USE OF AERIAL SURVEY AND AEROPHOTOGRAMMETRY METHODS IN MONITORING MANATEE POPULATIONS

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Prepared by:

Karl E. Miller[1]
Bruce B. Ackerman[2]
Lynn W. Lefebvre[3]
Kari B. Clifton[2]

[1]Florida Cooperative Fish and Wildlife Research Unit
and
Department of Wildlife Ecology and Conservation
University of Florida, Gainesville, FL 32611

[2]Florida Department of Environmental Protection
Florida Marine Research Institute, St. Petersburg, FL 33701

[3]National Biological Service, Sirenia Project, Gainesville, FL 32601

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EXECUTIVE SUMMARY/ ABSTRACT

Aerial surveys have been used to obtain information on the distribution and relative abundance of manatees (Trichechus manatus) in Florida for more than 25 years. Because managers and researchers believe surveys underestimate manatee population size, survey effort traditionally has been geared to maximize counts rather than to standardize counts. Consequently, surveys have not produced population estimates with associated confidence intervals, making them inadequate for estimating population size or determining trends in abundance over time.

We evaluated the use of strip-transect survey methods for manatees through a series of replicate aerial surveys in the Banana River, Brevard County, Florida, during summer 1993 and summer 1994. Transect methods sample a representative portion of the total study area, thus allowing for statistical extrapolation to the total area. Other advantages of transect methods are less flight time and less cost than total coverage, ease of navigation, and reduced likelihood of double-counting.

Our objectives were: (1) to identify visibility biases associated with the transect survey method and to adjust the counts accordingly; (2) to derive a population estimate with known variance for the Banana River during summer; and (3) to evaluate the potential value of this survey method for monitoring trends in manatee population size over time.

We selected the Banana River as a candidate site for transect sampling because it is a relatively homogeneous, shallow water body with good visibility and it is known to be an important summer area for manatees. Surveys were flown in a Cessna 172 at an altitude of 183 m (600 ft). Forty 250m-wide strip transects were established at 1 km intervals, resulting in 25% coverage of a 160 km^2 area. A team of independent observers in the right-front and right-rear seats simultaneously scanned the same transect. Their independent observations provided counts which were used in a Petersen mark-recapture model to estimate perception bias (the number of groups that are visible in the transect but are not observed). The number of observed groups was multiplied by the perception correction factor to obtain the corrected number of groups per transect, then multiplied by the mean group size to obtain the corrected number of individuals per transect. Finally, a ratio estimator was used to estimate the total population size and its variance.

Eight replicate surveys were conducted between August and September each year. A total of 775 individuals belonging to 374 groups was observed during the 16 surveys,

for a mean group size of 2.07. Total survey time was 25.0 hrs, for a sighting rate of 31 manatees per hr (0.52 per min).

Double counts by 2 right-side observers produced survey-specific correction factors for perception bias averaging 1.13 (range: 1.00 - 1.60). A perception correction factor (C_p) of 1.13 indicates that 88% (the reciprocal) of the groups estimated to be available were observed by at least one of the observers. The C_p was highest on days with poor (1.60 on 25 Aug 1993) or fair (1.42 on 15 Aug 1994) survey conditions. Observers performed similarly in their ability to recognize manatee groups. Although the proportion of groups detected varied from survey to survey, within a survey date it was relatively similar between the 2 observers. Single animals were more likely to be overlooked by at least one observer than were larger groups.

Mean group size per survey for the right-side observer team ranged from 1.65 to 3.10. Most of the groups sighted were single animals (51% of groups) or groups of two (26% of groups), but a few large (>6) groups also were seen. These statistical outliers resulted in larger variance in mean group size and, consequently, larger variance in the overall population estimate ($\hat{Y}$).

Manatees were not evenly distributed throughout the study area. Four aggregation sites ("hot-spots") along the Banana River shoreline were identified and manatees were counted by repeated circling over these areas. Hot-spots were treated as a separate sampling stratum.

Population estimates were moderately consistent among survey dates, with the exception of 2 surveys (25 Aug 1993, 28 Sep 1993) conducted under extreme weather conditions. Excluding these surveys, mean population size was 125 ± 4 (SE) in 1993 (N=6 flights) and 179 ± 8 (SE) in 1994 (N=8 flights). We added the daily counts of manatees in the hot-spot stratum to each day's population estimate to obtain an estimate of the total population size ($\hat{Y}_+$) in the survey area. Mean $\hat{Y}_+$ was 159 ± 7 (SE) in 1993 (N=6 flights) and 238 ± 10 (SE) in 1994 (N=8 flights).

Although mean population size differed between years ($P < 0.05$), we cannot infer an increasing trend in population size based on 2 annual estimates. To assess the possibility of detecting statistically significant trends in the Banana River population, we used power analysis software for linear regression (TRENDS). Manatee density in the Banana River is relatively high (>1/km^2) and our sampling intensity is high (25% of the total survey area is sampled, 7-8 replicate flights are performed each year), resulting in annual population estimates with high levels of precision. With the stringent assumptions of cv = .04 and power = 0.75, we would need 4 sampling periods (i.e., years) to detect an annual rate of change (r) = 0.05. An increase in r or a decrease in the cv would increase the power of our test.

The strip-transect survey technique presented here is an improvement over past attempts to estimate absolute manatee abundance, because it is a repeatable, standardized survey design that produces population estimates with known precision. The technique should be useful in trend analysis in the Banana River. However, application of the survey technique to other areas in Florida during summer appears to be limited because of excessive water depths or water turbidity. In addition, we have not measured the availability bias associated with these surveys.

Despite limitations, we feel managers would benefit by continuing warm-season transect surveys in the Banana River for the following reasons: (1) Banana River is clearly important as a manatee summer "sanctuary"; (2) Complementary long-term datasets are needed to corroborate other analyses that suggest a manatee population increase on the east coast of Florida.

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I. INTRODUCTION

Aerial surveys have been used to identify seasonal patterns in distribution and relative abundance of manatees (Trichechus manatus) in Florida for more than 25 years. In recent years, state-wide "synoptic" surveys have been conducted during the winter months to derive a minimum estimate of the size of Florida's manatee population (Ackerman 1995). Because aerial surveys are believed to underestimate manatee population size (Hartman 1974, Irvine and Campbell 1978, Eberhardt 1982, Kinnaird 1985, Packard 1985, Packard et al. 1985), survey effort traditionally has been geared to maximize counts rather than to standardize counts (Lefebvre et al. 1995). Consequently, state-wide "extended-area" surveys produce composite counts with unknown variance, which cannot be compared statistically across years (Lefebvre et al. 1995). Most manatee surveys also have not been corrected for sources of visibility bias (Lefebvre et al. 1995). Thus, current aerial surveys may provide important information on the distribution and relative abundance of manatees, but they are inadequate for estimating population size or determining trends in abundance over time (Ackerman 1995, Lefebvre et al. 1995).

Researchers at the 1992 Technical Workshop on Manatee Population Biology (O'Shea et al. 1992, Ackerman 1995, Lefebvre et al. 1995) recommended that the testing of transect survey methods should be a high priority for future manatee research. In Australia, Helene Marsh and her colleagues have developed fixed-width transect surveys for dugongs (Dugong dugon) to provide standardized population estimates and density-distribution maps for management purposes (Marsh and Saalfeld 1989; Marsh and Sinclair 1989a,b; Marsh et al. 1994; Marsh 1995). Transect surveys are superior to counts that attempt total coverage of an extended area because a complete count is rarely possible; extensive counts do not quantify the area actually surveyed or produce an estimate of absolute abundance. In contrast, transect methods sample representative portions of the study area and allow statistical extrapolation to the total area (Burnham et al. 1980). An additional advantage of transect surveys is that they require less flight time and less cost than total coverage. For example, Johnson et al. (1991) conducted aerial surveys for pronghorn (Antilocapra americana) with line transect methods and with "trend" counts that attempted total areal coverage, and found that adequate line transect samples were obtained in 19-51% of the flight time required for "trend" counts. Transect sampling methods also are superior to quadrat or block sampling in terms of lower cost, ease of navigation, reduced likelihood of double-counting, and less fatigue for observers (Norton-Griffiths 1978, Firchow et al. 1990).

The goal of this research project was to evaluate the use of transect survey methods for manatees through a series of replicate aerial surveys in the Banana River, Brevard County, Florida, during the summers of 1993 and 1994. The Banana River lagoon was selected as a candidate site because of its importance as a warm-season refuge for manatees and because it is a shallow body of water with good visibility. Previous aerial surveys in Brevard County (e.g., Shane 1981, 1983; Bonde, unpubl. data from mid-1980s; Provancha and Provancha 1988, 1989; Ackerman, unpubl. data from 1992) have indicated that large numbers of manatees use the area throughout the year.

