterdam. According to the author, at that time manatees could

be found west of Paramaribo and the Suriname river, in upperwaters of the Commewijne river, and affluents of Suriname river, and in the Nanni swamp, next to the Guyana border. In 1971, he captured 11 manatees at the mouth of large rivers, as Nanni. An interesting fact is that he described that some animals were imprisoned in the drainage canals of plantations, indicating the probable use of the species to control aquatic vegetation. Also in 1978, Duplaix and Reichart compiled information on the species in Suriname in a US Fish and Wildlife Service research report.

A few manatee records in Suriname are reported in articles, book chapters or project reports dedicated to other species, or to a specific area. Mohadin (1993) reported the occurrence of manatees in the Cusewijne river, in the Boven-Cusewijne (or Bove-Coesewijne) Nature Reserve. Duplaix et al. (2001) indicated that T. manatus was hunted to extinction in the area, but still occurred in Nanni Creek and Nanni lake, in the northwestern portion of the country.

In 2012, Pool indicated that in Suriname, four major rivers flow to Atlantic Ocean: Marowijne, Suriname, Coppename and Corantijn, and the estuaries formed by these rivers with contributing rivers are the prime habitat of manatees in the country. As in Guyana, the species was not observed in coastal waters of Suriname. The author indicated the lack of appropriate habitat or insufficient research in the area.

11.2.5 French Guiana

According to Bertram and Bertram (1962, 1963), there was little suitable habitat for manatees farther eastern from Suriname, where "the coastal plain disappears and the mountains come down to the sea". After this, information on manatee in French Guiana came only from Whitehead (1977), who indicated that the species was rarely found to the south of Cayenne. Best and Teixeira (1982) interviewed a manatee hunter in Amapá, a Brazilian state at the border with French Guiana, and reported the presence of the species in rivers Approuague, Mahury, Laughan and Ouanary, as well in some of the smaller rivers in eastern portion of the country.

Only in the twenty-first century, robust studies on manatees started in the country. De Thoisy et al. (2003) conducted interviews and boat surveys in 12 cities and villages along the coast and large river mouths, including fishermen on the Brazilian side of the Oiapoque river, in Amapá state. The results indicated that the species is still present all along French Guiana coast and in most estuaries.

In larger rivers, as Oiapoque, Approuague and Maroni, manatee sightings were reported up to 80 km upriver. Also, the presence of the species was recorded in the rocky coastal areas and around an offshore island 5 km from the continent. The Coswine, a large estuarine mangrove area in the northwestern portion of the country (border with Suriname) was identified as an important habitat for manatees, with the greatest number of sightings. Spiegelberger and Ganslosser (2012) studied the habitat and feeding banks of the species in this estuary, indicating that the area is able to

support a large manatee population, with sufficient food supply and free from human disturbance at that time (data collected in 2001).

In 2012, Castelblanco-Martínez visited five regions in French Guiana to recognize the ecological scenario where manatees inhabit: Coswine, Iracoubo, Kourou, Cayenne (Cayenne river and beaches near the city) and Kaw (including part of Oiapoque river). Through shore and boat surveys and surveys using side-scan sonar and hydrophone, the author recorded the presence of the species in Kaw river, Les Vagues beach (near Cayenne city), Counami and Iracoubo region. Interviews with fishermen revealed the presence of manatees in Kourou and Coswine.

11.2.6 Brazil

An expressive amount of information on manatees was published in Brazil in the last decade. Data from significant effort through interviews, strandings and sightings (fixed-based platform, boat and aerial surveys) were recorded in theses, articles, books and conference abstracts. The most recent review on the species biology and conservation in the country became available in a book published by the NGO Aquasis (2016).

There is a significant quantity of historical information on the presence of *T. manatus* in Brazil, since the Pedro Alvares Cabral expedition, in 1500. Most records are from the states of Bahia and Espírito Santo (~19°S), apparently the southernmost limit of the species distribution at that time. According to Whitehead (1977), human predation and possibly habitat destruction exterminated the southerly populations of manatee in Brazil. Domning (1981) reported the species distribution in the northern coast, indicating its occurrence in Amapá and Maranhão coasts, but its extermination from Pará coast and Marajó Island. The author also indicated the Mearim river, in Maranhão, as an important habitat to *T. manatus*, where a large population could be found. In the 1980s, the Brazilian Government coordinated an effort to collect data on manatee distribution in the country through interviews. After this first effort, Albuquerque and Marcovaldi (1982) indicated the former species distribution from Amapá to Espírito Santo. However, it was extirpated from Espírito Santo, Bahia and Sergipe states. Lima et al. (1992) and Luna (2001) complemented the interview efforts and reported a fragmented distribution of the West Indian manatee in Brazil.

