ELSEVIER

Biological Conservation 95 (2000) 67–75

BIOLOGICAL CONSERVATION

www.elsevier.com/locate/biocon

Distribution and habitat use by manatees (*Trichechus manatus manatus*) in Belize and Chetumal Bay, Mexico

Benjamín Morales-Vela [a,*], David Olivera-Gómez [b], John E. Reynolds III [c], Galen B. Rathbun [d,e]

[a] *El Colegio de la Frontera Sur, Apdo. Postal 424, C. P. 77049, Chetumal, Quintana Roo, Mexico*
[b] *Centro de Investigación Científica y de Estudios Superiores de Ensenada, Km 107 Carr. Tijuana — Ensenada, Apdo. Postal 2732, C.P. 22800, Ensenada, B.C., Mexico*
[c] *Marine Science Department, Eckerd College, St Petersburg, FL 33711, USA*
[d] *Piedras Blancas Field Station, Western Ecological Research Center, US Geological Survey, San Simeon, CA 93452-0070, USA*
[e] *Department of Ornithology and Mammalogy, California Academy of Sciences, Golden Gate Park, San Francisco, CA 94118, USA*

Received 2 May 1999; received in revised form 28 November 1999; accepted 23 December 1999

Abstract

The nearshore coastal areas of Belize and of Chetumal Bay, Mexico, support one of the largest populations of manatees (*Trichechus manatus manatus*) in the Caribbean. In order to further document the distribution, relative abundance, habitat associations, and status of this population, we conducted three aerial surveys. The flights were done in January 1994, May 1994, and January 1995. Total manatee counts for each survey were 266, 207, and 171, respectively. Calves represented 7.4% of the grand total. Solitary manatees represented 62.8% of the total count. Manatees were numerous around the cays east of Belize City, in Placentia and Indian Hill lagoons, and in Chetumal Bay. Most manatees were observed in lagoons and rivers. Growing tourist activities should be assessed to avoid undesirable effects on manatees. Poaching and marketing of manatee products continues to jeopardize the animals in some areas. Current research and management activities are part of a cooperative international program to conserve the manatee in the Caribbean region.

Keywords: Manatee; Aerial surveys; Conservation; Belize; Mexico

1. Introduction

The West Indian manatee (*Trichechus manatus manatus*) is protected in Belize by the Wildlife Protection Act of 1981 and in Mexico by the Ecological Act of 1994, under which it is classified as a species at risk of extinction. Historical reports suggest that the manatee population in Belize may have been larger than those of other Caribbean countries (Charnock, 1968, 1970; Charnock et al., 1974). More recently, O'Shea and Salisbury (1991) stated that Belize harbors the most important present day manatee population in the Caribbean region. Adjoining Belize to the north, Chetumal Bay, located in the southern part of the state of Quintana Roo, has the largest population of manatees on the Caribbean coast of Mexico (Morales and Olivera, 1997). There is a continuous manatee habitat from Chetumal Bay southward throughout Belize (Morales and Olivera, 1994a). The importance of the Belize and southeastern Mexico coasts to manatees in Central America is underscored by Lefebvre et al. (1989) and Reynolds and Odell (1991).

Previous to our study, two aerial surveys were carried out to census manatees in Belize. They were conducted in September 1977 by Bengtson and Magor (1979) and in May 1988 by O'Shea and Salisbury (1991). In Quintana Roo, the first manatee aerial surveys were carried out in 1987 and 1988 by Colmenero and Zárate (1990). Additional surveys in Quintana Roo were conducted by Morales and Olivera (1994a). The surveys on which we report in this paper were implemented based on recommendations of participants at a Manatee Research and Management Workshop held in Chetumal, Mexico, in

* Corresponding author.
E-mail address: bmorales@ecosur-qroo.mx (B. Morales-Vela).

0006-3207/00/$ - see front matter
PII: S0006-3207(00)00009-4

September 1992. Participants, who included specialists on manatees or coastal habitat from Mexico, Belize, and the United States (Morales and Olivera, 1994b), agreed upon the importance of implementing manatee surveys of Chetumal Bay and Belize because of both the extensive manatee habitat and the reported high numbers of manatees in these areas.

The objectives of the surveys reported here were to determine manatee abundance, distribution, and preferred habitats. This information is required to effectively conserve the important West Indian manatee population in Belize and southeastern Mexico.

2. Methods

2.1. General features of the study area

Our study area included coastal areas of Belize and Chetumal Bay (Fig. 1). The coast of Belize stretches approximately 280 km from the Rio Hondo, which forms the natural border with Mexico, to the Sarstoon River on the Guatemalan border. This area has many river mouths, coastal lagoons and inlets, and it is protected by barrier reefs and cays.

Belize has a tropical climate. The highest temperatures occur from May to September and humidity is highest on the coast from June to October, with a short dry period in August. From November to February the wind blows mainly from the north. Tropical storms and hurricanes appear from June to November.

Chetumal Bay is an estuary that covers an area of about 2450 km^2 (including the Belizean area). Its depth ranges from 1 to 7 m with a mean of 3 m. The salinity ranges from 8 to 18 ppt and the water temperature ranges from 24.5 to 31.0°C (Morales et al., 1996). The main aquatic vegetation in the bay includes *Bathopora* sp., *Chara* sp., *Najas marina*, *Ruppia maritima*, *Halodule wrightii*, and *Thalassia testudinum* (Espinoza, 1996; Morales et al., 1996).