The study was conducted during the warm season in the belief that summer counts would be less subject to the influence of fluctuating environmental factors (e.g., water temperature) on visibility bias. Problems associated with counting large aggregations of animals also were avoided because of the more even dispersion of manatees throughout coastal water bodies during summer.

We are indebted to our pilots, J.T. Lundstrom and V. Renaud, for skillfully and safely piloting flights in 1993 and 1994, respectively. Thanks are due C. Deutsch, A. Perry, and A. Spellman for filling in as left-side observers on survey flights. We also wish to extend our gratitude to J. Provancha and the Bionetics Corporation for coordinating their helicopter surveys with our fixed-wing surveys and for making their data available to us. J. Harrison of the University of Florida's Institute of Food and Agricultural Sciences (IFAS) Statistics is acknowledged for assistance with the derivation of variance estimators. H.F. Percival and B. Fessler of the U.S. Fish and Wildlife Service (USFWS) provided administrative support.

II. OBJECTIVES

(1) To identify visibility biases associated with counting manatees with the transect aerial survey method and to adjust the counts accordingly.

(2) To derive a population estimate with known confidence intervals of the manatee population in the Banana River in summer 1993 and summer 1994.

(3) To evaluate the potential value of this survey method for monitoring trends in manatee population size over time.

III. STUDY AREA

The Banana River is an estuarine lagoon in Brevard County on the east coast of central Florida. It is a shallow water body (average water depth outside of dredged canals = 1.2 m, Provancha and Provancha 1988) with submerged aquatic vegetation (SAV) throughout most of the river bottom. Four seagrasses, manatee grass (Syringodium filiforme), shoal grass (Halodule wrightii), widgeon grass (Ruppia maritima), and star grass (Halophila engelmannii), and several species of algae dominate the SAV (Provancha and Provancha 1988; L. Lefebvre, unpubl. data).

Aerial surveys have indicated that the Banana River has the highest late winter-early spring concentration of manatees along Florida's east coast (B. Wiegle unpubl. data cited in Provancha and Provancha 1989). Numbers peak in the spring, and then decline to a stable population that persists throughout the summer (Provancha and Provancha 1989).

We surveyed a 160 km^2 area extending from Jack Davis Cut at the northern end of the Banana River south to state Highway 404 (Fig. 1). The study area incorporates lands administered by several government agencies, including Merritt Island National Wildlife Refuge (USFWS), Kennedy Space Center (NASA), and Patrick Air Force Base. Recreational boating and fishing are common throughout the river except for the portion north of the NASA Causeway which is closed to the public.

IV. METHODS

Strip-transect Surveys

Line transect sampling is often used to survey marine fauna from ships (e.g., Barlow 1988), where the observers have sufficient time to measure perpendicular distances from the center line. However, in a rapidly moving aircraft there is usually inadequate time to measure distances correctly while thoroughly searching the entire field-of-view and counting the number of animals in each group (Pollock and Kendall 1987), and, thus, strip-transects are usually used in aerial surveys (Leatherwood et al. 1978; Gasaway et al. 1985; Barlow et al. 1988; Conroy et al. 1988; DeYoung et al. 1989; Firchow et al. 1990; Marsh and Sinclair 1989a,b; Marsh 1995). We used strip-transect sampling because we believed that it would be more efficient to focus on a narrow "window" of view. We selected a 250-m strip-width in accordance with other aerial surveys for sirenians (Bayliss 1986; Marsh and Sinclair 1989a,b). A fundamental assumption of strip-transect sampling is that all objects present in the strip have an equal probability of being observed (Eberhardt et al. 1979, Seber 1982). We tested this assumption by estimating perpendicular distance from the plane to each manatee group on a subset of our surveys. No significant decrease in sightability occurred beyond the outer edge of the strip, although appreciably more groups were seen in the middle of the strip (Fig. 2).

Forty parallel transects were established at 1 km intervals in the Banana River, with the 250-m strip-width enabling 25% coverage of the study area. We spaced transects evenly at 1 km intervals both for ease of navigation and to ensure that animals were not counted twice, as often happens in closely-spaced transects (Caughley 1977a:32). Transects were oriented on an east-west axis perpendicular to the linear Banana River to maintain homogeneity among transects, thereby minimizing sampling error (Norton-Griffiths 1978), as well as to reduce glare from the morning sun (Marsh and Sinclair 1989a).

Eight surveys per year were flown in a Cessna 172 (Merritt Island Air Service) at 70-80 knots along these predetermined transects. Transects were drawn and labelled on a small-scale map, and reference to topographic features and landmarks were used effectively by the pilot to navigate along transects. Survey altitude was standardized at 183 m (600 ft); restrictions on flights over inhabited areas precluded flights at lower altitudes. Calibration of strip-width followed Pennycuick and Western (1972) and Norton-Griffiths (1978). The 250m strip-width was measured beginning from the outer edge of the wheel of the plane. Lines were drawn with wax pencil on the windows of the aircraft and on the plane's struts to delineate inner and outer strip-width boundaries and to divide the strip into 5 distance bands for estimating perpendicular distances. Due to federal aviation restrictions, plastic streamers, rods, or other attachments to the outside of the aircraft were not used to mark strip-width boundaries. All surveys were completed before 1200 h Eastern Standard Time.

Visibility Bias

Aerial surveys are biased because sighting probabilities often are no better than 50-60% (Caughley 1977). Two common types of bias in aerial survey for marine mammals are perception bias and availability bias (Marsh and Sinclair 1989b, Lefebvre et al. 1995). Perception bias in manatee surveys results when a proportion of manatees visible within the strip-transect is missed by the observer(s). Availability bias in manatee surveys occurs when a proportion of manatees within the strip-transect area is not "available" to be counted because it is submerged under turbid water or hidden by some other habitat feature.

We estimated perception bias using a double count by two independent observers (Seber 1982, Pollock and Kendall 1987). Observers in the right-front and right-rear seats of the aircraft formed a tandem team searching the same 250m-wide transect independently. Right-side observers recorded their sightings on small-scale maps, then conferred afterwards to determine whether each group was seen (a) by the front observer only, (b) by the rear observer only, or (c) by both observers. Their independent observations provided counts which were used in a modified mark-recapture model (Petersen estimator) to determine the number of animals missed by both observers. This technique has been used successfully in surveys for a variety of species, including crocodiles (Crocodylus porosus; Magnusson et al. 1978), emus (Dromaeous novaehollandiae; Caughley and Grice 1982), feral horses (Equus caballus; Graham and Bell 1989), and dugongs (Marsh and Sinclair 1989b, Marsh et al. 1994, Marsh 1995). Three different biologists rotated among seating positions so that different right-side combinations could be used to calibrate observer performance.

Because members of a group of animals are not sighted independently, groups, rather than individuals, were considered appropriate sample units. Matching of groups seen by right-side observers occurred during the flight via intercom (11 Aug 1993 - 10

Aug 1994) or after the survey flight was completed (11 Aug 1994 - 23 Aug 1994). Conversations during the flight were tape-recorded directly from the intercom as a back-up for later verification if needed. The following information was recorded for each manatee group sighted: location, time, behavior (feeding, resting, travelling, cavorting), total number in group, and number of calves. When observers differed as to the number of manatees in a group, the higher number was used in analyses. Although the right-front and right-rear observers formed the primary survey team, on most flights a left-rear observer was also present. However, data collected by left-side observers could not be adjusted for perception bias and so are not used in population estimates.

Availability bias was intentionally minimized by the selection of a study area with shallow water and good visibility. We did not use an availability correction factor to correct our counts because we found it was not feasible to establish different sighting probabilities for manatees based on their position in the water column (but see Marsh and Sinclair 1989b).

Population Estimates

The equations used to calculate survey-specific correction factors for perception bias follow that of Marsh and Sinclair (1989b). Despite small sample sizes, the Chapman modification of the Petersen estimator (Seber 1982) was not used because it did not significantly reduce the variance of overall population estimates. The corrected number of manatees per transect was obtained by multiplying these components: (a) the number of groups on the transect sighted by right-side observers, (b) the survey-specific correction factor, and (c) the mean group size for that survey (Marsh and Sinclair

1989b:1021-1022). Because transects were of variable length, the ratio method (Norton-Griffiths 1978, Seber 1982, Marsh and Sinclair 1989b) was used to estimate the total population size in the 160 km^2 study area. Population estimates were averaged to obtain a mean and standard error for each year.

Trend Analysis

The utility of these surveys for trend analysis was explored using power analysis software for linear regression (TRENDS, T. Gerrodette, Southwest Fish. Sci. Center, La Jolla, Cal.). A power analysis allows estimation of the probability of being able to detect an upward or downward trend in population size given the number of replicate samples per year and sample variability (Gerrodette 1987, 1991, 1993).