Alves et al. (2013) conducted one aerial survey in northeastern Brazilian coast, from Alagoas to Piaui states, covering 4,026 km, recording 36 sightings of manatee (41 individuals). The species was not observed in the Potiguar basin, at the northwestern coast of Rio Grande do Norte state (RN), where the authors described extremely harsh conditions with strong coastal currents associated to intensive exploration and coastal degradation due to oil industry and salt and shrimp farming. However, the presence of the species in this area was recorded through interviews (Choi 2011) and aerial surveys (Petrobras 2014), and this absence reported by Alves et al. (2013) can be related to other factors, as poor visibility associated with low manatee density. In the same aerial survey, the authors reported the absence of man-

atees in most of Pernambuco coast, and the west coast of Ceará, where Lima (1997) indicated that the species was not present. In Ceará west coast, we believe that the absence of the species is related to the lack of favorable ecological characteristics, which makes it the major discontinuity area in the manatee distribution in Brazil. Lima (op. cit) also indicated that the species was not present in the southern portion of Alagoas state. In 1994, Brazilian Government started a translocation program in Alagoas and Paraíba states, to release rehabilitated calves stranded in the country's coast (Lima 2008; Normande et al. 2015; Normande et al. 2016) to re-colonize areas of historic distribution.

In the states of Ceará and Rio Grande do Norte, interviews (Alves 2007; Aquasis 2006; Choi 2011), aerial (Alves et al. 2013; Aquasis 2006; Costa 2006; Petrobras 2014), boat (Aquasis 2006; Costa 2006) and land-based surveys (Alves 2003, 2007; Aquasis 2006; Moretz-Sohn 2013) and beach monitoring for stranding records (Meirelles 2008; Silva 2010) were performed to identify species distribution and critical areas for conservation. Aerial (24 h effort) and boat surveys (157 h of effort in Ceará coast; Aquasis 2006; Costa 2006), from Fortim to Icapuí, in the eastern portion of the coast, indicated the presence of the species only in Icapuí municipality (Fig. 11.3), mainly in Retiro Grande, Picos, Quitérias and Cajuais Bank. Aerial surveys reported by Petrobras (2014) between Aquiraz, in Ceará, and Touros, in Rio Grande do Norte, in an area of 6,000 km^2, indicated the presence of the species from

Fig. 11.3 An adult manatee sighted during a boat survey performed by Aquasis in Peroba beach, Icapuí municipality, in Ceará, northeastern Brazil. In open coastal areas, manatees lift the entire head out of the water to breathe, avoiding the entrance of water into the nostrils (Photo: Juaci Oliveira/Aquasis' Collection)

Aquiraz to Touros, with a concentration of manatees in the coast of Icapuí municipality, and an absence of records between São Miguel de Touros and Porto do Mangue (RN) and west to Aquiraz.

Choi (2011) through interviews (n = 678) in 77 localities between Beberibe, in east Ceará coast, and Touros, in northwestern Rio Grande do Norte state, indicated the absence of manatees west to Aracati (Beberibe and Fortim) and in Guamaré. The author also reported a high occurrence index in Icapuí and Aracati municipalities. Also, according to interviews, manatees occur only in coastal areas, but used to be observed in the six estuaries of the studied region. In these regions, manatees drink freshwater from the underground aquifers which emerge in the bottom of the sea (Aquasis 2006; Meirelles et al. 2016a).

Interviews were also performed in the border of Ceará and Piauí states, where the species inhabits the estuary of Timonha and Ubatuba rivers and adjacent coastal areas (Aquasis 2008; Choi et al. 2009), a huge estuary with a low human impact (Fig. 11.4). Choi-Lima et al. (2014) also tested the side-scan sonar in this estuary, indicating the viability of the use of this tool to detect manatee in the area (Fig. 11.5). The species is also present in the estuary of Canárias Island, in the border of Piauí and Maranhão states. In Maranhão, Alvite (2008) monitored the presence of manatees in Gato Island, in Tubarão bay, and in Guarapiranga beach, in São José de Ribamar, through fixed-platforms.

