VARIATION OF VISIBILITY BIAS DURING AERIAL SURVEYS OF MANATEES

JANE M. PACKARD, Florida Cooperative Fish and Wildlife Research Unit, 117 Newins-Ziegler Hall, University of Florida, Gainesville, FL 32611
ROBERT C. SUMMERS, P.O. Box 14084, Gainesville, FL 32604
LINDSAY B. BARNES, 331 Colomba Rd., DeBary, FL 32713

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Several factors influencing aerial counts of terrestrial species have been identified (Caughley 1974). When it is not possible to control for such variables in experimental design, Caughley et al. (1976) recommended that the specific biases involved in each survey situation should be measured to correct estimates.

The magnitude of bias due to incomplete visibility of animals during aerial surveys has been measured in several ways. Estimates of the percentage of animals counted ranged from 23 to 80% in 17 studies reviewed by Caughley (1974). Visibility is difficult to estimate where actual density is not known, as is the case for many wildlife populations. This problem was surmounted in a census of white-tailed deer (*Odocoileus virginianus*) by determining the visibility of a known number of individuals located by radiotelemetry within the survey area (Floyd et al. 1979). Ground counts have been compared with aerial counts in attempts to estimate the visibility bias during surveys of sea otters (*Enhydra lutris*) (Eberhardt et al. 1979) and manatees (*Trichechus manatus*) (Shane 1981). Accurate ground counts of marine mammals are difficult because of movement of submerged animals to different locations during the counting period and individual differences in rates of surfacing.

Aerial surveys of manatees have not incorporated techniques for estimating bias due to visibility or other factors (Irvine and Campbell 1978, Hartman 1979, Leatherwood 1979, Odell 1979, Irvine et al. 1981, Shane 1981, Powell and Rathbun 1984). These surveys yielded information on the minimum number of manatees present in an area and distribution of visible manatees. Manatee counts from aerial surveys may be construed to provide the basis for estimates of abundance, although no empirical data have been available regarding the proportion of manatees observed during aerial surveys or variance in visibility as a function of survey conditions and distribution of manatees in different habitat types.

Irvine and Campbell (1978) reported a minimum count of 738 manatees in Florida based on a 2-day survey of coastal waters and ground counts at two sites. They discussed the problems involved in estimating a correction factor due to site differences in water clarity and commented that probably fewer than 90% of manatees are observed during surveys. Without estimates of bias associated with this minimum count, it does not provide a baseline against which to evaluate subsequent changes in manatee abundance.

If visibility of animals is constant over a range of survey conditions, then a single correction factor may be used to obtain population estimates from aerial counts. If visibility varies across surveys, then trends in aerial counts may be biased, and specific correction factors for each survey must be obtained. We used radiotelemetry to evaluate visibility bias during surveys of a group of manatees whose range was restricted by the need to return daily to a warm-water refuge where all individuals could be identified. The purposes of this study included (1) evaluation of the general problem of whether visibility varies by survey and by habitat type; and (2) evaluation of the specific problems associated with obtaining correction factors for bias in visibility of manatees during aerial surveys.

STUDY AREA

The study was conducted on the St. Johns River from Lake Monroe to the southern end of Lake George in northeastern Florida. This area is the winter range of manatees that seek refuge from cold at a natural warm-water spring located 23.5 km south of the northern boundary of the study area and 13 km north of Lake Monroe. Because Blue Spring is the principal warm-water refuge utilized by manatees in the area, counts of individual manatees identified at the spring are a reliable indication of the total number of manatees in the study area during the winter (Bengtson 1981). Manatees gath-

Table 1. Comparison of three methods for correcting visibility bias during five surveys when the expected number of manatees in the survey area was determined by identification of individuals at Blue Spring, Florida, 1983.

Survey date	Total manatees		Correction factor (C)		Corrected counts		
	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	−0.36	−1.78
P =					0.50	0.36	0.04

[a] Number of radioed and nonradioed manatees sighted on survey of study area (excludes Blue Spring).
[b] Number of radioed and nonradioed 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] Wilcoxon's ranked signs test with pairwise comparison between E and each corrected count over all surveys. For a two-tailed test, $P < 0.025$ would indicate a significant difference.

er 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 (late afternoon and night) or during warm weather (Hartman 1979; Bengtson 1981; J. A. Powell et al., unpubl. data). 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.