V. RESULTS

Survey Counts

Eight surveys were conducted each year in August-September (Table 1). A total of 775 individuals belonging to 374 groups was counted during the 16 surveys, for a mean group size of 2.07 ± 1.74 (SD). Flights were conducted under standardized survey conditions with good visibility except on 25 Aug 1993, when overcast, rainy weather associated with a stationary front produced poor visibility; the low count of 11 undoubtedly underestimated the number of manatees actually present. Daily survey conditions and personnel are summarized in Appendix A. Total survey time was 25.0 hrs, with a sighting rate of 31 manatees per hr (0.52 per min) by all observers and 22 manatees per hr (0.36 per min) by right-side observers.

Observer Bias

Right-front observers sighted a total of 206 manatee groups, whereas right-front and right-rear observers combined for a total of 253 manatee groups. Compared with a conventional single-observer aerial survey, the double-observer technique increased the number of manatee groups by 23% due to the presence of the second observer and by 36% when the double counts were corrected by the Petersen model.

Double counts by 2 right-side observers produced survey-specific correction factors for perception bias averaging 1.13 (range: 1.00 - 1.60) (Table 2). A perception correction factor (C_p) of 1.13 indicates that 88% (the reciprocal) of the groups estimated to be available ($\hat{N}$) were observed by at least one of the two right-side observers. The C_p was highest on days with poor (1.60 on 25 Aug 1993) or fair (1.42 on 15 Aug 1994) survey conditions. Although the proportion of groups detected varied from survey to survey, within a survey it was relatively similar between observers (Table 3). Mean detection probabilities for each biologist ranged from 75-78% in 1993 and 70-78% in 1994.

Group Size

Mean group size per survey for the right-side observer team ranged from 1.65 to 3.10 (Table 2). Most of the groups sighted were single animals (51% of groups) or groups of two (26% of groups), but a few large (>6) groups also were seen (Fig. 3). These statistical outliers resulted in larger variance in mean group size and, consequently, larger variance of the overall population estimate (Table 2). Although more single manatees were seen in 1994 than in 1993 (Fig. 4), mean group size did not differ between years (Wilcoxon rank sum test, $\underline{Z}$ = 1.058, $\underline{P}$ = 0.2902).

Combining all data collected by right-side observers, sighting probability was 0.87 for single manatees (N=123), 0.96 for groups of 2 manatees (N=62 groups), and 0.99 for groups of 3 or more manatees (N=68 groups). Single animals were more likely to be seen by only one observer than were larger groups (X^2 = 18.737, 2 df, $\underline{P} < 0.0005$, Table 4).

Of the 253 groups sighted by right-side tandem observers, 151 (60%) were seen by both members (Table 4). Observers differed in their estimates of group size for 26 (17%) of these 151 groups. Discrepancies were somewhat more frequent with larger groups, suggesting that observers may have had greater difficulty counting larger groups of manatees.

Clumped Distributions

Manatees formed summertime aggregations at a few sites along the Banana River shoreline (hereafter referred to as "hot-spots"). These areas were attractive to manatees primarily because they were sources of freshwater. Counts at 4 hot-spots were made by repeated circling by the aircraft over each area (Table 5). On 12 of 16 (75%) surveys the total count at hot-spots exceeded the total number of manatees counted on transects. More manatees were counted at hot-spots in 1994 (mean = 59.4) than in 1993 (mean = 45.7) due to the increased numbers at the 520 Causeway (520C) and Cape Canaveral Sewage Plant (CCSP) (Table 5).

The clumped distribution of manatees is further demonstrated by comparing the number of manatee groups observed on each transect (Fig. 5). We collapsed the 40 transects into 8 zones of 5 adjacent transects and performed a Chi-square Goodness-of-

Fit test to see if groups were distributed evenly across the study area (Table 6). Manatee distribution did not fit the expected distribution in either year (1993: $\underline{P} < 0.005$; 1994: $\underline{P} < 0.001$), indicating that the number of manatees observed in each of the 8 zones was not proportional to the area surveyed in each zone. Manatee density was highest between transects 41-45 (the area north and south of Hwy 528 Causeway); more manatees occupied this zone than expected in both years. Note also that some of the highest manatee densities were observed south of transect #43 in the area outside the manatee "sanctuary" (Fig. 5, Table 6).

Population Estimates

Population estimates ($\hat{Y}$) ranged from 64 to 240 in 1993 and 148 to 208 in 1994 (Table 2). Population estimates were moderately consistent among surveys, with the exception of 2 surveys conducted under extreme weather conditions. Results from 25 Aug 1993 ($\hat{Y} = 64$) are suspect because of poor visibility caused by bad weather, and we excluded that survey from all analyses of population size. Results from 28 Sep 1993 ($\hat{Y} = 240$) also may be unreliable because they were obtained late in the season coincident with the first fall cold-front. We suspect that cool weather probably changed manatee behavior and distribution, but because we cannot verify this, we conducted analyses of population size both with and without this survey (hereafter referred to as "late" survey).

There are several components of the variance estimator for $\hat{Y}$, including variance from the correction factor, variance from group sizes, and variance from sampling.

Generally, high variance was mostly due to group size variability and sampling variability in number of manatees per transect.

Mean population size in 1993 was 142 ± 17 (SE) with the late survey (N=7), and 125 ± 4 (SE) without the late survey (N=6). Mean population size in 1994 was 179 ± 8 (SE) (N=8). The benefit of replicate sampling is clear; although the coefficient of variation (cv) of $\hat{Y}$ from a single survey was large (generally 30-40%, Table 2), the cv of mean $\hat{Y}$ was smaller (8% in 1993 without the late survey, 13% in 1994; Table 7).

By adding the daily counts of manatees in the high-density hot-spot stratum to $\hat{Y}$, we obtained an estimate of the total population size in the survey area (hereafter referred to as $\hat{Y}_+$) (Table 7). Mean $\hat{Y}_+$ was 27% and 33% greater than $\hat{Y}$ in 1993 and 1994, respectively, indicating that the proportion of the population using hot-spots was similar between years.

Trend Analysis

Mean population size ($\hat{Y}$) differed between years (late 1993 survey excluded: Wilcoxon rank sum test, Z = -3.034, P = 0.0024; late 1993 survey included: Wilcoxon rank sum test, Z = -2.257, P = 0.0240). Obviously, we cannot infer an increasing trend in population size based on 2 annual estimates. To assess the possibility of detecting statistically significant trends in the Banana River population, we used TRENDS software (Gerrodette 1993) for a power analysis of linear regression. We used a cv of 0.04 and 0.05 in our power analysis, because the cv of mean $\hat{Y}$ was in this range in both years. The following parameters also were selected: alpha = .05; 1-tailed test; linear model of rate of change; cv is proportional to the square root of the abundance estimate (appropriate when strip-transect or line-transect methods are used for estimating abundance; Gerrodette 1987); standard normal (Z) distribution (because an estimate of variance of mean $\hat{Y}$ is produced each year; Gerrodette 1991, 1993).

When number of sampling periods (n) is parameter to be computed:

For r = .05 and power = .75:	If cv = 0.04,	n = 4
	If cv = 0.05,	n = 4
For r = .10 and power = .75:	If cv = 0.04	n = 3
	If cv = 0.05	n = 3

When power (1 - β) is parameter to be computed:

For r = .05 and n = 5:	If cv = 0.04	power = 0.96
	If cv = 0.05	power = 0.86
For r = .10 and n = 5:	If cv = 0.04	power = 1.00
	If cv = 0.05	power = 1.00

With the stringent assumptions of high precision (cv = 0.04) and a high level of power (power = 0.75), we would need 4 sampling periods (i.e., years) to detect an annual rate of change (r) = 0.05. An increase in r or a decrease in the cv will increase the power of our test. Note that the above analyses are for detecting an increasing trend ($r > 0$) with a one-tailed test; to detect a decreasing trend (r is negative) of the same magnitude with a one-tailed test, the power will be reduced slightly (Gerrodette 1993).

VI. DISCUSSION

Observability Bias

Sighting probabilities in this study were consistent among observers and averaged nearly 80% (Table 3). In contrast, mean sighting probability of manatees was <50% in areas in the St. Johns River with turbid water and/or overhanging tree branches (Packard et al. 1985). Sighting probabilities in aerial surveys for terrestrial mammals are generally less than 60-70% (Floyd et al. 1979, Bartmann et al. 1986, Beasom et al. 1986, DeYoung et al. 1989, Firchow et al. 1990, Fuller 1990, Potvin et al. 1992), due in part to environmental factors such as tree cover and broken terrain that help to obscure animals. We believe that low perception bias in our study may be due primarily to the conspicuous nature of the manatees in the predominately clear, shallow water of the Banana River. Water turbidity and depth influence both availability bias and perception bias (Lefebvre et al. 1995). Therefore, we may have reduced perception bias by selecting a study area with optimal survey conditions that minimize availability bias (but see Marsh and Sinclair 1989b).