Fig. 11.4 Two manatees sighted in the estuary formed by Timonha and Ubatuba rivers, in the border of Ceará and Piauí states, northeastern Brazil. Compared to other estuaries in the region, this one is relatively well preserved. In this area, manatees feed on seagrass, saltmarsh, algae and mangrove

Note that in calm waters, animals slightly bring the snout out of the water to breathe (Photo: Aquasis' Collection)

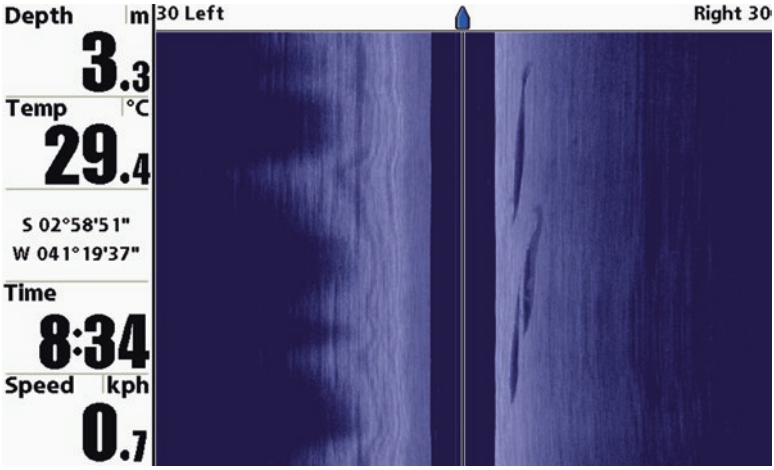

Fig. 11.5 Full-screen capture from Side-scan-sonar Humminbird® 998 cx in Timonha and Ubatuba rivers estuary, during boat surveys performed by Aquasis in 2012 and 2013. Note on the *right side* the presence of three manatees in the bottom of the river

Manatees are also present in the Mamanguape river estuary, in Paraíba state, where the species is abundant (Lima 1997; Silva et al. 1992). Recently, the side-scan sonar was also tested in this estuary as a tool to detect manatees (FMA 2015).

In the northern region, in the state of Amapá, in the border with French Guiana, West Indian manatee is present in the coast and in the estuary. Barbosa (2013) reported the species in coastal protected areas as Estação Ecológica Maracá-Jipioca, in Parque Nacional do Cabo Orange and Reserva Biológica Parazinho. Interviews indicated the species is more commonly observed in Bailique archipelago and Amapá city. Most animals were reported in estuarine systems, followed by river and coastal areas.

The species also occurs in the Oiapoque river where, according to De Thoisy et al. (2003), it can be observed 80 km upriver. Manatees are also present in the river mouth.

In the state of Pará, the species inhabits areas around islands and indentations. There are records in Algodoal and Marajó Islands (Emin-Lima et al. 2010; Sousa et al. 2013), in Salvaterra and Soure municipalities.

11.3 Spatial Ecology

The initiative by few research groups effectively conducting research in South America has produced important biological information on manatees, however, data on movements are scarce. Tagging manatees for telemetry monitoring allows to estimate home range, document movements and seasonal migrations, identify

patterns of habitat selection and use, and understand population dynamics aspects, all crucial information to support conservation actions and protected area design. In most cases, logistics, financial and personnel resources impose limitations to the use of sophisticated methodologies, but this has been changing over the last decade, both by the introduction of new technologies and collaborative research initiatives.

The West Indian manatee occurs along almost 15,000 km of coastal area of six countries in South America (Brazil, French Guiana, Guyana, Suriname, Venezuela and Colombia), where no more than 2,000 individuals are believed to exist (Self-Sullivan and Mignucci-Giannoni 2012; Alves et al. 2016). So far, only Colombia and Brazil have implemented captures and/or releases of wild-ranging or captive-raised West Indian manatees, to use telemetry monitoring.

The first release of a captive-raised West Indian manatee in Brazil took place in 1994, and by August 2011 30 animals had been released along the coasts of the Brazilian northeastern states (Normande et al. 2015). Prior to release animals are adapted with a belt around the caudal peduncle, where one or more transmitter types are attached: a VHF-only, a platform-type (PTT) that uses an ARGOS link, and a global positioning system (GPS) that also has an ARGOS link (Normande et al. 2015). All satellite transmitters have built-in VHF transmitters, making it possible to track the target manatee in the field. Satellite data are obtained through the ARGOS service. Twenty-one (eight females and 13 males) were telemetry-monitored between November 2008 and June 2013, with a mean tracking period per animal of 107.48 +− SD 73 days (Normande et al. 2016).

