CORRECTION FACTORS FOR OBSERVABILITY OF MANATEES DURING AERIAL SURVEYS

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Abstract: The use of radio-telemetry to obtain correction factors for aerial counts of manatees was investigated in a river where the actual number of manatees present was known from counts of individuals identified at a warm-water refuge. About 33 to 57% of the manatees present in the area were sighted during each aerial survey. Estimated abundance based on the ratio-of-radios-sighted or the mean ratio-of-manatees-sighted did not differ significantly from known counts of individuals on five surveys. Three methods of calculating corrected counts did not differ significantly. Sightability of manatees with radios did not differ significantly from sightability of unmarked manatees. However, the ratio-of-radios-sighted differed among three habitat types. Manatees were more easily sighted in lake and creek habitat than in river habitat. Because the distribution of manatees in the three habitats changed between surveys, corrected counts based on a correction factor obtained for each survey were closer to total counts than corrected counts based on the mean ratio-of-radios-sighted over all surveys.

INTRODUCTION

Manatees (Trichechus manatus) have been censused by aerial surveys (Irvine and Campbell 1978, Leatherwood 1979, Odell 1979, Hartman 1979, Shane 1981, Irvine et al. 1981). However, results have been difficult to interpret because neither the proportion of the population sighted nor variation in observability by habitat type has been determined. For example, estimates obtained from ground counts of manatees at a winter aggregation were twice as high as those obtained from aerial surveys (Shane 1981).

Factors influencing aerial counts have been investigated for a number of terrestrial species (Caughley 1974). Caughley et al. (1976) suggested that the specific biases involved in each survey situation should be measured to correct estimates and, by this empirical approach, general models for improving accuracy of aerial surveys may be developed.

Correction factors have been obtained by comparing aerial counts with a known number of animals in an area (LeResche and Rausch 1974, Caughley et al. 1976). Where the actual density is not known, the observed proportion of a known number of animals carrying radio-transmitters has been determined (Floyd et al. 1979).

We investigated the use of radio-telemetry to obtain correction factors for aerial surveys of manatees in a freshwater system. To compare corrected counts with the actual number of manatees present, surveys were conducted during the winter when manatees congregated at a warm water refuge and all individuals occupying the area could be identified and counted.

STUDY AREA

The study was conducted on the St. Johns River from Lake Monroe to the southern end of Lake George in northeastern Florida (Figure 1). The ecology of the area has been described by Bengtson (1981). The waterways within this region vary in width and depth, and were classified in this study as three habitat types: lakes, river channel and creeks. Lake habitat comprised approximately 66% of the water surface area surveyed, and was generally characterized by widths greater than 100 m and depths ranging from 1 to 2 m. About 21% of the water area was river habitat, characterized by channels approximately 60 to 100 m wide and 4 to 8 m deep. Creek habitat was narrow, meandering waterways or canals, which were often obscured by overhanging vegetation. Creeks represented about 13% of the water area surveyed, and were approximately 20 to 60 m wide and 2 to 3 m deep.

Submerged and floating vegetation consumed by manatees is located in the shallow portions of creeks and lakes and along the edges of the river where the vegetation is not disturbed by boat traffic. The St. Johns River is a travel route for recreational boats and commercial barges.

The study area consisted of the winter range of manatees that are known to aggregate at Blue Spring, a natural warm-water refuge (Bengtson 1981). The spring is located 23.5 km south of the northern boundary of the study area and 13 km north of Lake Monroe. Fourteen manatees, whose movements were