Low correction factors for perception bias in this study also could be reflective of observer skill level, as each of the 3 principal observers had prior multi-year experience in the aerial survey of ungulates or marine fauna or both. Packard et al. (1985) reported that observer experience influenced the observability of manatees in aerial surveys. Aerial surveys conducted by Holt and Cologne (1987) indicated that experienced observers saw more dolphins than did inexperienced observers but the difference were not statistically significant.

For the Petersen estimator to be valid, 4 main assumptions must be met: (1) the population is closed during the time between the 2 sampling periods; (2) animals do not lose their marks between the 2 sampling periods; (3) all marks are correctly identified, noted, and recorded; and (4) each animal has the same probability of capture in the first sample, and marking does not affect the capture probability of an animal in the second sample (Otis et al. 1978, Seber 1982).

The first assumption is valid because observers see manatees almost at the same instant. Although aircraft noise can cause ungulates to flee from the flight path (e.g., Bartmann et al. 1986, Johnson et al. 1991), we did not observe a flight response by manatees. Manatees are typically slow-moving creatures, and it is unlikely that they can move laterally outside of the transect in the short period of time between observation by front and rear observers.

The second and third assumptions are linked. Each manatee group must be uniquely identified so that groups can be matched properly, and recorded as seen by the front observer only, the rear observer only, or by both observers (Seber 1982, Pollock and Kendall 1987). Separate intercom systems can be used for the 2 right-side observers to communicate independently with a third person acting as recorder (see Marsh and Sinclair 1989b, Marsh 1995). Such an intercom system was unavailable in our aircraft, thus, we used 2 other systems for recording data. Initially, right-side observers recorded their sightings on small-scale maps, then conferred immediately afterwards to determine whether each group was seen by one or by both observers. Later (after 10 Aug 1994), observers recorded their sightings in silence and conferred after the flight to determine group identity. Matching of groups after a double-count is facilitated when the density of the species surveyed is low, because observations are usually separated by enough time that no confusion arises (Graham and Bell 1989, Potvin et al. 1992). Criteria used to describe a group, such as size, movement, and behavior also helped to discriminate between groups in cases where they occurred close together (Potvin et al. 1992). (In the few cases where it was difficult to interpret the observer's sightings we erred toward matching groups together rather than separating them, thus reducing the correction factor and making a conservative estimate of population size.) At any rate, correction factors were similar whether we conferred during the flight or afterwards, leading us to believe that observers operated independently without taking cues from each other as to the timing and nature of their observations. We also note that the problem of matching groups is not solved by using separate intercoms, as simultaneous registration of a group by 2 observers does not necessarily prove they are one and the same---the only sure documentation would be a high-quality photographic record of the strip as it is surveyed.

The fourth assumption is perhaps the most difficult assumption to meet. Some have argued that marking and recapturing in the aerial survey double-count technique are not truly independent because observers have essentially the same vantage point from the aircraft (Caughley and Grice 1982, Pollock and Kendall 1987), thus, the second sample is not random. Also, animals are not likely to have equal capture probability (i.e., probability of being sighted) because some may be inherently more difficult to see. Larger groups of animals were more easily detected than smaller groups in aerial surveys of white-tailed deer (Odocoileus virginianus; Fuller 1990), mule deer (O. hemionus;

Ackerman 1988), elk (Cervus canadensis; Samuel et al. 1987), and feral horses (Graham and Bell 1989), and in shoreline surveys of sea otters (Enhydra lutris; Estes and Jameson 1988). In contrast, group size was not a factor in the sightability of dugongs in aerial surveys (Marsh and Sinclair 1989a). Our data suggest that single manatees or manatees in groups of 2 are more likely to be missed than larger (≥3) manatee groups, but the bias is not as significant as in surveys of the above-mentioned species. Our sample sizes were inadequate to calculate group-size-specific correction factors for each survey. However, our results are bolstered by the fact that simulations have shown the technique to be robust to unequal capture probability (Magnusson et al. 1978) unless the sighting probability is below 0.45 (Caughley and Grice 1982). Sighting probability in this study far exceeds the minimum recommended by Graham and Bell (1989) in their survey of feral horses, or that recommended by Caughley and Grice (1982) in their simulations of the mark-recapture model for emus.

Spatial Distribution of Manatees

Contrary to our expectations, manatees tended to aggregate in large groups (usually ≥10 manatees) at a few shoreline locations we labelled "hot-spots". We stratified these groups into a separate "high-density" stratum to improve the precision of our population estimates (Norton-Griffiths 1978). Marsh (1995) stratified out groups of 10 or more dugongs from transect estimates by interrupting the flight path whenever they were sighted inside or outside transects, and circling and photographing the group to obtain a total count. We found groups of >10 manatees were restricted almost entirely to shoreline hot-spots (<1% of groups on strip-transects were >10 manatees).

The pattern of concentration at hot-spots changed between years (Table 5). The 520C was more heavily occupied by manatees in 1994 than in 1993, while the area west of Cocoa Beach Golf Course (CBGC) was essentially unused by manatees in 1994. The ephemeral nature of the CBGC hot-spot underscores the fact that manatee distribution changes over time (see Fig. 5). Observers need to adequately search the study area each year to identify changes in the location and size of hot-spots if they are to be counted accurately and added to the strip-transect population estimate. Knowledge of the proportion of the population that is aggregated is necessary to assess population trends.

Despite stratification, variance in mean group size among transects and variance in the number of groups sighted per transect were still high; these components were responsible for high variance of each population estimate (Table 2). Similarly, variability in moose (Alces alces) distribution was the most important component of corrected population estimates in aerial surveys of moose in winter (Crête et al. 1986).

Population Estimates and Population Trends

Manatee population size in the Banana River was higher in 1994 (mean $\hat{Y}_+$ = 238) than in 1993 (mean $\hat{Y}_+$ = 159) (P = 0.0024; late 1993 survey excluded), an increase of nearly 50%. The survey design, survey conditions, flight-path, type of aircraft, and observers used were the same in both years. Summer surveys of manatees conducted since 1977 (Shane 1983; Provancha and Provancha 1988; J. Provancha, NASA, unpubl. data) indicate a steady increase in the manatee population occupying the northern portion of the Banana River. The portion of the river surveyed by Provancha is closed to boating and protected as a manatee sanctuary. Provancha and Provancha (1988) suggested the observed increase could be due to an increase in manatee use of the sanctuary rather than an actual increase in the manatee population in Brevard County. However, some of the highest densities of manatees we observed were south of the protected portion of the river. Although we conducted only 2 years of surveys, our data support the hypothesis that the manatee population of the entire Banana River is increasing.

Biologists generally have difficulty detecting trends in vertebrate species that occur at low densities (Forney et al. 1991, Taylor and Gerrodette 1993). Manatee density in the Banana River is relatively high ($>1/km^2$) and our sampling intensity is high (25% of the total survey area is sampled, 7-8 replicate flights are performed each year). Together, these factors produce annual population estimates with high levels of precision. We should be able to use the current survey protocol to detect annual rates of change of 5-10% within only a few years, with alpha = 0.05 and power ≥ 0.75. Trend analysis will be valid only if the same survey effort (i.e., 7-8 flights per year with a cv of 4-5%) is maintained from year to year (Gerrodette 1987, 1993). Surveys should be performed at regular intervals (e.g., every year, or every second year) if possible. Fortunately, TRENDS software is not very sensitive to missing data points as long as they occur at fairly regular intervals (T. Gerrodette, pers. comm.). Thus, the fact that surveys were not performed in 1995 is not a detriment.

We also assume that biases not directly measured (i.e., availability bias, absence bias) remain constant from year to year. Availability bias is likely to remain constant from year to year as long as water quality and other environmental conditions in the river remain unchanged. We also must assume that the proportion of animals using the survey area remains reasonably constant if we are to extrapolate survey trends to the Brevard County region. If the proportion of manatees using creeks and canals contiguous to the river changes each year then we are limited in our ability to infer trends about the region. It is recommended that analysis of telemetry data for radio-tagged manatees in Brevard County waterways be conducted to explore diel, seasonal, and annual patterns of movement in and out of the Banana River study area.

VII. SUMMARY AND MANAGEMENT RECOMMENDATIONS

The strip-transect survey technique represents an improvement over past attempts to estimate absolute manatee abundance because it is a repeatable, standardized survey design that produces population estimates with associated variance and confidence intervals. Observer bias in our surveys was adjusted for with survey-specific correction factors derived from double counts (Petersen estimator). Although our data indicate perception bias is low relative to other studies, it is still beneficial to include double-counts in the survey protocol. Compared to a conventional single-observer aerial survey, the double-observer technique increased the number of manatee groups by 23% due to the presence of the second observer and by 36% when the double counts were corrected by the Petersen model. Survey-specific correction factors are advantageous because they adjust for variable weather conditions and different observer skill levels.