Tracking data of released and reintroduced animals documented a wide manatee distribution in the region, from Rio Grande do Norte to Sergipe states and use coastal corridors for exploratory movements (Lima et al. 2012). Manatees may engage in long movements up to hundreds of kilometers for feeding and reproduction (Lima 2008; Lima et al. 2012; Normande et al. 2016).

Movement pattern was described as dichotomous. Some individuals present sedentary habits, with low rates of daily travel, strong site fidelity and reduced home range size. Wide-ranging manatees have higher daily travel rates and larger home ranges. Home range size (kernel 95%) of 21 (13 males and eight females) manatees released in Alagoas or Paraíba after rehabilitation varied from 4.24 to 30.96 km^2, lower than home ranges reported for other areas (Normande et al. 2016). Home-range size was not significantly influenced by gender, age at release or release site. Centers of activity were strongly associated with freshwater and feeding sites and reefs and estuaries as shelters (Normande et al. 2016).

In Colombia, manatees maintained in semi-captivity in the Sinú river were recaptured and had belt-mounted VHF and floating satellite transmitters adapted to their caudal peduncle. Researchers documented rapid movements towards and between river mouths during the dry season, in search of plants, a behavior similar to wild manatees in the area (Góngora-Correa 2009). In 2009, a female manatee was rescued in the Colombian department of Córdoba, and after a successful rehabilitation process, was released in Ciénaga Grande de Lorica. As of 2015 more than three years passed since her release and she is monitored with VHF technology with the help of the community (Caicedo-Herrera et al. 2015).

Free-ranging manatees were captured for the first time in Brazil, in the state of Ceará, using a small mesh, 200-m long, 7-m-deep seine net launched from a specially designed 10-m long vessel. Six manatees were captured and monitored by satellite telemetry between May 2012 and April 2013 (Petrobras 2014). Home range of four animals were estimated and varied from 41.33 km^2 (female with calf) to 155.56 km^2 (adult male). The studied animals did not use the estuaries of the area. Areas up to 5 m deep were used by the majority of the monitored individuals. Only the adult male used regions with up to 10 m deep. At the time of this writing, four manatees had been captured (two previously captive females with their native calves) in the coast of Alagoas state.

In order to monitor manatees at lower costs, a group of researchers recently developed satellite transmitters with GPS locator in Brazil, that use the Globalstar system and a SPOT Messenger module; a VHF transmitter is also part of the hardware. Tests conducted with captive manatees demonstrated good buoyancy of the housing, transmission mechanism and GPS location, with excellent precision of received coordinates. The use of lower cost materials available in the national market should turn the technology more accessible to users in South America (Borges et al. 2016).

11.4 Abundance

To estimate *T. manatus* abundance in South America is not an easy task. The species occurs mainly in riverine dark waters that, associated with their evasive behavior, makes their detection a challenge.

In Colombia, Arévalo-González et al. (2014) estimated manatee abundance in Ciénagas de Paredes through boat surveys, side-scan sonar surveys and interviews in 2002 and 2010. By boat survey, the maximum number of simultaneous sightings was 17. Using SSS and Distance sampling, a population of 12 manatees was estimated to occur in Los Pozos.

In Suriname, Pool (2012) indicated two manatee abundance estimates for the country: 500–600 (Duplaix and Reichart 1978) and 200–300 with a maximum of 500–600 at best (Wassink 1997). However, no details are presented on these studies' methods.

In Brazil, Lima (1997) and Luna (2001) proposed manatee abundance in northeastern and northern region, respectively, based on interviews. Despite the unusual method, without accuracy, these estimates were the only available in the country for years.

More recently, Alves et al. (2016) conducted aerial surveys from Canárias Island, on the mouth of Parnaíba river (Piauí) to São Francisco river mouth, covering 2,590 km^2, using strip transect method. Through a Bayesian approach, the authors estimated manatee abundance as 1,104 animals (CI 95%: 485–2,221), an inaccurate result that could be improved with additional efforts in a smaller spatial scale.

In the states of Ceará and Rio Grande do Norte, a monitoring project related to federal environmental licensing process conducted by IBAMA estimated manatee abundance through linear transects in aerial surveys from Aquiraz (CE) to Touros (RN) (387 km) (Petrobras 2014). Distance sampling estimated 193 manatees in the area (CI 95%: 93–378).

11.5 Feeding

The manatee is an exclusively herbivorous animal. As the species may occur in a wide variety of habitats, such as marine, freshwater and estuarine environments, the animals feed on a variety of plants, which may be submerged, floating or emergent, and the choice between these types will depend on the availability and nutritional value of each (Marsh et al. 2011).