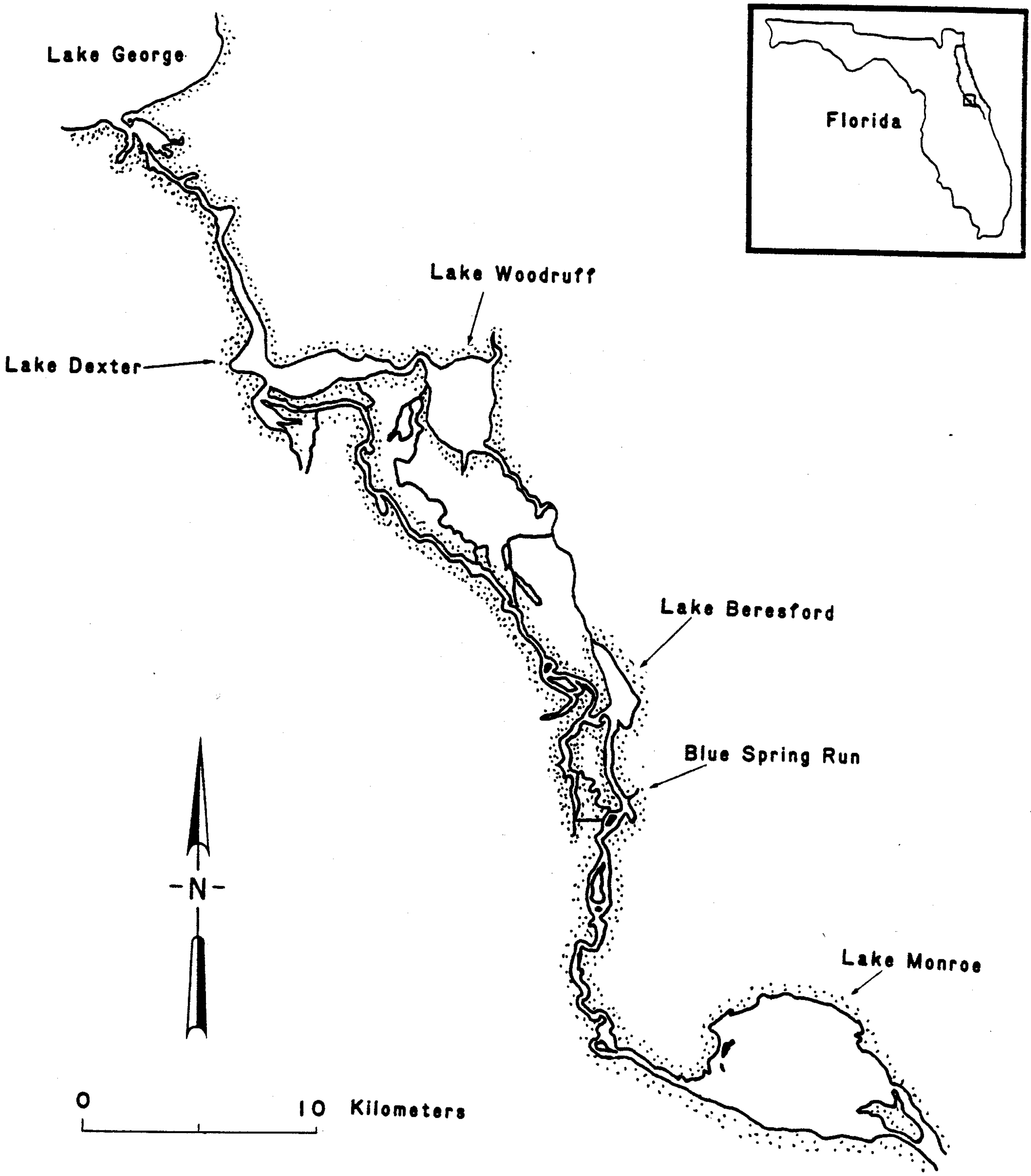

Figure 1. Study area on the St. Johns River.

monitored by radio telemetry, did not leave the study area during winters 1978-1980 (Bengtson 1981). During the winter, manatees gather in Blue Spring when the river water temperature drops below 20°C, and leave the spring periodically to feed during the warmest part of the day (afternoon) or during warm weather (Powell, O'Shea and Rathbun, unpublished data, Hartman 1979, Bengtson 1981). In contrast to the river (secchi disk readings of 60-90 cm), water clarity is excellent in the Blue Spring run, facilitating accurate counts of manatees.