Chetumal Bay is fed by several fresh water rivers, including the Rio Hondo and New River. Other sources of fresh water include many small artesian springs, and a few larger ones with diameters of more than 30 m, which produce somewhat saline water. None of the springs has been well studied.

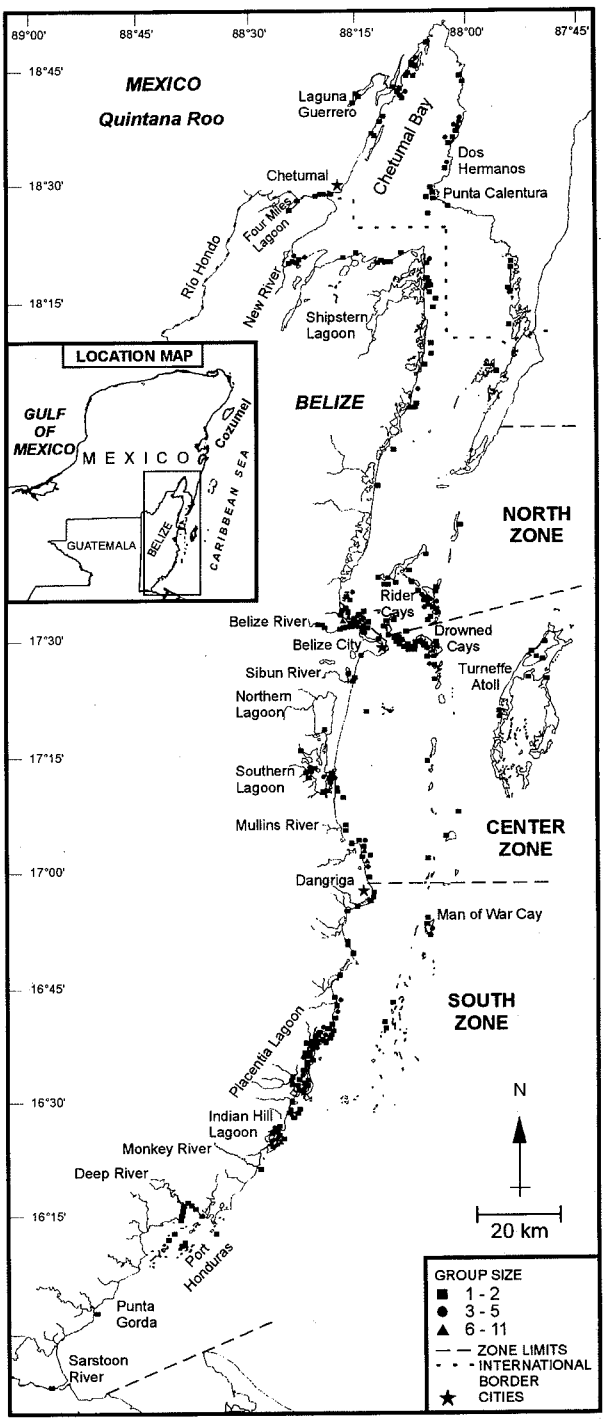

Fig. 1. The study area in Belize and Quintana Roo, Mexico. The three group size categories of manatee sightings that are illustrated (see key) represent the pooled data from three aerial surveys conducted in January and May 1994, and January 1995.

2.2. Survey methods

We conducted aerial surveys from high winged Cessna Sky Master or Cessna 206 aircraft in January and May 1994, and January 1995 (Table 1). Our three surveys were carried out along the entire coast of Belize and Chetumal Bay at altitudes of 150 to 180 m and airspeeds of 130–150 km/h. We followed the protocol of Lefebvre (1995) for conducting safe aerial surveys.

Our aerial survey techniques were generally similar to those reported by Reynolds and Wilcox (1986) in Florida; O'Shea et al. (1988) in Venezuela; Mou et al. (1990) in Panama; and Morales and Olivera (1994a) in Chetumal Bay. Three or four observers participated in each survey; at least two observers on each flight had

Table 1
General characteristics of the three aerial surveys carried out in Belize and Chetumal Bay, Mexico[a]

Survey	Days	Zone	Time	Aircraft	Overall conditions	General conditions
January 1994	27–29	Central	04:56	Sky Master	3	Winds SE, 10–15 knots, good visibility, except
	30	South	03:11		3	around Belize City.
	31	North	03:17		2	Winds W–NW, 3–5 knots, good water visibility.
		Total	11:24			
May 1994	9	South	02:20	Cessna 206	2	Winds E–SE, 7–9 knots, good visibility except around
	10	Central	05:22		2	Belize City. Better visibility than the January 1994 survey in the lagoons.
	11	North	04:16		2	Winds E, 10–12 knots, generally good visibility.
		Total	11:58			Turbid water in the Belizean part of Chetumal Bay.
January 1995	12–13	Central	04:00	Cessna 206	3–4	Winds SE, 18 knots, poor visibility. Turbid water in coastal zone from Belize City to Gales Point.
		South	03:09		4	Winds SE, 18 knots, poor visibility and turbid water.
		North	04:46		3	Winds W–NW, 15–20 knots, fair visibility.
		Total	11:55			

[a] Time represents the amount of time spent surveying each zone. Overall conditions for each part of the survey are rated on a scale of 1–5, where 1 denotes excellent conditions and 5 represents very poor conditions.

experience conducting manatee surveys. They sat on each side of the aircraft and maintained their position during the entire survey. To minimize observer fatigue each survey lasted no longer than 4 h. The right door of the aircraft was removed to allow better visibility. All observers wore polarized sunglasses. Observers also used hand-held tape recorders to record sighting information. The location of manatees was plotted on topographic maps (scale: Belize 1:350,000; Chetumal Bay 1:50,000), and also recorded using a Trimble Navigation, Ensign XL Global Position System (GPS) receiver.