Trichechus manatus feeding preference is related to species availability, nutritional value, and palatability (Hartman 1979; Best 1981). In South America, the species inhabits a variety of habitats, as rivers, swamps, estuaries and coastal areas. Thus, in each of these habitats animals' diet varies. In Table 11.1, a review on manatee diet in the continent is presented.

An interesting fact when observing the table is the restriction in terms of items quantity in some areas of Brazil, as the states of Ceará and Alagoas, where manatees eat basically *Halodule wrightii* as it has a higher nutritional value than algae (Meirelles et al. 2016a). This fact is alarming, since impact on seagrass meadows can severely affect manatees inhabiting these areas.

11.6 Genetics

Garcia-Rodriguez et al. (1998) compared the mitochondrial DNA control region among eight locations across the western Atlantic Ocean, from Florida to Brazil. Low levels of genetic diversity were observed in Florida and Brazil (at the limits of species' range). Also, the study indicated three mtDNA lineages: Florida and West Indies; from the Gulf of Mexico to the Caribbean rivers of South America; and northeastern Atlantic coast of South America. With a larger sample, Vianna et al. (2006) corroborated these findings. According to Santos et al. (2016), through mtDNA Bayesian phylogeny and chronological calibration with sirenian fossils, separation time between manatee populations from the northern Atlantic region and for those of Caribeean and Gulf of Mexico was estimated in 590,000 years.

Recently, a detailed karyotype analysis revealed differences between chromosomal pair 4 and 10 from *T. manatus* from Brazil and those from Puerto Rico and Caribbean (Barros 2013; Barros et al. 2017). The same authors studied 3D geometric morphometrics of manatee skulls and identified important differences between

Table 11.1 Food items described for West Indian manatee in South America

Country	Region	Food itens	Method	Source
Colombia	Puerto Carreño, Vichada	*Paspalum* sp., *Paspalum fasciculatum*, *Paspalum repens*, *Alchornea castanaeifolia*, *Eichhornia crassipes*, *Ceratopteris thalictroides*, *Mikonia* sp.	Indirect evidence and interviews	Gómez-Camelo et al. (2004)
	Puerto Carreño, Vichada	*Paspalum repens* and *P. fasciculatum*	Interviews, indirect evidence	Castelblanco-Martínez (2004)
	Brazo de Loba and Panceguita, Magdalena ríver	*Eichhornia* sp. and *Paspalum* spp.	Interviews, indirect evidence	Aguilar-Rodríguez et al. (2004)
	Ciénaga de Paredes, caño Peruétano	*Paspalum fasciculatum*, *P. repens* and *Polygonum ferrugimeum*	Interviews, indirect evidence	Castelblanco-Martínez (2004)
Venezuela	Llano Venezoelano	*Eichhornia* sp.		Linares (1998)
	Lower Orinoco	*Paspalum repens* and *Eichhornia crassipes*	Indirect evidence	Rívas-Rodríguez et al. (2012)
	Centroocidental and southwestern Maracaibo lake	*Eichhornia* sp. and *Pistia stratioides*	Interviews	Montiel-Villalobos and Barrios-Garrido (2005)
	Northwestern Maracaibo Lake	*Rhizophora mangle*, *Avicennia germinans*, *Balanus balanoides*	Interviews	Montiel-Villalobos and Barrios-Garrido (2005)
	Orinoco Delta	*Paspalum repens, Eichhornia crassipes, Eichhornia azurea, Pistia stratiotes, Hydrocotile umbellata, Ludwigia helminthorrhiza, Limnobium laevigatum*	Interviews	Rodulfo (2012)

(continued)

Table 11.1 (continued)