METHODS

The number of manatees known to be in the study area was determined by counts of individuals in Blue Spring run. Individuals were identified by characteristic scar patterns (Hartman 1979), a technique that has been used to monitor manatee attendance at Blue Spring since 1970/71 (Powell, O'Shea and Rathbun, unpublished data). Manatees in Blue Spring were counted from the ground at the same time as the plane passed over the run. Because Blue Spring was not included in aerial surveys, the number of manatees in the survey area was estimated to be the total identified at the spring during one to two days prior to the survey, minus the number in the spring run during the survey.

To obtain correction factors for the proportion of manatees observed during aerial surveys, we conducted five surveys during February and March 1983 when the number of manatees in the study area could be determined. Radios were attached to the peduncles of seven manatees, as described by Bengtson (1981). Two ratios were calculated for each survey: (1) the ratio ($C_m = O/E$) of total manatees observed from the air (O) to total identified individuals expected to be in the survey area (E) and (2) the ratio ($C_r = O_r/E_r$) of observed radioed manatees (O_r) to the number of radioed manatees verified by telemetry to be in the survey area (E_r).

The same pilot and two passengers (junior authors) conducted each survey. The pilot was experienced and passengers had three training flights prior to collection of the reported data. The back-seat passenger (referred to as Observer) searched visually for manatees and the front-seat passenger (referred to as Tracker) monitored the radio signals. The Observer recorded location, cumulative duration visible, portion of body observed, behavior, and presence of a peduncle attachment for each manatee sighted. When a radioed manatee was not sighted, the Tracker informed the pilot and Observer and the plane circled back to determine the location and possible reason why the radio was not sighted.

Corrected counts were calculated for each survey and compared with the actual number of identified manatees known to be in the survey area (E). Three methods for calculating corrected counts were compared: (1) the mean ratio of manatees observed ($\bar{C}_m$) over the five surveys was divided into the number of manatees observed on each survey (O), (2) the ratio-of-radios-sighted (C_r) for each survey was divided into the number of manatees observed on each survey (O), and (3) the mean ratio-of-radios-sighted ($\bar{C}_r$) over all surveys was divided into the number of manatees observed on each survey (O). The Friedman two-way analysis of variance (Conover 1971) was used to compare the three methods of calculating corrected counts ($O/\bar{C}_m$, O/C_r, $O/\bar{C}_r$).

Differences between the known number of manatees (E) and corrected counts, paired for each survey, were tested by Wilcoxin's signed ranks test (Conover 1971).

Radios were attached to the peduncles of seven manatees, as described by Bengtson (1981). Manatees carrying radios are henceforth referred to as "radioed manatees."

Factors known to influence aerial counts were relatively constant during the surveys. Surveys were conducted in the afternoon, with durations from 1.8 to 3.1 hrs. Weather conditions were sunny to partly cloudy, wind velocity ranged from 7 to 16 knots, water temperature in the river near Blue Spring was 17 to 18°C and water surface conditions ranged from small ripples to a steady chop without whitecaps. Water clarity in the river was at least 60 cm as measured by a secchi disk and monitored by objects submerged at known depths and visible from the airplane. Surveys were flown in a Cessna 172 at heights of 85 to 95 m and speeds of 70 to 80 knots/hr.

Surveys of the study area followed a consistent route from south to north. The plane flew along the west bank of the river, looping back along the east bank at approximately two-km intervals. Creek habitat was usually covered in one pass, unless the observer judged that the water was obscured by vegetation and requested a loop. The perimeters of large lakes were searched and transects were flown over the centers.

To determine factors likely to influence correction factors obtained from radio-telemetry, an additional 10 surveys were conducted at times when the number of manatees in the study area could not be determined with certainty. The data from all 15 surveys were pooled to determine if sightability of radios differed by habitat type (river, lake, creek), the frequency distribution of sighting duration, and relative visibility of three portions of the body (anterior third, middle third and posterior third).