The ecology of the area has been described by Bengtson (1981). The waterways within this region varied in width and depth and were classified as three habitat types: lakes, river channels, and creeks. Lake habitat composed approximately 66% of the water surface area surveyed and was generally characterized by widths greater than 100 m and depths ranging from 1 to 3 m. About 21% of the water area was river habitat characterized by channels approximately 60–100 m wide and 4–8 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 20–60 m wide and 2–3 m deep.

METHODS

Visibility bias was measured by two methods: (1) aerial counts were compared with the number of manatees presumed to be in the survey area, based on identification of individuals at Blue Spring; and (2) visibility of manatees located by radiotelemetry was determined. The total number of manatees present could be determined with specified confidence on five survey dates as listed in Table 1. Visibility of manatees carrying radio transmitters was also evaluated on 10 additional surveys conducted between 23 February and 5 April 1983.

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 et al., unpubl. 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 1–2 days prior to the survey minus the number in the spring run during the survey. We are confident that estimates of total abundance are accurate within 3–5%, because we used data only from surveys on dates when all individuals were seen at the run or were seen 1–2 days prior to the survey.

Radios were attached to the peduncles of seven manatees, as described by Bengtson (1981). Manatees carrying radios are henceforth referred to as "radioed manatees." A radioed manatee was counted as located in the survey route when the radio signal was found during an aerial survey. The manatee was counted as visible when any portion of its body could be seen. If more than one manatee was present in

the area where the radio signal was located, the observer watched until the radioed manatee could be identified.

The same pilot and two passengers (junior authors) conducted each survey. The pilot was experienced in manatee surveys and the 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. When a radioed manatee was not sighted by the Observer, the Tracker informed the pilot and Observer and the plane circled for at most 4 minutes to determine the location and possible reason why the radioed manatee was not sighted. If nonverbal cues from the Tracker indicated presence of a radioed manatee to the Observer, the sighting was not included in analysis. The Observer recorded location of manatees and whether radios were sighted.

For each of the five surveys for which the total number of manatees in the study area could be determined, two ratios were calculated: (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). Corrected counts were calculated for each survey and compared with the actual number of identified manatees presumed to be in the survey area (E). Three methods for calculating corrected counts (O/C_m, $O/\bar{C}_r$, O/C_r) were compared by the Friedman two-way analysis of variance (Conover 1971). Differences between the expected number of manatees (E) and corrected counts, paired for each survey, were tested by Wilcoxon's signed ranks test (Conover 1971).

The data from all 15 surveys were pooled to determine if visibility of radioed manatees differed by habitat type (river, lake, creek). For each habitat type, the number of times radioed manatees were located was compared with the number of times that radioed manatees were seen. A single manatee observed in the same location as the radio signal was presumed to be radioed, although the radio sometimes was not visible.

Factors known to influence aerial counts were relatively constant during the surveys. Surveys were conducted in the afternoon (1330–1730), with durations from 1.8 to 3.1 hours. Weather conditions were sunny to partly cloudy, wind velocity ranged from 13 to 30 km/hour, water temperature in the river near Blue Spring was 17–18 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 85–95 m and speeds of 130–148 km/hour.

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 2-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.

RESULTS AND DISCUSSION

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 from the expected number of manatees present (Table 1), nor was there a difference among the three sets of corrected counts ($\chi^2 = 2.8$, 2 df, $P = 0.75$).

These results indicate that actual abundance of manatees in turbid waterways such as the St. Johns River may be roughly double the number counted. This estimate of visibility bias is similar to the ratio of aerial counts to manatee abundance estimated by ground counts (Shane 1981) and mark–resighting of scar patterns (J. M. Packard, unpubl. data) at two power plant effluents.

We caution against the use of a general factor for correcting visibility bias in aerial surveys of manatees, because our estimates of visiblity varied between surveys. The mean ratio-of-radios-sighted ($\bar{C}_r$) was not as good a correction factor as the specific ratio (C_r) obtained for each survey. Corrected counts were higher ($P < 0.05$) than expected counts when the general factor ($\bar{C}_r$) was used but not when the survey-specific

factors (C_r) were used (one-tailed test in contrast to the two-tailed test reported in Table 1).