Country	Region	Food itens	Method	Source
Guyana	Irrigation canals	*Cabomba aquatica, Nelumbo speciosa, Paspalum repens, Utricularia foliosa, Luziola spruceana, Paspalum vergatum and Hymenachne amplexicaule.*		Haigh (1991)
Suriname		*Montrichardia arborescens, Nymphaea odorata*	Indirect evidence	Lefebvre et al. (2001); Dekker (1974)
French Guiana	Coswine swamps	*Rhizophora* sp., *Rhizophora racemosa*, *Montrichardia arborescens* and *Scleria pterota*	Indirect evidence	Spiegelberger and Ganslosser (2012)
	Kaw river	*Crinum erubescens*, *Echinochloa polystachya*	Indirect evidence	Castelblanco-Martínez and De Thoisy (2012)
Brazil	Amapá	*Montrichardia* sp., *Hymenachne* sp., *Avicennia* sp., *Eichhornia crassipes*	Interviews	Barbosa (2013)
	Northern Brazil	*Avicennia nitida, Rhizophora mangle, Laguncularia racemosa, Montrichardia arborescens, Spartina brasiliensis, Eichhornia crassipes, Eleocharis interstincta*	Interviews	Best and Teixeira (1982)
	Marajó Island, Pará	Seagrass, *Spartina brasiliensis*	Interviews	Sousa et al. (2013)
	Gato Island, Maranhão	*Spartina alterniflora*	Observation	Alvite (2008)
	Maranhão	*Spartina* sp., magrove	Stable isotopes (carbon and nitrogen)	Ciotti (2012)
	Timonha and Ubatuba rivers estuary, Piauí	*Spartina* sp., mangrove, seagrass, algae and fish	Interviews	Aquasis (2008)
	Timonha and Ubatuba rivers estuary, Piauí	*Halodule wrightii*, *S. alterniflora*, mangrove, algae	Stable isotopes (carbon and nitrogen)	Ciotti (2012)

(continued)

Table 11.1 (continued)

Country	Region	Food itens	Method	Source
	East coast of Ceará	Mainly *H. wrightii*	Interviews, direct observation, stomach contents	Aquasis (2006); Vasconcelos (2013)
	East coast of Ceará	*H. wrightii*	Stable isotopes (carbon and nitrogen)	Ciotti (2012)
	Paraíba	Red algae	Stomach contents and feces samples	Borges et al. (2008)
	Paraíba	Mainly algae, but also *H. wrightii*	Stable isotopes (carbon and nitrogen)	Ciotti (2012)
	Alagoas	Mainly *H. wrightii* but also algae	Stable isotopes (carbon and nitrogen)	Ciotti (2012)

skull shape from animals from Brazil and those from Caribbean and Florida, indicating an urgent reassessment of species taxonomy.

In Colombia, Satizábal et al. (2012) tested the Male-biased dispersal (MBD) hypothesis in the country's rivers (Sinú, northern Magdalena, San Jorge, Ciénaga de Paredes, Meta and Orinoco). D-loop analyses indicated high levels of structuring between Sinú, San Jorge and Magdalena rivers, as also between Northern Magdalena and Ciénaga de Paredes. Some evidence of structuring between the Orinoco and Meta rivers was also observed, despite the small number of samples. Microsatellite data suggested no structure. These results indicate male-biased gene flow dispersal in manatees that inhabit Colombia rivers.

In Brazil, Luna et al. (2012) reported three haplotypes (M01, M03 and M04) for the species, with only one (M01) recorded in animals from Ceará to Alagoas. The authors indicated that rehabilitated calves from the states north of Ceará should not be released in current release areas (Paraíba and Alagoas) due to risk of genetic swamping. However, according to Santos et al. (2016), this is not a plausible explanation to restrict release sites in Brazil, since M04 differs from M01 by just one mutation that can happen spontaneously in one generation.

Also in Brazil, in the east coast of Ceará and northwestern Rio Grande do Norte, where a high frequency of newborn live calves strand in the country (Meirelles 2008; Parente et al. 2004; Silva 2010), Silva (2015) studied genetic structuring and kinship between stranded manatees. There was no population structuring between CE and RN. The majority of animals in which it was possible to define kinship had some level of genetic kinship (34.4% of total). This is an indication of a small manatee population in the studied region.

11.7 Health Status

Knowledge on the health of populations of *T. manatus* in South America comes mainly from animals rescued after stranding and/or bycatch, maintained in captivity for rehabilitation and release purposes or for display in zoos and aquariums (Fig. 11.6). Although there are records of maintenance of the species in captivity since the late nineteenth century in Brazil and Guyana, rescue activities were established only in the 1980s in most South American countries (Adimey et al. 2012; Lima et al. 2001). Currently, there are about 11 institutions holding captive manatees in the continent, in Brazil, Guyana, Venezuela and Colombia, serving different purposes (Adimey et al. 2012; Carlos Javier Silva, personal communication; Carvalho and Borges 2016).

In Guyana and Suriname, there are current and historical records of manatees maintained in captivity for the control of aquatic vegetation from irrigation canals, without assessing the risk of this activity for the health of the animals. Dozens of manatees were captured in these countries and sent to aquariums and zoos in Europe and Asia, where they participated in breeding programs (Adimey et al. 2012; Dekker 1974; Haigh 1991). We emphasize the serious concern about these crossbreedings between animals from different populations, even under the control of studbooks, since recent studies indicate that the population from Guyana to Brazil represents a distinct significant evolutionary unit from the Caribbean population and the region of origin of these animals, west of the mouth of the Amazon River, is a hybridization zone (Santos et al. 2016).