When manatees were sighted the aircraft circled to obtain the most accurate count possible (variable effort recount method; Lefebvre and Kochman, 1991). We took photographs for later verification of counts. Manatees were classified as adults or calves. Those that were estimated to be less than 2 m long and were closely associated with a larger animal were considered to be calves. Large animals closely associated with calves were presumed to be females. Aggregations of two or more manatees (including female-calf pairs) were defined as groups.

2.3. Survey coverage

We arbitrarily divided the study area into North, Central, and South zones (Fig. 1) based on easily recognizable geographic features that allowed us to fly efficient aerial survey paths. The zones also allowed us to make spatial comparisons of our counts. The North Zone extended from the northern tip of Chetumal Bay to an imaginary line extending east from Rider Cays to just north of Turneffe Atoll. The Central Zone, which include the Belize river and its mouth, was delimited at the southern end by a line extending east from Dangriga City. The South Zone terminated on the south side of the Sarstoon River. Our survey path followed shoreline contours 500–800 m offshore. We surveyed rivers upstream and then downstream by flying over land following their course so that a clear view of the water from the near bank to mid-river was obtained. We circled the central portions of large lagoons to ensure complete coverage, and cays and their small inner lagoons were also circled. For example, in the North Zone (primarily Chetumal Bay; Fig. 1) the surveys included the Laguna Guerrero system, the lower 6 km of the Rio Hondo, Four Miles Lagoon, and offshore cays. The entire shoreline of every large cay, and the coastline and lagoons of Turneffe Atoll in the Central Zone, was surveyed. South of Dangriga (South Zone) the survey followed a zig-zag pattern and only the larger cays were surveyed. During the second and third surveys (but not the first) we included the lower 5 km of the New River, 6–7 km of the Belize River, 3 km of the Sibun River, 2 km of Mahogany Creek (located off Southern Lagoon), 3 km of the Deep River (near Port Honduras), and 7 km of the Sarstoon River. Only the Rio Hondo was surveyed during the first survey.

We divided the study area into five habitat types: river, lagoon, coast, cay, and Turneffe Atoll. Rivers included their mouths. Small cays located within 1 km of the mainland were considered as coastal habitat. Manatees observed in channels traveling towards a lagoon were considered lagoon sightings. The flying time over each habitat was recorded.

We used the Kruskal–Wallis Test by single classification to analyze the frequency of manatee sightings in

each of the zones, and a one-way ANOVA to compare the occurrence of manatees in each habitat. A least-significant-difference (LSD) test was applied when significant differences were detected. The number of manatees observed per survey hour (Index of Relative Abundance, IRA) was used as the dependent variable; it was log transformed to normalize the residual plot and to stabilize the variances.

3. Results

3.1. Distribution

During the January 1994 survey, 266 manatees (252 adults + 14 calves) were sighted in 11 h and 24 min of survey time (IRA was 23.3 manatees per flight h). During the May 1994 survey, 207 manatees (187 adults + 20 calves) were counted in 11 h and 58 min (IRA was 17.3 manatees per flight h). During the January 1995 survey, 171 manatees (157 adults + 14 calves) were counted in 11 h and 55 min (IRA was 14.3 manatees per flight h). During the first survey the only river surveyed was the Rio Hondo. In the latter two surveys the lower reaches of the other principal rivers in all three zones were surveyed. The total number of manatees counted in the three surveys was 644 with a mean of 214.7 ± 48 and a coefficient of variation (CV) of 22.4%.

The number of manatees sighted per survey in each zone is shown in Table 2. Mean number of manatees sighted in the three zones were not significantly different (Kruskal–Wallis; $H = 1.6889$, $P = 0.4298$). The most consistent counts occurred in the North Zone (CV was 21.0%). The South Zone had the highest variation (CV was 70.3%).

Manatees occurred along much of the coast of Chetumal Bay and Belize (Fig. 1). Areas where manatees concentrated included Laguna Guerrero; Dos Hermanos and Rocky Point in Chetumal Bay, the cays near Belize City, the Belize River, Southern Lagoon, the Dangriga area, Placentia Lagoon, Indian Hill Lagoon, and Port Honduras. In all three surveys only one manatee was seen in Northern Lagoon, and only 11 manatees were observed at Turneffe Atoll.

Table 2
Number of manatees and percentage sighted per survey in each zone[a]

Survey	North	Central	South	Total
January 1994	103	46	117	266
	38.7%	17.3%	44.0%	100%
May 1994	91	85	31	207
	44.0%	41.1%	14.9%	100%
January 1995	67	57	47	171
	39.2%	33.3%	27.5%	100%
$\overline{X}$	87.0	62.7	65.0	214.7
SD	18.3	20.0	45.7	48.0
CV	21.0%	31.9%	70.3%	22.4%

[a] Mean ($\overline{X}$), standard deviation (SD) and coefficient of variation (CV) are given for each zone.