To examine the visibility of passive marks, vinyl flags (15 cm diameter half-circles) were attached to three manatees by peduncle straps. The threshold at which flags were visible from the air was monitored by submerging flags on a structure at depths of 60, 80 and 100 cm.

RESULTS AND DISCUSSION

About 43-67% of the manatees present in the St. Johns River were not sighted during aerial surveys. The proportion of total manatees sighted (C_m) ranged from 0.33 to 0.57 with a mean of 0.47 (Table 1). The proportion of radioed manatees sighted (C_r) was lower than the proportion of total manatees sighted; C_r ranged from 0.0 to 0.75 with a mean of 0.38. All methods for correcting counts yielded estimates that did not differ significantly from the known number of manatees present (Table 1). Results of the three methods of correcting counts did not differ significantly (X_r^2= 2.8, 2 degrees of freedom, p = 0.75).

The use of radio-telemetry to obtain observability correction factors is most valid when the ratio-of-radioed-manatees-sighted on a survey is used to correct the count from the same survey. Because of the mean ratio-of-radios-

Table 1. Comparison of corrected and actual counts of manatees.

	TOTAL MANATEES		CORRECTION FACTOR (C)		CORRECTED COUNTS		
SURVEY DATE	Observed[a] (O)	In Survey[b] Area (E)	% manatees[c] (C_m)	% radios[d] (C_r)	$O/\bar{C}_m$	O/C_r	$O/\bar{C}_r$
23 Feb	8	24	0.33	0.75	17	11	21
25 Feb	11	23	0.48	0.00	23	-	29
3 Mar	10	19	0.53	0.33	21	30	26
4 Mar	9	20	0.45	0.33	19	27	24
16 Mar	8	14	0.57	0.50	17	16	21
Mean	9	20	$\bar{C}_m$=0.47	$\bar{C}_r$=0.38	19	21	24
T[e] =					0	-.36	-1.78
p =					0.50	0.36	0.04

[a]Number of marked and unmarked manatees sighted on survey of study area (excludes Blue Spring).

[b]Number of marked and unmarked manatees identified in Blue Spring prior to survey minus the number of manatees in Blue Spring during the survey.

[c]O divided by E

[d]Number of radioed manatees sighted in study area divided by number of radioed manatees located in study area.

[e]Wilcoxins ranked signs test with pairwise comparison between E and each corrected count over all surveys. For a two-tailed test, p less than 0.025 would indicate a significant difference.

sighted ($\bar{C}_r$) was lower than the mean ratio-of-manatees-sighted ($\bar{C}_m$),counts corrected by $\bar{C}_r$ would tend to overestimate abundance. Using a one-tailed test, counts corrected by $\bar{C}_r$ were significantly higher than the known number of manatees (E) ($p < .05$). However, counts corrected by the ratio (C_r) obtained for each survey were not significantly higher than expected counts (E) using a one-tailed test ($p > .05$).

Factors potentially influencing observability of radios were examined. The sightability of radioed manatees did not differ significantly from unmarked manatees (Chi square = .54, 1 degree of freedom, $p > 0.25$). Radioed manatees were sighted on 8 of 20 occasions that the radio signal was located, and unmarked manatees were sighted in 35 of 71 potential occasions during the five surveys when the known number of manatees could be determined.

The ratio-of-radios-sighted was influenced by habitat type. During the 15 surveys, radios were located 67 times. Locations of radioed manatees were more frequent in lake habitat ($n = 30$) than in creek ($n = 21$) and river habitat ($n = 16$). The proportion of times radios were sighted was lower in river habitat (25%) than in lake (66%) and creek habitat (71%). The frequency of sighting vs. no sighting of radioed manatees was significantly non-random when all three habitat types were compared (Chi-square = 9.639, 2 degrees of freedom, $p < .05$). Differences among habitats were examined by Freeman-Tukey deviates (Bishop et al. 1975). The number of manatees sighted was lower than expected in river habitat ($z = -1.94$), and higher than expected in lake ($z = +\ 0.63$) and creek habitat ($z = +\ 0.81$).