Fig. 11.6 A 2-year old manatee calf (named "Tico") in the management area of a rehabilitation tank of Marine Mammal Rehabilitation Centre/Aquasis, in Ceará, northeastern Brazil. The stranding of newborn calves is a serious problem in the country. Natural and human-related causes are involved in the separation of females and their offspring (Photo: Aquasis' Collection)

Little information has been published on non-infectious diseases, infectious and parasitic diseases, serological surveys and contaminants that affect the health of native West Indian manatees in South America. In general, publications on *T. manatus* mortality in the continent categorize the origin of these events as anthropogenic (bycatch, hunting, collision with vessels, injury by projectile, solid waste ingestion, etc.), natural (disease, senility, etc.), perinatal and undetermined events, but final pathological diagnoses are unsufficiently detailed. In the Orinoco River, Colombia, Castelblanco et al. (2009) reported that more than 85% of manatee deaths were related to human activities, especially calves and juveniles. In Northeastern Brazil, the perinatal causes are predominant (75–80%), followed by those of anthropogenic origin (Fig. 11.7) (Meirelles 2008; Parente et al. 2004; Silva et al. 2016). Hunting is still a threat on the Northern coast, representing more than 94% mortality (Luna et al. 2008). In Guyana and Suriname, mortality events are poorly documented, but are mainly related to bycatch and hunting, while in Venezuela there are still sporadic records of deaths from boat collisions (Quintana-Rizzo and Reynolds 2010). In French Guyana, at least 10 deaths associated with bycatch and hunting were reported between 2000 and 2002 (De Thoisy et al. 2003).

Medical exams in wild-caught animals are important to determine the influence of environmental change on the health of individuals and populations, hence, they can be used as a tool for conservation (Stamper and Bonde 2012). This activity is still in its infancy in South America, since there are data only on six individuals captured on the coast of Ceará, Northeastern Brazil (Petrobras 2014). The construction of a long-term database is essential for an accurate assessment of the health of populations of manatees in the continent.

Fig. 11.7 Aquasis' rescue team carrying out biometric measures of an adult male manatee accidentally caught in fishing nets in Ponta Grossa beach, Icapuí, northeastern Brazil (Photo: Aquasis' Collection)

Rehabilitation programs are well-established as a strategy for *T. manatus* conservation in Brazil, where it is estimated that more than 100 newborns have been rescued and sent to specialized centers, since the mid-1980s (Carvalho and Borges 2016). Of this total, more than 40 animals were released into the wild, with a success rate exceeding 75% and at least six records of births (Normande et al. 2015, 2016.). In Venezuela, manatee rescues are casual, with most of the animals intended for zoos, with only one record of release. By 2014, the country had seven specimens in captivity, of which three were born in the captive environment (Boede and Mujica-Jorquera 2016). In Colombia, although there is a considerable number of captive animals in artificial lakes, which are kept under inadequate clinical and nutritional support, rescue and rehabilitation programs are not intended for the release of the animals (Caicedo-Herrera et al. 2004).

Several studies have been conducted to determine hematological reference parameters for *T. manatus*, both in captive and free ranging animals. This information is essential for the diagnosis of diseases and to guide the appropriate treatments (Bossart et al. 2001). However, most of these studies were performed on Florida animals, except for the studies of Converse et al. (1994), Silva et al. (2007, 2009) and Boede and Mujica-Jorquera (2016), which showed blood parameters of captive manatees in Guyana, Brazil and Venezuela, respectively. Few native specimens were evaluated in South America, with no further parameters available for these populations. The levels of thyroid hormones were evaluated for captive manatees from Brazil and native animals from Colombia, showing that they are influenced by diet and that despite the low metabolism of the species, the levels found were similar to other marine and terrestrial mammals (Ortiz et al. 2000).

Information on microorganisms that constitute the normal microbiota or act as agents of infectious diseases of manatees has been collected from native and captive animals from Brazil. About 27 species and 15 genera of bacteria and 16 species of yeasts were isolated from the microbiota of natural cavities of these animals, with the detection of strains resistant to multiple antibiotics (beta-lactam, macrolide and aminoglycoside) and antifungals (azole derivatives), respectively (Attademo 2014; Petrobras 2014; Sidrim et al. 2015a; Sidrim et al. 2016; Vergara-Parente et al. 2003a). There were also differences in the composition of colonizing bacteria between captive and native manatees, demonstrating the influence of environmental factors on microbial communities (Petrobras 2014; Vergara-Parente et al. 2003a).