3.2. Calves

During the three surveys, calves represented 5.3% ($n = 14$); 9.7% ($n = 20$) and 8.2% ($n = 14$) of the total manatees observed on each census. The overall percentage of sighted calves was 7.4%. Placentia and Indian Hill lagoons and the cays east of Belize City were the most important areas for calves (Table 3). Placentia and Indian Hill lagoons contained 29.2% ($n = 14$) of all calves sighted, whereas waters around the cays east of Belize City contained 22.9% ($n = 11$) of all calves sighted.

3.3. Groups

The frequency distribution of different group sizes sighted during the surveys is shown in Fig. 2. The proportion of solitary manatees was 62.8% and of groups was 37.2%. Mean group size ± one standard deviation for all surveys was 1.7 ± 1.5 manatees. The number of cow-calf pairs included in each group category was: 26 in groups of 2 manatees, 5 in groups of 3, 4 in groups of 4, 4 in groups of 5, 4 in groups of 7, 1 in a group of 9, 3 in groups of 10, and 1 in a group of 11.

During our first survey, 76 of 130 sightings (58.5%) were of solitary individuals and 54 sightings (41.5%) were of groups. Mean group size was 2.0 ± 1.9, with the largest groups (9 to 11 manatees) being located in Chetumal Bay, near Dandriga and in Indian Hill Lagoon (Fig. 1). In the second survey, 81 of 127 sightings (63.8%) were of solitary individuals and 46 sightings (36.2%) were of groups. Mean group size was 1.6 ± 1.1, and the largest group was 9 manatees located in Indian Hill Lagoon (Fig. 1). In the third survey, 74 of 111 sightings (66.7%) were of solitary individuals and 37 (33.3%) were of groups. Mean group size was 1.5 ± 1.1, and the largest group was 7 manatees located near the Belize River (Fig. 1).

3.4. Habitat use

The relative abundance of manatees in the five habitat types (river, lagoon, coast, cay, and Turneffe Atoll) was significantly different (ANOVA; $Fs = 18.851$, $P = 0.0001$; Fig. 3). Using the LSD test ($P < 0.05$), we found that Turneffe Atoll habitat was significantly different from the other four. Rivers were different from cays, and lagoons were different from cays. The same test showed homogeneity between coast and cay habitats and between coast and lagoon habitats.

Table 3
Number of adult manatees (*n*), calves (in parentheses), and percent of survey totals (%) in different areas of Belize and Chetumal Bay, Mexico[a]

Area	Survey date									
	September 1977		May 1989		January 1994		May 1994		January 1995	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Chetumal Bay system	NS	–	NS	–	68 (3)	25.6 (1.1)	44 (1)	21.3 (0.5)	36 (1)	21.0 (0.6)
Four Miles Lagoon	NS	–	1	1.0	3	1.1	0	0.0	NS	–
New River	12	16.2	7 (1)	6.9 (1.0)	0*	0.0	2* (1)	1.0 (0.5)	3*	1.7
Belize River	2	2.7	16 (2)	15.7 (2.0)	NS	–	20 (4)	9.7 (1.9)	16 (2)	9.4 (1.2)
Cays east of Belize City	12 (2)	16.2 (2.7)	10 (1)	9.8 (1.0)	30 (2)	11.3 (0.7)	60 (5)	29.0 (2.4)	31 (4)	18.1 (2.3)
Placentia and Indian Hill lagoons	10 (1)	13.5 (1.3)	8 (1)	7.8 (1.0)	65 (6)	24.4 (2.3)	20 (4)	9.7 (1.9)	26 (4)	15.2 (2.3)
Southern Lagoon	31 (4)	41.9 (5.4)	55	53.9	3	1.1	16 (2)	7.7 (1.0)	5	2.9
Dangriga coastal area	NS	–	NS	–	52 (2)	19.5 (0.7)	4 (1)	1.9 (0.5)	5	2.9
Port Honduras	0	0.0	NS	–	7	2.6	4	1.9	9	5.3
South of Port Honduras to Sarstoon River	NS	–	NS	–	1	0.4	1	0.5	0	0.0
Other areas of Belize	NS	–	NS	–	23 (10)	8.6 (0.4)	16 (2)	7.7 (1.0)	26 (3)	15.2 (1.7)
Total	67 (7)	90.6 (9.4)	97 (5)	95.0 (5.0)	252 (14)	94.7 (5.3)	187 (20)	90.4 (9.6)	157 (14)	91.8 (8.2)

[a] Data from Bengtson and Magor (1979) in September 1977, O'Shea and Salisbury (1991) in May 1989, and in this study. NS indicates that an area was not surveyed. An asterisk (*) indicates that an area was incompletely surveyed. Note that differences in survey coverage and methods make meaningful comparisons difficult (see text).

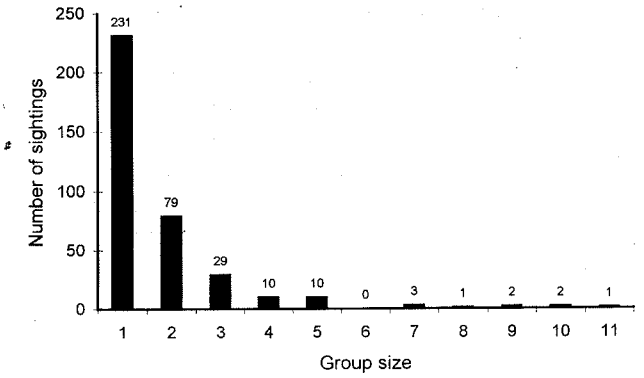

Fig. 2. Frequency distribution of different sized groups of manatees observed during aerial surveys of Belize and Quintana Roo, Mexico, in 1994 and 1995. Lone cow-calf pairs were considered to be a group of two manatees. The total number of sightings was 368.