The strip-transect surveys also allow for the detection of trends in population size with reasonable statistical power, which makes them useful for monitoring purposes in the Banana River. Because of the assumption that availability bias and absence bias remain relatively constant among years, transect surveys perhaps are best used for monitoring in conjunction with other datasets.

An important, still unresolved, issue is whether the strip-transect survey method can be used successfully in other areas in Florida during summer. Transect surveys for manatees are most appropriate in large, homogeneous areas (Ackerman 1995). Researchers recently selected 3 areas to evaluate warm-season strip-transect surveys for manatees: Banana River, Charlotte Harbor, and the Ten Thousand Islands (O'Shea et al. 1992, Ackerman 1995). Trials in the Ten Thousand Island region in Collier County during June-August 1993 were hampered by excessive water turbidity and other environmental features (B. Ackerman, unpubl. data). Because manatees commonly inhabit coastal waters that are turbid or partially obscured by overhanging vegetation (Lefebvre et al. 1995), it may be very difficult to find other areas like the Banana River. Marsh (1995) questioned the applicability of dugong transect survey methods to manatee habitats because the spatial configuration of manatee habitats tends to be linear, precluding the use of parallel transects.

Despite these limitations, we feel managers would benefit by continuing warm-season transect surveys in the Banana River for the following reasons: (1) Banana River is clearly important as a manatee summer sanctuary and we have a need to continue to monitor the abundance, survival, and movements of manatees in this area. Our data support the hypothesis that manatees are increasing throughout the Banana River and not just within the northern portion protected from development and disturbance, but additional years of data are needed to verify this; (2) We need complementary datasets to confirm recent analysis that suggests manatee population size on the east coast of Florida is increasing (e.g., Garrott et al. 1994). Garrott et al. (1994) developed a population index by using a temperature covariate to model a linear trend in aerial survey data from the winters of 1977-78 through 1991-92. Their analyses showed an increasing trend in the temperature-adjusted counts of 7-12% annually on the Atlantic coast, but the degree to which these increases are related to true population growth is unknown. Changes in manatee behavior may have altered the proportion of manatees in winter aggregations (Garrott et al. 1995). Different aerial surveys (including NASA funded aerial surveys in Banana River; see Appendix B) and different demographic datasets should be used to corroborate evidence of population trends in manatee populations.

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Table 1. Manatees observed on strip-transect aerial surveys, Banana River, Brevard County, Florida, summer 1993-94.

Date	Right observers		Left observer		All observers	
	Groups	Individuals	Groups	Individuals	Groups	Individuals
1993						
11 Aug	11	22	9	22	20	44
25 Aug[a]	5	10	1	1	6	11
26 Aug	13	31	--[b]	--	13	31
31 Aug	12	24	2	2	14	26
01 Sep	12	30	6	9	18	39
02 Sep	11	28	5	13	16	41
16 Sep	10	31	--[b]	--	10	31
28 Sep[c]	27	54	9	18	36	72
Total	101	230	32	65	133	295
1994						
08 Aug	20	40	12	25	32	65
09 Aug	21	45	13	28	34	73
10 Aug	20	49	4	6	24	55
11 Aug	18	36	6	7	24	43
15 Aug[d]	17	28	12	30	29	58
18 Aug	19	34	8	15	27	49
19 Aug	19	42	13	22	32	64
23 Aug	18	37	21	36	39	73
Total	152	311	89	169	241	480

[a] Very poor survey conditions---overcast with scattered rain.
[b] No left observer.
[c] Survey coincided with first cold front of the fall season.
[d] Fair survey conditions---partly cloudy with moderate wind.

Table 2. Manatee counts corrected for perception bias (Petersen estimator), multiplied by mean group size, and adjusted for area sampled (ratio estimator) to obtain population estimates for Banana River, Brevard County, Florida, summer 1993-94.

	Number of groups on transects[a]							Sampling	Estimated
Date	RF	RR	RB	N seen	N hat	C_p (cv)[b]	Mean group size (cv)	coverage[c]	Population size (cv)
1993									
11 Aug	3	4	4	11	14.00	1.27 (0.15)	2.00 (0.32)	21	130.70 (0.47)
25 Aug[d]	1	3	1	5	8.00	1.60 (0.49)	2.00 (0.16)	25	64.42 (0.63)
26 Aug	1	3	9	13	13.33	1.03 (0.02)	2.38 (0.19)	25	128.02 (0.34)
31 Aug	4	3	5	12	14.40	1.20 (0.11)	2.00 (0.23)	24	117.68 (0.36)
01 Sep	1	2	9	12	12.22	1.02 (0.01)	2.50 (0.20)	25	123.03 (0.32)
02 Sep	2	0	9	11	11.00	1.00 (0.00)	2.55 (0.16)	25	112.74 (0.42)
16 Sep	1	0	9	10	10.00	1.00 (0.00)	3.10 (0.28)	25	139.45 (0.41)
28 Sep[e]	8	5	14	27	29.86	1.11 (0.04)	2.00 (0.20)	22	240.43 (0.31)
1994									
08 Aug	5	3	12	20	21.25	1.06 (0.03)	2.00 (0.15)	24	172.66 (0.27)
09 Aug	2	4	15	21	21.53	1.03 (0.01)	2.14 (0.18)	24	187.46 (0.31)
10 Aug	3	4	13	20	20.92	1.05 (0.02)	2.45 (0.19)	24	208.25 (0.28)
11 Aug	6	4	8	18	21.00	1.17 (0.07)	2.00 (0.16)	21	198.09 (0.28)
15 Aug[f]	6	6	5	17	24.20	1.42 (0.17)	1.65 (0.25)	24	161.93 (0.35)
18 Aug	5	3	11	19	20.36	1.07 (0.03)	1.79 (0.16)	24	148.04 (0.28)
19 Aug	5	2	12	19	19.83	1.04 (0.02)	2.21 (0.16)	19	203.79 (0.32)
23 Aug	2	1	15	18	18.13	1.01 (0.00)	2.06 (0.14)	24	151.43 (0.27)

[a] RF = seen by right front observer only; RR = seen by right rear observer only; RB = seen by both right observers; N seen = total groups seen on transects (RF+RR+RB); N hat = estimated number of groups available on transects.
[b] Perception correction factor (N hat / N seen).
[c] Percentage of study area sampled.
[d] Very poor survey conditions---overcast with scattered rain.
[e] Coincided with first cold front of the fall season.
[f] Fair survey conditions---partly cloudy with moderate wind.

Table 3. Detection probabilities for 3 right-side observers on strip-transect aerial surveys, Banana River, Brevard County, Florida, summer 1993-94. Proportions indicate the number of manatee groups seen by the observer divided by the number of groups estimated to be available on transects.

	Observer A (Ackerman)	Observer B (Miller)	Observer C (Clifton)
1993			
11 Aug	.50	.57	--
25 Aug[a]	--	--	--
26 Aug	--	.90	.75
31 Aug	.63	.56	--
01 Sep	.82	.90	--
02 Sep	1.00	.82	--
16 Sep	1.00	--	.90
28 Sep	.74	--	.64
Mean	.78	.75	.76
1994			
08 Aug	.80	.71	--
09 Aug	.79	.88	--
10 Aug	.76	.81	--
11 Aug	.57	.67	--
15 Aug	--	.45	.45
18 Aug	--	.79	.69
19 Aug	.86	--	.71
23 Aug	.88	--	.94
Mean	.78	.72	.70

[a] Poor survey conditions produced insufficient data.

Table 4. Total groups of each size class observed by both right-side observers (RB) versus those observed by only one right-side observer (RF or RR), strip-transect aerial surveys, Banana River, Brevard County, Florida, summer 1993-94.

	Group size			
Observer	1	2	≥ 3	Total
RB	57	42	52	151
RF or RR	66	20	16	102
Combined	123	62	68	253

Table 5. Manatee concentrations observed at "hot-spots" in Banana River during strip-transect aerial surveys, summer 1993-94. Hot-spots were counted by 2 right-side observers; highest count is presented.

Date	Hangar AF	Cape Canaveral Sewage Plant	South of 520 Causeway	Cocoa Beach Golf Course	Total
1993					
11 Aug	14	33	---[a]	3	50[b]
25 Aug	29	14	---	15	58[b]
26 Aug	15	---	---	8	23
31 Aug	16	21	---	1	38[b]
01 Sep	10	4	---	0	14
02 Sep	17	6	10	7	40[b]
16 Sep	22	7	6	0	35[b]
28 Sep	15	6	17	1	39
Total	138	91	33	35	297
Mean	17.3	13.0	11.0	4.4	45.7[c]
1994					
08 Aug	11	18	14	0	43[b]
09 Aug	20	20	28	5	73[b]
10 Aug	18	14	11	0	43
11 Aug	26	20	18	0	64[b]
15 Aug	9	15	17	0	41[b]
18 Aug	11	23	38	0	72[b]
19 Aug	11	29	35	0	75[b]
23 Aug	11	16	31	6	64[b]
Total	117	155	192	11	475
Mean	14.6	19.4	24.0	1.4	59.4[c]

[a] No data.
[b] "Hot-spot" total was greater than total number of manatees counted on transects during same survey.
[c] Sum of column means.