Diagnoses of infectious diseases are uncommon in manatees. Among bacterial diseases, abscesses caused by *Staphylococcus* sp., *Proteus* sp. and *Escherichia coli*; ear infections by *Pseudomonas* sp., *Proteus mirabilis* and *Staphylococcus* sp.; colitis by *Klebsiella pneumoniae* and *Morganella morganii* and systemic infections by *Salmonella panama*, *Pseudomonas* sp. and *Klebsiella* sp. stand out (Attademo 2014; Carvalho and Silva 2016; Lazzarini et al. 2014; Montoya-Ospina et al. 2001; Vergara-Parente et al. 2001, 2003b). Infections by *Flavobacterium meningosepticum* and *Xanthomonas maltophilia* were reported as cause of death of three neonates in Colombia (Montoya-Ospina et al. 2001). Fungal diseases are uncommon, with phaeohyphomycosis reports caused by *Bipolaris hawaiiensis* and outbreak of

superficial skin fusariosis in calves kept in captivity (Sidrim et al. 2015b; Carvalho et al. 2015). Regarding viral diseases, Attademo et al. (2013) detected the presence of rotavirus in captive and semicaptive manatee feces without associated clinical signs.

As to parasitic diseases, nasal trematode *Pulmonicola cochleotrema* was the only helminth diagnosed in stranded animals and specimens reintroduced in Northeastern Brazil (Borges et al. 2016; Carvalho et al. 2009). Among the protozoa, cryptosporidiosis is prevalent in both captive and pre-release stage animals in Brazil, with associated intestinal clinical signs (Borges 2007, 2016). A case of myocarditis caused by *Toxoplasma gondii* was detected in a captive manatee that died in Guyana (Dubey et al. 2003). Giardia lamblia infection has been detected in a captive calf (Carvalho and Silva 2016). Garzón (1997) conducted parasitological and microbiological evaluation of *T. manatus* in Colombia.

Non-infectious diseases are poorly described. In the last decade we have seen a higher prevalence of malformations in newborns stranded in Northeastern Brazil, including fatal cases of hydrocephalus, atresia of the right ventricle, and other less severe locomotor disorders, such as spinal fusion in the lumbar region, permanent folding of the caudal fin and scapular-humeral arthropathy. Neoplasias are rare, with a diagnosis of uterine leiomyoma in adult female stranded in Ceará, Brazil (Carvalho and Silva 2016). The diagnosis of disseminated malignant lymphoma was conducted in a specimen exported from Guyana to an aquarium in Denmark, which still had recurrent cutaneous papillomatosis due to immunosuppression (Hammer et al. 2005). Brito (2015) conducted histopathological evaluation of 38 dead manatees in the Northeast coast of Brazil, and diagnosed disorders such as stomatitis, cardiac fibrosis, myocarditis, liver fibrosis, pancreatic atrophy and metritis. Two specimens rescued in the 1990s in Colombia had suspected dwarfism due to a slow development, during more than four years in semicaptivity (Millian-Sánchez et al. 1995).

Serological surveys for the detection of antibodies against *Toxoplasma gondii*, *Leptospira interrogans*, *Brucella abortus* and Morbillivirus have been conducted in captive South American specimens of *T. manatus*. Silva et al. (2001) detected a positive animal for *T. gondii* in Brazil. Later, Attademo (2014) observed prevalence of 10.9% of seropositivity against the same parasite and 9.2% of positivity for anti-*Leptospira* antibodies. Native individuals captured in the country were seronegative for the surveyed agents (Petrobras 2014). Anti-Morbillivirus antibodies were not detected in captive manatees in Guyana (Duignan et al. 1995). Jiménez-Marrero et al. (1998) have measured levels of IgG from 20 semicaptive animals in Colombia, whose parameters can be used in immunological studies and for the diagnosis of immunosuppression.

Anzolin et al. (2012) performed the main toxicological study of manatees in Brazil and found high levels of the metals aluminum, lead, cadmium and tin in specimens maintained in captivity and semicaptivity in Paraíba state. Lailson-Brito et al. (2010) and Cavalheiro et al. (2016) found low concentrations of mercury and organochlorines (DDT, HCH, PCBs and Mirex) in tissues of manatees stranded dead in Ceará and Rio Grande do Norte.

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