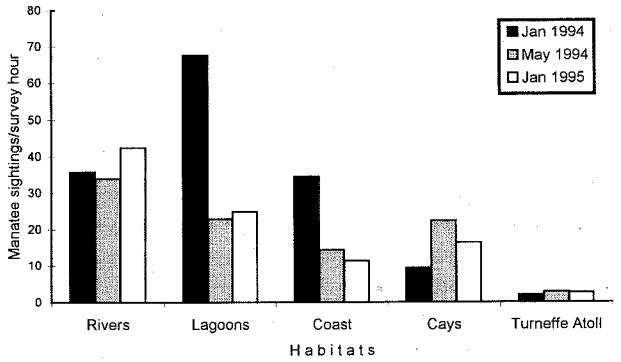

Fig. 3. Use of different habitats by manatees observed during three aerial surveys conducted in Belize and Chetumal Bay, Mexico, in 1994 and 1995.

3.5. Manatee mortality

Only one dead manatee was observed in our surveys. It was entangled in a fishing net south of Belize City, near the coast.

4. Discussion

4.1. Survey design

After our first survey, we adjusted the survey route to include the lower areas of rivers. This modification should be considered as we discuss our results.

The South Zone had the highest CV (70.3%), mainly because of the variation in counts in three locations: Placentia and Indian Hill lagoons and in the Dangriga coastal area (Table 3). This may be due, at least in part, to seasonal changes in use of the area by manatees and to poor water clarity in the South Zone. Such conditions suggest that survey methods need modifications in future aerial surveys of Belize (see Recommendations section).

4.2. Comparisons with previous surveys

There have been few surveys of manatees in waters of Belize and southeastern Mexico. The small sample size, spread over a number of years, makes it difficult to compare results of the different surveys. The problem is compounded by the fact that the surveys covered different geographic areas, at different times of year, and

employed somewhat different survey methods. Although it seems appropriate to attempt to compare findings of various surveys to try to determine whether habitat use or manatee counts have changed, the following comparisons should be viewed with some caution.

Table 3 compares results of our study with those done by Bengtson and Magor (1979) and O'Shea and Salisbury (1991). The most striking features of the data are that our surveys produced higher counts than did the earlier surveys, but as noted above, the lack of consistency makes comparisons difficult. There are several other factors besides survey routes that may help explain the different results among these surveys. In 1977, the survey altitude was 264 m, rather than the 150–180 m we used. In 1989, a helicopter was used instead of a fixed wing airplane. However, Rathbun (1988) compared helicopter and airplane surveys in Florida and found them to be comparable; thus, aircraft type may not have been a significant variable. Also, only a few areas were surveyed in 1989: Four Mile Lagoon, New River, lower Belize River, cays offshore of Belize City, Southern Lagoon, and Placentia Lagoon. In our surveys we were able to document that some of these areas continue to be important for manatees: the lower part of Belize River, the cays near Belize City, and Southern and Placentia lagoons (Fig. 1). In 1977 and 1989, Southern Lagoon was considered the most important area for manatees, but this was not true in our surveys. We found the greatest concentration of manatees in the cays near Belize City and in Placentia Lagoon. We also found numerous manatees in Indian Hill Lagoon.

The low number of manatees in Southern Lagoon during our surveys in January 1994 and 1995 might be the result of seasonal changes in the water level of the lagoon or possibly temporal changes in temperature and salinity. When water levels drop either due to the dry season (late spring) or to seasonal (winter) high northerly winds, manatees may leave certain coastal lagoons. For example, Laguna Guerrero (Fig. 1) is used less frequently by manatees in winter, when water levels are low, than at most other times of year. In winter the manatees may leave to avoid being trapped when the shallow and narrow channel between the lagoon and the deeper waters of Chetumal Bay becomes constricted (Rivas, 1997). Southern Lagoon is connected to the sea by a similarly narrow channel where water levels may be strongly affected in the windy season; the previous surveys which produced high counts in Southern Lagoon were conducted in the rainy season (i.e. September; Bengtson and Magor, 1979) and dry season (i.e. May; O'Shea and Salisbury, 1991). Variations of temperature, salinity, and light intensity affect aquatic plant distribution and abundance (Dawes, 1986). The availability of plant food resources can influence the distribution and abundance of manatees.

Another possible reason why counts in Southern Lagoon were low is that manatee abundance and distribution may have responded to increasing human activity. For example, Augusta (1992) indicated that the number of speed boats has recently increased in this area.

Northern Lagoon (Fig. 1) is used infrequently by manatees. We observed only one manatee in our surveys. O'Shea and Salisbury (1991) did not observe any manatees in this lagoon.