Variation in the ratio-of-radios-sighted may be partially attributed to changes in manatee distribution among habitat types. Over the entire study (15 aerial surveys), the ratio-of-radios-sighted ranged from 0.0 to 1.0 with a mean of .54. As manatees moved away from Blue Spring when temperatures rose, they gathered in groups in Lake Monroe and were less frequently sighted in river habitat. The mean ratio for seven surveys conducted prior to March 19th was lower ($\bar{C}_r = 0.34$) than the mean ratio for the remaining surveys ($\bar{C}_r = .70$).

If activity of manatees varies seasonally, it could also influence the ratio-of-radios-sighted. Reasons why radioed manatees were not sighted were determined in 27 cases. In 33% of these cases, manatees were obscured by vegetation, usually when they were feeding in mats of floating plants. In 59% of the cases, manatees were submerged and activity could not be determined. Manatees that rest in a submerged position leave few clues to their presence; when feeding or traveling occurs under water, mud plumes usually indicate the activity of the manatee (Hartman 1979).

Learning by the Observer probably influenced the ratio-of-radios-sighted. Manatees tended to remain in one location for a few days after they dispersed from Blue Spring following a rise in water temperature. The Observer could anticipate sighting an individual where it had been located the previous day. This source of error could be minimized by scheduling surveys at two to three day intervals. Because the ratio-of-radios-sighted increased from the beginning to the end of the study, the possibility of improvement in observation skills of the Observer cannot be discounted.

Survey conditions could influence variation in the ratio-of-radios-sighted. Although conditions were relatively constant for the five surveys from which corrected counts were calculated, conditions varied during the additional surveys. For example, on a day with whitecaps, no radios were sighted (this survey was not included in analyses). Wind velocities of 12 to 15 knots were considered to be at the upper threshold for adequate visibility. Glare on sunny days and cloud reflections reduced visibility, but overcast skies and rain were not a problem.

Non-verbal communication from the Tracker to the Observer may partially influence the ratio-of-radios-sighted. Whenever the observer was aware of cues from the Tracker, which indicated presence of a radio, the sighting was not counted. This problem was difficult to avoid, because a minimal time delay was necessary to reduce the chance that the manatee changed location or activity. If the Observer sat in the front and the Tracker sat in the back, the problem might be reduced, but communication between the Tracker and the pilot would be more difficult.

A major problem with the use of radio-telemetry to develop correction factors for manatee surveys is the attenuation of the radio signal in saline water. A large portion of manatee habitat in Florida is brackish or saline water (Irvine et al. 1981). To evaluate the potential use of passive marks to obtain correction factors in brackish habitat, we collected some information regarding the visibility of vinyl flags attached to the peduncle.

When manatees were at the surface, the vinyl flags were readily visible from the air. However, the stationary flags were never visible below 80 cm, and rarely visible below 60 cm. Visibility of stationary flags corresponded closely to secchi disk readings, which varied from 60 to 90 cm. Blue was less visible than red and yellow; it was never observed below 60 cm.

A mark attached to the peduncle is less likely to be visible than a mark attached to the anterior two-thirds of the body of a manatee. Portion of the body observed was recorded on 153 sightings of manatees. The posterior third of the body was sighted less frequently (71%) than the anterior third (95%) and the middle third of the body (98%).

When a manatee is sighted, it usually remains visible long enough to identify a mark. In 63% of 151 sightings, manatees were visible for longer than 90 seconds. Only 11% of the sightings were briefer than five seconds, 18% were between 5 and 30 seconds duration, and 8% were between 31 and 90 seconds duration.

Our results suggest that care should be taken in interpreting data from manatee aerial surveys for which correction factors were not determined. Radio-telemetry may be used effectively in freshwater to obtain specific correction factors for aerial surveys, but additional research is needed to control survey conditions such that a general correction factor could be applied. If flags attached to the peduncle are used to determine sightability in saline habitat, correction must be made for the probability of sighting a manatee at the surface. Methods of attaching marks to the anterior portion of the body should be developed.

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