Table 6. Observed distribution of manatee groups in 8 zones (each zone = 5 consecutive transects) and the expected distribution of manatee groups in relation to the area surveyed in each zone, Banana River, Brevard County, Florida.

	1993[a]			1994[b]		
Transect Zone	Observed groups	Area km^2	Expected groups	Observed groups	Area km^2	Expected groups
56-60	2	67.1	5.5	5	58.6	7.3
51-55	20	173.4	14.2	13	161.9	20.2
46-50	12	214.8	17.6	37	214.8	26.8
41-45	24	177.8	14.6	34	177.8	22.2
36-40	18	196.0	16.1	28	196.0	24.4
31-35	14	100.8	8.3	2	89.5	11.2
26-30	7	203.2	16.7	16	203.2	25.3
21-25	4	97.8	8.0	17	116.8	14.6
Total	101	1230.9		152	1218.6	

[a] $X^2 = 24.275$, 7 df, $\underline{P} < 0.005$.
[b] $X^2 = 25.368$, 7 df, $\underline{P} < 0.001$.

Table 7. Mean annual population estimates with and without hot-spot stratum, Banana River, Brevard County, Florida, summer 1993-94.

	$\hat{Y}$ [a]	$\hat{Y}_+$ [b]
1993		
	130.7	180.7
	128.0	151.0
	117.7	155.7
	123.0	137.0
	112.7	152.7
	139.5	174.5
Mean	125.3	158.6
SE	3.9	6.6
(cv)	(.031)	(.042)
1994		
	172.7	215.7
	187.5	260.5
	208.3	251.3
	198.1	262.1
	161.9	202.9
	148.0	220.0
	203.8	278.8
	151.4	215.4
Mean	179.0	238.3
SE	8.4	9.9
(cv)	(.047)	(.042)

[a] Population estimate derived from strip-transects (excludes manatees counted at aggregation sites.

[b] Population estimate derived from strip-transects, added to the number of manatees counted at aggregation sites.

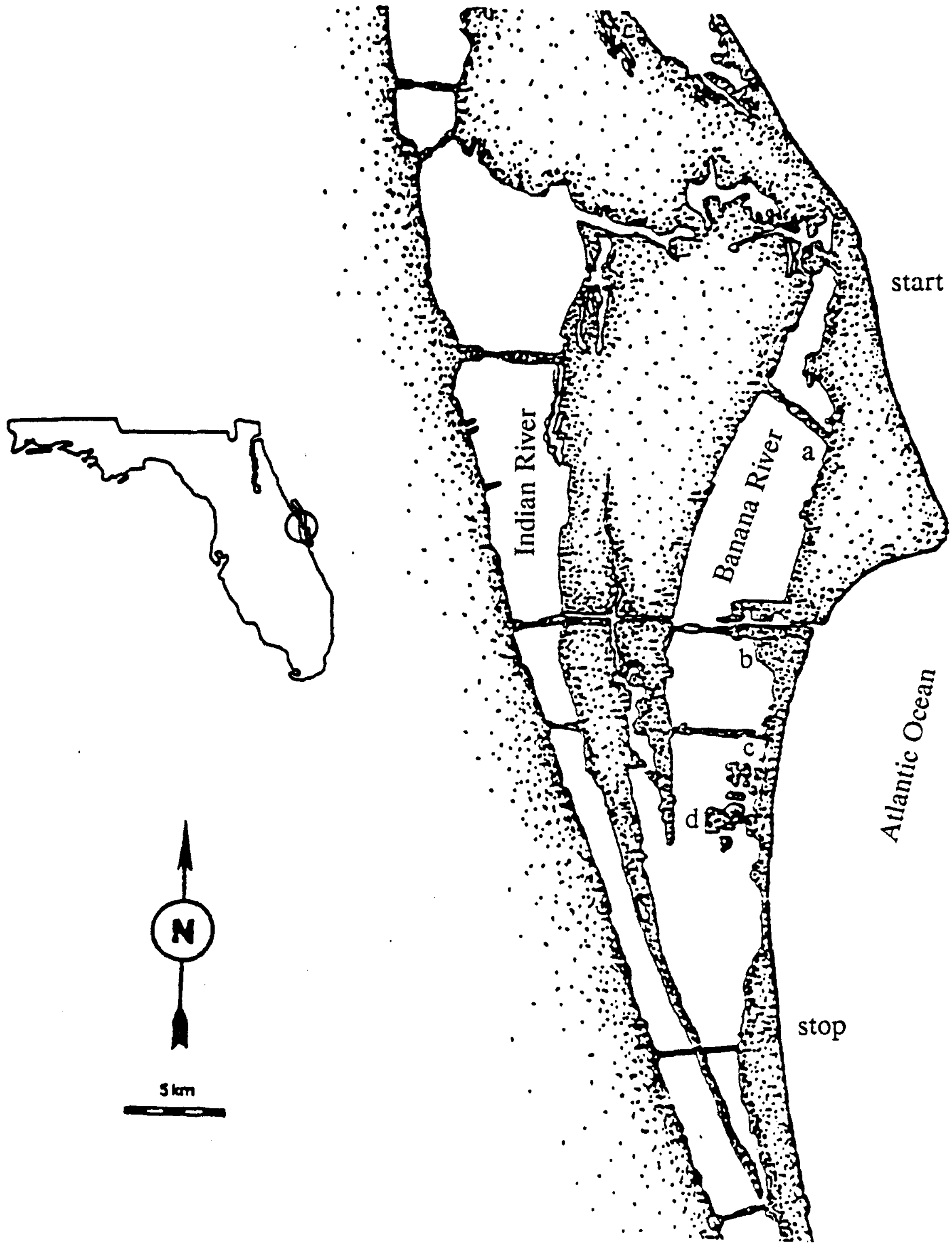

Figure 1. Area surveyed for manatees in Banana River lagoon, Brevard County, Florida, 1993-94. Parallel strip-transects were flown from Jack Davis Cut (start) to Highway 404 (stop). High-density stratum included (a) Hangar AF, (b) Cape Canaveral Sewage Plant, (c) 520 Causeway, and (d) Cocoa Beach Golf Course.