4.3. Calves

Our overall percentage was 7.4%, which is below the 8.9 and 10.6% that have been previously documented (Bengtson and Magor, 1979; O'Shea and Salisbury, 1991). Counting calves is difficult even under the best of conditions, and therefore we do not believe the differences in these figures are very meaningful. In addition, the 7–10% range compares favorably with percentages from several areas in Florida where manatee populations are thought to be healthy (Rathbun et al., 1990). We agree with the suggestion of O'Shea and Salisbury (1991) that in Belize manatee reproduction and recruitment appear to be adequate to maintain the population. We now extend this conclusion to Chetumal Bay.

During our surveys there was no evidence of twinning, but during other surveys, Morales (unpubl. data) once sighted a female with two, equally-small calves in Chetumal Bay. The presence of twins also has been reported in Belize (Charnock, 1968), and twinning occurs about 1.4% of the time in free-ranging manatees in Florida (Rathbun et al., 1995).

4.4. Habitat distribution

The cays near Belize City are an important area for manatees. This is especially true for the cays that have protected channels or small springs where the manatees take refuge.

Many springs of different widths and depths are distributed along some parts of the coast and are often used by manatees. One is located near Chicken Cay, a few km north of Belize City. Manatees were observed in this spring during our surveys. Another is Punta Calentura spring in Chetumal Bay, which is about 20 m across and 11 m deep; the annual water temperature range is from 24 to 31°C in the upper 3 m and the salinity range is from 11 to 17.5 ppt. The bottom of this spring lacks vegetation and the deeper waters are completely clear, with water temperatures between 21 to 22°C, and salinities of 24 to 26 ppt (Morales et al., 1996). The stratified temperature and salinity create a lens that prevents manatees below 3 m deep from being seen during aerial surveys. The reason manatees use this or other springs is unknown.

Manatees also use offshore cays and other areas. Our surveys of Turneffe Atoll were the first for this location. We observed 11 manatees including a cow/calf pair in the first survey. This large atoll is surrounded by waters up to 150 m deep and is located 11 km of the barrier reef. In Mexico, recreational divers recently reported manatees at the southern part of Cozumel Island, which is located 16.8 km offshore. Cozumel Island is surrounded by waters 400–500 m deep, and currents flow around the island at about 2–3 knots.

4.5. Manatee mortality

Occasionally, manatees are accidentally killed in fishing nets in Belize (O'Shea and Salisbury, 1991), but this type of incidental mortality does not appear to be common because only one dead manatee was reported during our survey period. In Chetumal Bay from 1990 to 1996, there were two records of manatees being killed by fishing activities (Morales et al., 1996).

Poaching of manatees for meat in Belize, however, is a serious problem. Hunting pressure in southern Belize was reported by McCarthy (1986) to be the result of poachers from Guatemala and possibly Honduras. This illegal hunting is still practiced. In August–September 1995, at least 35 manatee carcasses were found in the Port Honduras area (Bonde and Potter, 1995). In October 1996, a second report of poaching in Belize documented another nine dead manatees in Punta Gorda, south of Port Honduras (Maheia, 1997). Both areas deserve special attention because of illegal manatee hunting. Specific recommendations to stop the poaching are included in the Belize Manatee Recovery Plan (Auil, 1998).

In Chetumal and other cities of the Yucatan Peninsula, the commercial use of manatee bones was frequently practiced as recently as 1994 (Morales and Olivera, 1992). Articles such as earrings, necklaces, and small sculptures made of manatee ribs were common in local markets. Recently, souvenirs made from manatee bones have begun to appear for sale in Belize.

5. Recommendations

5.1. Manatee surveys

We recommend that the manatee population occupying Chetumal Bay and Belizean coastal waters be surveyed at least twice a year, using the following general guidelines:

- Based on past surveys, develop a consistent survey route and survey methods (aircraft type, airspeed, altitude, number of observers, etc.) that can be maintained over time to allow meaningful comparisons to be made among surveys.
- Avoid conducting surveys when winds exceed 14 knots. We believe that the low number of manatees counted in the third survey (January 1995) could have been a consequence of strong winds and turbid water (Table 1). In general, schedule surveys at times when winds are minimal and when water clarity is optimal.
- In the North Zone, the survey should include the New River and the southern boundary should be extended to the southern end of Ambergris Cay (San Pedro).
- Northern Lagoon and Turneffe Atoll should not be included in each survey because manatees do not appear to use these locations often. By dropping these sites, more survey time can be devoted to those locations frequented by manatees, including Southern Lagoon and the Dangriga area, where manatee numbers have shown greatest variation. The large variation among recounts in areas of high manatee density requires increasing the number of airplane passes, as suggested by Lefebvre and Kochman (1991). Since distribution of manatees could shift over time, lower level monitoring of Northern Lagoon and Turneffe Atoll should still be conducted at least once a year during the dry season (May is preferred).
- The survey effort should be increased around the rivers and mouths of Mullins River, North Stann Creek (Dangriga), Mango and Big Creek (Placentia Lagoon), Monkey River, Payne's Creek, and Deep River.

5.2. International cooperation

Since 1996, the National Manatee Working Group of Belize has collaborated with specialists from Mexico and the United States to develop research priorities, educational programs, and conservation efforts designed to stop manatee poaching. This initiative should be extended to Guatemala, Honduras, Nicaragua, and Costa Rica to create an international working group that meets annually. This group would promote regional efforts to stop hunting of manatees and to create better research and educational programs. In this way, a cooperative approach to conserving the largest West Indian manatee population outside Florida (USA) would be built.