The variability in visibility bias has not been fully examined in other studies using radiotelemetry to obtain correction factors. Although visibility of radioed deer was consistent (50–56%) over three surveys (Floyd et al. 1979), our results suggest that variation in correction factors should be assessed before it is assumed to be low.

Variation in visibility bias may be partially attributed to changes in manatee distribution among habitat types. Over the entire study (15 aerial surveys), visibility of radioed manatees ranged from 0.0 to 1.0 with a mean of 0.54. 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 19 March was lower ($\bar{C}_r = 0.34$) than the mean ratio for the remaining eight surveys ($\bar{C}_r = 0.70$).

Habitat type influenced the visibility of manatees. The proportion of times radioed manatees were sighted was lower in river habitat (25%, $N = 16$) than in lake (66%, $N = 30$) and creek habitat (71%, $N = 21$). The frequency of sighting vs. no sighting of radioed manatees was nonrandom when all three habitat types were compared ($\chi^2 = 9.639$, 2 df, $P < 0.05$). 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 ($z = +0.81$, Freeman-Tukey deviates, Bishop et al. 1975).

Radiotelemetry can be a useful technique to obtain correction factors in areas or at times (e.g., summer) when the total number of manatees present cannot be determined. The visibility of radioed manatees did not differ from unmarked manatees ($\chi^2 = 0.54$, 1 df, $P > 0.25$). 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. Existing technology limits use of radiotelemetry to freshwater habitat. However, manatees occupy most of the major accessible river systems of Florida during nonwinter months (Irvine and Campbell 1978), and three of the nine major winter refuges are in fresh water.

The number of radioed animals (7 manatees) in our study was smaller than the number (10–15 deer) observed by Floyd et al. (1979). A larger sample size might reduce the variability in visibility estimates. In a few cases, we could not visually identify the radioed manatee. The ratio observed may thus be overestimated if the manatee sighted near the signal was not actually the radioed manatee (J. L. Bengtson, pers. commun.). However, we do not believe our results were biased in this manner, because our mean visibility estimate for radioed manatees was lower than our mean visibility estimate for all manatees.

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 2–3-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 cannot be discounted and should be monitored.

Sun glare, cloud reflections, and wind varied during the additional surveys and may have affected visibility. For example, on a day with whitecaps, no radios were sighted (this survey was not included in analyses).

Our results suggest that visibility can vary across surveys, even when survey techniques are standardized. Therefore, single-survey counts should not be used as an index of manatee abundance unless visibility bias is measured, or variability is otherwise assessed. Factors that influenced observability of manatees included habitat type, manatee distribution, weather conditions, and observer experience. Because these factors vary among surveys in a manner that is not easily controlled, we recommend against the use of a constant ratio to correct counts of manatees for abundance estimates. Higher accuracy may be obtained by using radiotelemetry to estimate specific correction factors for each survey.

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PROTEIN REQUIREMENT OF ADULT COLLARED PECCARIES

GARY R. CARL, Department of Zoology, Washington State University, Pullman, WA 99164
ROBERT D. BROWN, Caesar Kelberg Wildlife Research Institute, Texas A&I University, Box 218, Kingsville, TX 78363

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The collared peccary (*Tayassu tajacu*) is an important game animal with unusual aesthetic value. This species is unique to the New World; the northern limit of its range includes desert and rangeland of South Texas, southern New Mexico, and southern Arizona. Knowledge of its protein requirement is necessary for intensive habitat management. Such information will allow comparison to other game species and contribute to theory on ungulate nutritional ecology.

Protein requirement and nitrogen metabolism have been studied for several wild ungulates (French et al. 1956, McEwen et al. 1957, Ullrey et al. 1967, Eisfeld 1974, Robbins et al. 1974, Smith et al. 1975, Holter et al. 1979, Mould and Robbins 1981) but not for the peccary. The only nutritional studies done thus far on the peccary were comparative digestion trials and aspects of volatile fatty acid production (Dyson 1969, Shively 1979) and seasonal digestible energy requirements (Zervanos and Hadley 1973). Thus, the objective of this study was to determine the maintenance protein requirement of adult collared peccaries through a series of nitrogen balance trials.