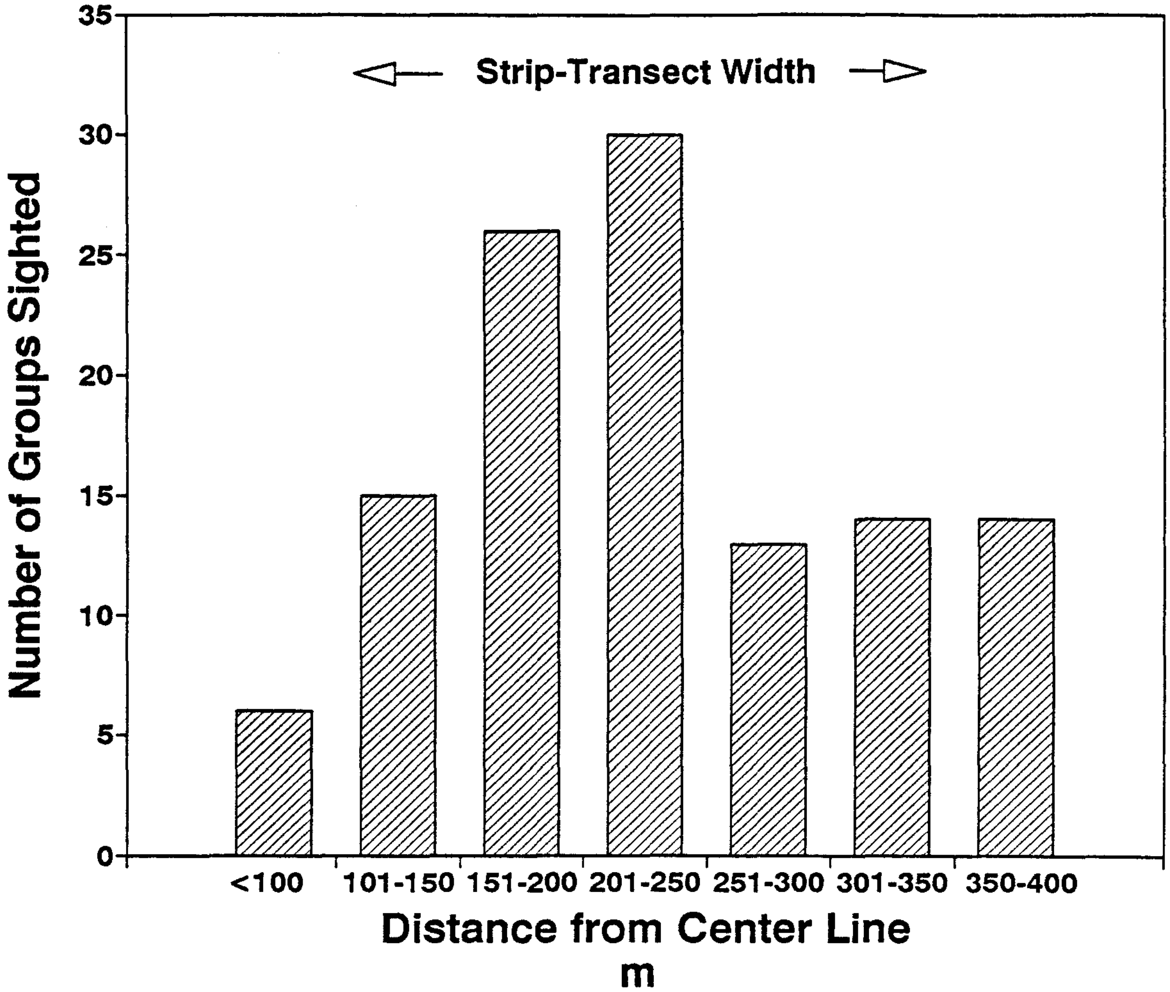

Figure 2. Manatee observability at different distance intervals from the aircraft on 7 survey flights.

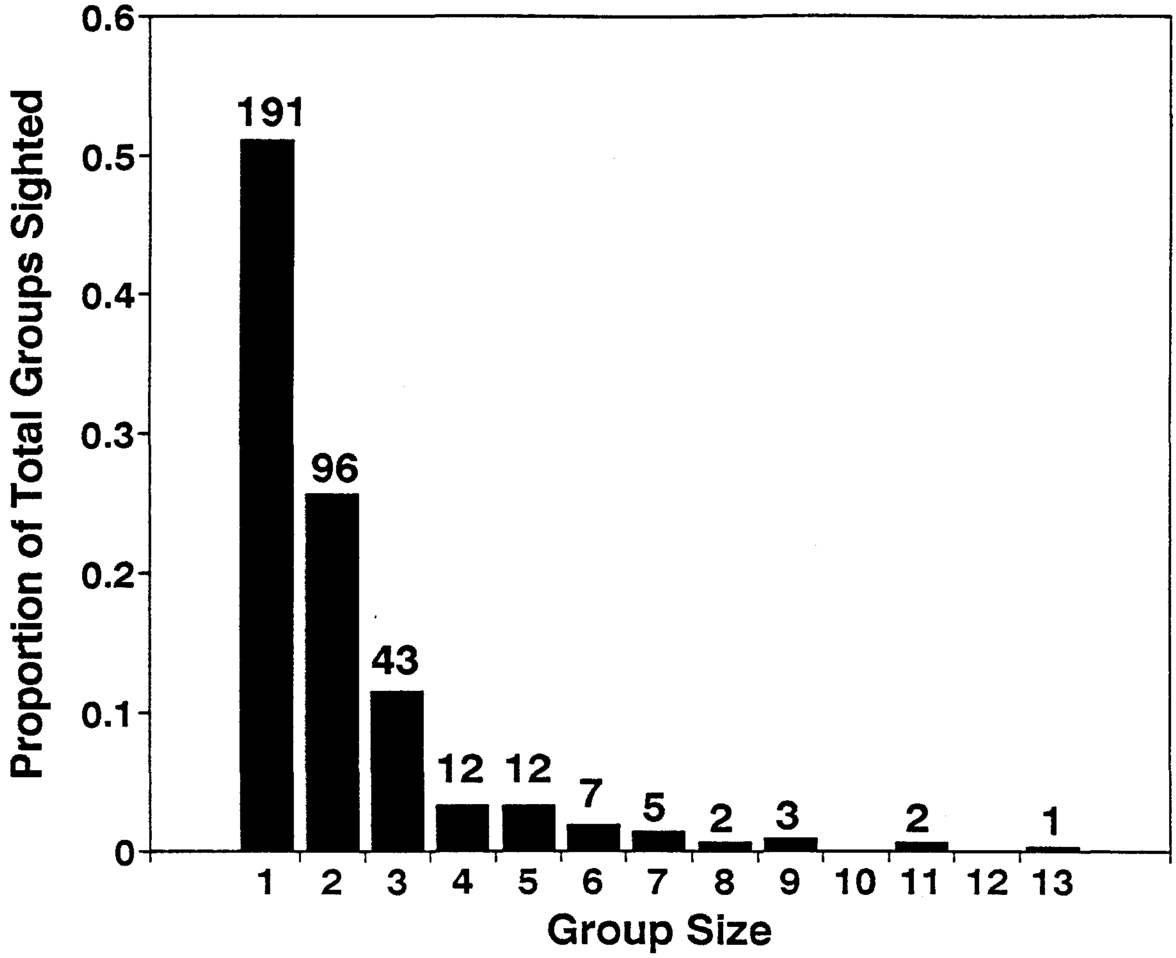

Figure 3. Size class distribution of all manatee groups (N=374) observed by right- and left-side observers on 16 strip-transect aerial surveys, Banana River, Florida, summer 1993-94.

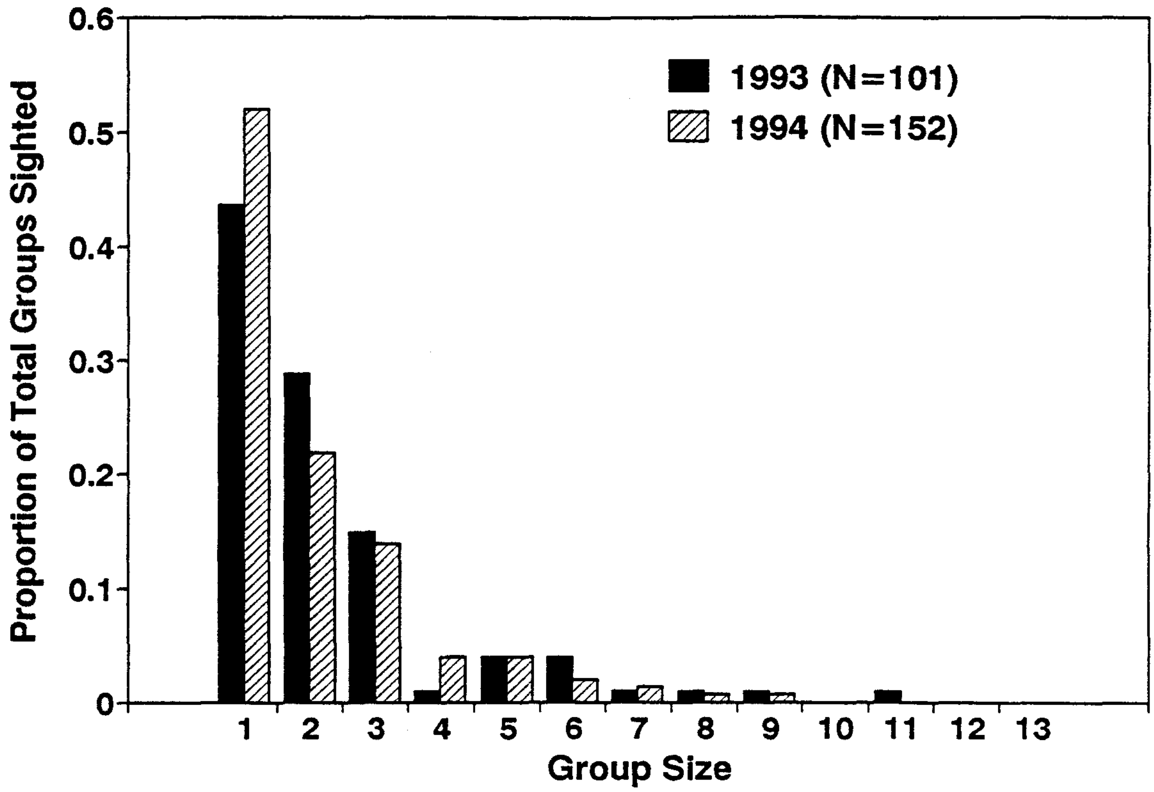

Figure 4. Annual difference in size class distribution of manatee groups observed by right-side observers in summer 1993 (N=101) and 1994 (N=152).