International cooperation among Belize, Guatemala and Honduras will be essential to stop manatee poaching activities in Port Honduras. In all of these countries, as well as neighboring ones that develop manatee research/conservation programs, a program to examine manatee carcasses for biological information (e.g. life history data, gut contents, disease) and cause of death is recommended.

At the International Marine Mammal Meeting held in Chetumal, Mexico, in April 1996, a group of specialists

from different countries of Central America showed great interest in jointly implementing manatee conservation activities in the region. This approach also is supported by Reynolds et al. (1995), among others.

5.3. Tourist activities and conservation

In Quintana Roo and Belize the importance of manatees as a tourist attraction is increasing. Important sites frequented by manatees in Quintana Roo, including Chetumal Bay, also are intensively used by tourists for boating and other activities (Morales and Olivera, 1997). The use of speedboats also has recently increased in locations in Belize (e.g. Southern and Placentia lagoons) where counts of manatees have been high. In light of the great impact boats have on manatees in Florida (Ackerman et al., 1995), as well as the fact that ecotourism may produce many undesirable and/or unforeseen impacts to species and habitats (see Lindberg and Hawkins, 1993), it is important to: (1) evaluate the effects of tourism on the manatee population (direct impacts) and on habitat required by manatees (indirect impacts) in Belize and Quintana Roo, and (2) create lines of communication that will permit such evaluations to be factored into careful and comprehensive planning of human activities in areas in which manatees are numerous. Only in this way can the manatee population and the human ecotourism activities be sustained (see review by Reynolds, 1999).

It may be an especially opportune time for Mexico and Belize to initiate discussions on regulating tourist activities in general, and boat speed and access to certain areas in particular. On 25 October, 1996, the Mexican portion of Chetumal Bay was declared a Manatee Protected Area (Periódico Oficial del Gobierno del Estado de Quintana Roo, 1996), the first officially protected area for manatees in Mexico. On 28 April, 1998, the Government of Belize created the Corozal Bay Wildlife Sanctuary (Statutory Instrument, 1998) specifically to protect manatees. All of Chetumal Bay is now a protected area for manatees. These measures demonstrate that adjoining countries can and should work together to protect a species common to both countries, such as the manatee.

Acknowledgements

We thank Janet Gibson from the Belize Coastal Zone Management Institute for her collaboration and assistance with the surveys in Belize; Alfonso Aviléz and Earl Young from the Fisheries Department of Belize for their participation in surveys; Light Hawk for use of their aircraft and expert pilots Duane Cornell and Kemp Hiatt; Janneth Padilla Saldívar for her assistance in preparing the manuscript and figures; the US Marine Mammal Commission (Contract T10155657) and Consejo Nacional de Ciencia y Tecnología (CONACYT N9301-2017) for funding this project. We also thank Holly H. Edwards and an anonymous reader for their peer reviews. This work represents part of the PhD dissertation of Benjamin Morales-Vela at the Universidad Nacional Autónoma de México, where his research was conducted under the supervision of Víctor Sánchez-Cordero, John E. Reynolds III, Galen B. Rathbun and Luis Medrano-González.

References

Ackerman, B.B., Wright, S.D., Bonde, R.K., Odell, D.K., Banowetz, D.J., 1995. Trends and patterns in mortality of manatees in Florida, 1974–1992. In: O'Shea, T.J., Ackerman, B.B., Percival, H.F. (Eds.), Population Biology of the Florida Manatee. Information and Technology Report 1. National Biological Service, pp. 223–258.

Augusta, Ch., 1992. Manatee especial development area. Overview of manatee population and preliminary recommendations. Unpublished report, Belize Audubon Society.

Auil, N., 1998. Belize Manatee Recovery Plan. UNDP/GEF Coastal Zone Management Project,BZE/92/G31, Belize/UNEP Caribbean Environment Programme, Kingston, Jamaica.

Bengtson, J.L., Magor, D., 1979. A survey of manatees in Belize. J. Mammal. 60, 230–232.

Bonde, R.K., Potter, C.W., 1995. Manatee butchering sites in Port Honduras. Sirenews. Newsletter of the International Union for Conservation of Nature and Natural Resources/Species Survival Commission. Sirenia Specialist Group 24, 7.

Charnock, W.J., 1968. The manatee in British Honduras. Oryx 9, 293–294.

Charnock, W.J., 1970. Manatees and crocodiles. Oryx 10, 236–238.

Charnock, W.J., Bertram, K., Bertram, C., 1974. The manatee in Belize. Belize Audubon Society Bull. 6, 1–4.

Colmenero, R.L.C., Zárate, B.E., 1990. Distribution, status and conservation of the West Indian Manatee in Quintana Roo, México. Biological Conservation 52, 27–35.

Dawes, C.J., 1986. Botánica Marina. Limusa, México.

Espinoza, A.J., 1996. Distribution of seagrasses in the Yucatan Peninsula, Mexico. Bull. of Mar. Sci. 59 (2), 449–454.

Lefebvre, L.W., 1995. Manatee aerial survey safety rules. Sirenews. Newsletter of the International Union for Conservation of Nature and Natural Resources/Species Survival Commission. Sirenia Specialist Group 24, 2–3.

Lefebvre, L.W., Kochman, H.I., 1991. An evaluation of aerial survey replicate count methodology to determine trends in manatee abundance. Wildl. Soc. Bull. 19, 298–309.

Lefebvre, L.W., O'Shea, T.J., Rathbun, G.B., Best, R.C., 1989. Distribution, status, and biogeography of the West Indian manatee. In: Woods, C.A. (Ed.), Biogeography of the West Indies: past, present, and future. Sandhill Crane Press, Gainesville, Florida, pp. 567–610.

Lindberg, K., Hawkins, D.E. (Eds.), 1993. Ecotourism: A Guide For Planners and Managers. The Ecotourism Society, North Bennington, VT.

Maheia, W., 1997. Manatee poaching continues in Belize. Sirenews. Newsletter of the International Union for Conservation of Nature and Natural Resources/Species Survival Commission. Sirenia Specialist Group 27, 7–8.

McCarthy, T.J., 1986. The gentle giants of Belize. Part II: Distribution of manatees. Belize Audubon Society Bull. 18, 1–4.

Morales, V.B., Olivera, L.D., 1992. De sirenas a manatíes. Cuaderno de divulgación 4. Centro de Investigaciones de Quintana Roo, Chetumal, Quintana Roo, México.

Morales V.B., Olivera, L.D., 1994a. Distribución espacial y estimación poblacional de los manatíes en la bahía de Chetumal, Quintana Roo, México. Rev. Inv. Cient. Univ. Autón. B.C.S. Ser. Ciencias del Mar 2 (No. especial SOMEMMA, 2), 27–32.

Morales, V.B., Olivera, L.D., 1994b. Mamíferos acuáticos y su protección en la zona fronteriza México-Belice. In: Morales, S.E. (Ed.), Estudio Integral de la Frontera México–Belice: recursos Naturales, Centro de Investigaciones de Quintana Roo. Chetumal, Quintana Roo, México, pp. 197–211.

Morales, V.B., Olivera, L.D., 1997. Distribución del manatí (*Trichechus manatus*) en la costa norte y centro-norte del estado de Quintana Roo, México. Anales Inst. Biól. Univ. Nac. Autón. México, Ser. Zool. 68, 153–164.

Morales V.B., Olivera, L.D., Ramírez, P., 1996. Conservación de los manatíes en la región del Caribe de México y Belice. Reporte Técnico No. MM-01, El Colegio de la Frontera Sur (ECOSUR), Unidad Chetumal. Consejo Nacional de Ciencia y Tecnología, ref. N9301-2017. US Marine Mammal Commission Contract T10155657.

Mou, S.L., Chen, H.D., Bonde, R.K., O'Shea, T.J., 1990. Distribution and status of manatees (*Trichechus manatus*) in Panama. Mar. Mamm. Sci. 6, 234–241.

O'Shea, T.J., Salisbury, C.A., 1991. Belize, a last stronghold for manatees in the Caribbean. Oryx 25 (3), 156–164.

O'Shea, T.J., Correa, M., Ludlow, M.E., Robinson, J.G., 1988. Distribution, status, and traditional significance of the West Indian manatee (*Trichechus manatus*) in Venezuela. Biological Conservation 46, 281–301.

Periódico Oficial del Gobierno del Estado de Quintana Roo, 1996. Decreto por el cual se declara Area Natural Protegida la región conocida como Bahía de Chetumal, en la categoría de Zona Sujeta a Conservación Ecológica, Santuario del Manatí, ubicada en el Municipio de Othón P. Blanco, Estado de Quintana Roo. In: Organo del Gobierno de Quintana Roo, Vol. III (24), Extraordinario, 5ª. 24 October 1996.

Rathbun, G.B., 1988. Fixed-wing airplane versus helicopter surveys of manatees (*Trichechus manatus*). Mar. Mamm. Sci. 4 (1), 71–75.

Rathbun, G.B., Reid, J.P., Carowan, G., 1990. Distribution and movement patterns of manatees (*Trichechus manatus*) in Northwestern Peninsular Florida. Florida Marine Research Publications. Florida Marine Research Institute 48, 1–33.

Rathbun, G.B., Reid, J.P., Bonde, R.K., Powell, J.A., 1995. Reproduction in free-ranging Florida manatees. In: O'Shea, T.J., Ackerman, B.B., Percival, H.F. (Eds.), Population Biology of the Florida Manatee, Information and Technology Report 1. National Biological Service, pp. 135–156.

Reynolds III, J.E., 1999. Efforts to conserve the manatees. In: Twiss, J.R., Reeves, R.R. (Eds.), Conservation and Management of Marine Mammals. Smithsonian Institution Press, Washington, DC, pp. 267–295.

Reynolds III, J.E., Odell, D.K., 1991. Manatees and Dugongs. Facts on File, New York.

Reynolds III, J.E., Wilcox, J.R., 1986. Distribution and abundance of the West Indian manatee around selected Florida power plants following winter cold fronts: 1984–1985. Biological Conservation 38, 103–113.

Reynolds III, J.E., Szelistowski, W.A., León, M.A., 1995. Status and conservation of manatees *Trichechus manatus manatus* in Costa Rica. Biological Conservation 71, 193–196.

Rivas H.G., 1997. Contribución al conocimiento de la distribución y conducta del manatí, *Trichechus manatus manatus*, Linnaeus, 1758, en el Sistema Lagunar Guerrero, Bahía de Chetumal, México. Tesis profesional, Universidad Autónoma de Yucatán, Mérida, México.

Statutory Instrument, 1998. Corozal Bay Wildlife Sanctuary (Manatee) Order. National Parks System 48. Gazetted 2 May 1998, Belize.