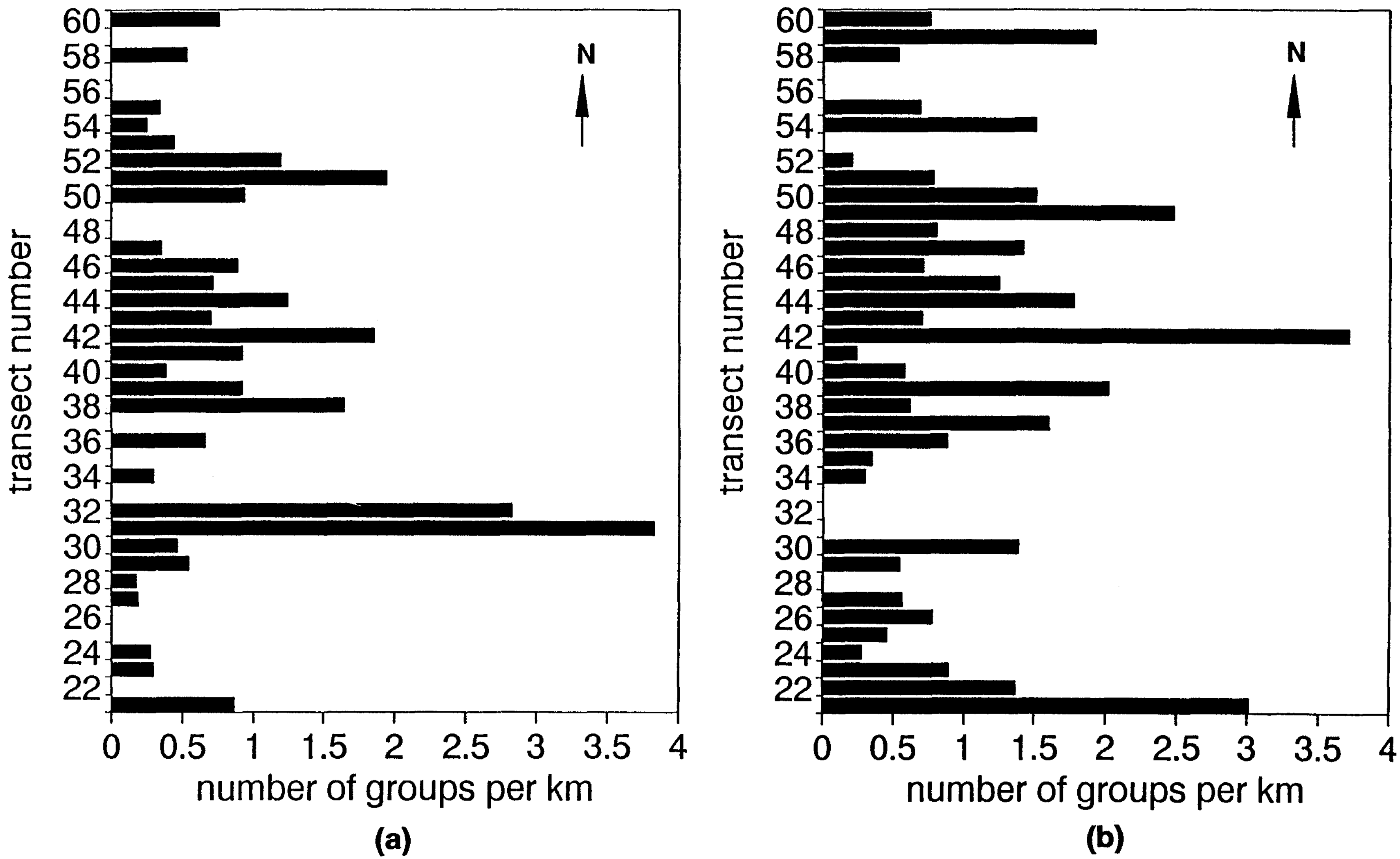

Figure 5. Total number of manatee groups observed on each transect in (a) 1993 and (b) 1994, Banana River, Florida.

APPENDIX A

DAILY RECORD OF AERIAL SURVEYS

Table A-1. Record of personnel, survey time, and flight conditions for strip-transect aerial surveys of manatees in Banana River, Brevard County, Florida, 1993-94.

Date	Personnel[a] P	RF	RR	LR	Start	Stop	Time[b]	GPS	Helo[c]	Conditions
8/11/93	JL	BA	KM	AP	1130	1303	1.6 (2.0)	no	no	good
8/25/93	JL	BA	KM	KC	1025	1149	1.4 (1.9)	no?	no	poor (heavily overcast)
8/26/93	JL	KC	KM	--	0957	1115	1.3 (1.7)	partial	no	good
8/31/93	JL	BA	KM	KC	1048	1206	1.5 (1.9)	yes	yes	fair (water turbidity)
9/01/93	JL	BA	KM	KC	1014	1146	1.5 (1.9)	yes	no	pretty good (some water turbidity)
9/02/93	JL	BA	KM	KC	1002	1129	1.5 (1.7)	yes	no	pretty good (some water turbidity)
9/16/93	JL	BA	KC	--	1031	1204	1.6 (1.9)	yes	yes	good
9/28/93	JL	BA	KC	AP	1025	1154	1.5 (1.9)	yes	no	good (cool; coincident with first fall cold front)
8/08/94	VR	BA	KM	KC	1053	1258	2.1 (2.4)	yes	no	good
8/09/94	VR	BA	KM	KC	1005	1208	2.1 (2.4)	yes	yes	good
8/10/94	VR	BA	KM	LL	0942	1138	1.9 (2.3)	yes	no	good
8/11/94	VR	KM	BA	KC	1045	1231	1.8 (2.2)	yes	no	good
8/15/94	VR	KM	KC	BA	1041	1245	1.1 (2.4)	yes	no	fair (partly cloudy, windy, some water turbidity)
8/18/94	VR	KM	KC	BA	1054	1300	1.1 (2.4)	yes	no	pretty good (windy)
8/19/94	VR	BA	KC	CD	1000	1157	1.9 (2.1)	yes	no	good
8/23/94	VR	KC	BA	KM	1037	1240	1.1 (3.1)	yes	yes	good

[a] Personnel: BA=Bruce Ackerman, KC=Kari Clifton, CD=Chip Deutsch, LL=Lynn Lefebvre, JL=J.T. Lundstrom, KM=Karl Miller, AP=Amy Perry, VR=Vern Renaud, AS=Ann Spellman.

[b] Actual transect survey time (total flight time in parentheses).

[c] Helicopter flight conducted simultaneously by Bionetics Corporation, NASA.

APPENDIX B

INTENSIVE AERIAL SURVEYS FOR MANATEES IN THE NORTHERN BANANA RIVER

Summary

A cost-benefit analysis of different survey methods is beyond the scope of this project. However, we present the following summary (Table B-1) of warm-season manatee surveys conducted by the Bionetics Corporation (now Dynamac), NASA, in the Banana River to illustrate their potential use in trend analysis. For more than 15 years, Bionetics has conducted intensive searches of the northern portion of our study area with the goal of a complete count of the manatees in that area (for details on methodology see Provancha and Provancha 1989). The data suggest a gradual but steady increase in the number of manatees that summer in the northern Banana River (Table B-1). However, the small number of replicates per year, as well as variability in the number each year, limit our ability to infer a population increase. A consistent sample of ≥6 flights per summer should provide the precision necessary to detect a statistical trend in population size in the Banana River (see **Population Estimates and Population Trends** above). Provancha and colleagues have assembled an excellent long-term database in the Banana River. These data can be used effectively to monitor population trends with only a small increase in the number of replicates during the summer months (late June - early September).

Acknowledgments

These data were graciously provided for comparison purposes by Jane Provancha and her co-workers.

Table B-1. Four years of summer (June-September) counts of manatees in the northern Banana River, Brevard County, Florida. Counts were obtained through intensive-search of a 78.5 km^2 study area by 3-4 observers in a NASA helicopter (Source: Jane Provancha, Bionetics Corp., unpubl. data).

	Date	Time	Condition[a]	Total Manatees Areas 1-7	Areas 3-7[b]
1990	04 Jun	69	2	40	37
	09 Jul	59	2	55	46
	17 Aug	69	2	41	34
	25 Sep	60	2	32	30
				42.0 (4.8)	**36.8 (3.4)**
1991	14 Jun	64	1	104	99
	25 Jun	65	1	91	63
	15 Jul	58	2	95	86
	30 Jul	54	2	68	50
	29 Aug	61	1	101	77
	25 Sep	60	2	80	72
				89.8 (5.6)	**74.5 (7.0)**
1992	19 Jun	58	1	67	45
	21 Jul	75	2	139	126
	20 Aug	63	2-3	83	67
	17 Sep	80	2	109	85
				99.5 (15.8)	**80.8 (17.2)**
1993	15 Jun	54	1-2	64	57
	17 Aug	67	2	118	110
	16 Sep	75	NA[d]	127	71
	27 Sep	64	2	120	87
				107.3 (14.5)	**81.3 (11.4)**

[a] Surveys conducted in conditions $\geq$3 were excluded from analysis.
[b] Areas 3-7 also were surveyed by the USFWS/FL-DEP transect method in 1993.
[c] Annual mean (SE).
[d] Data not available.