TEMPORAL AND SPATIAL DISTRIBUTION OF MANATEES IN KINGS BAY, CRYSTAL RIVER, FLORIDA

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J. WILDL. MANAGE. 49(4):921–924

The distribution of the manatee (*Trichechus manatus*) in Florida is seasonally influenced by changes in ambient temperature (Moore 1951, Hartman 1974:8–9, Shane 1983). During spring and summer, manatees are widely dispersed along the Gulf and Atlantic coasts of the Florida peninsula (Hartman 1974:205–206, Powell and Rathbun 1984). In autumn, manatees migrate southward and are attracted to warm-water discharges where water temperatures remain 20 C or higher throughout the winter (Hartman 1974:13; Powell and Waldron 1981; Shane 1983, 1984). Although most warm-water refuges used by manatees in Florida involve thermal effluents from industrial plants, 6 of the 25 known sites are natural artesian springs (Hartman 1974:13). The largest manatee aggregation at a natural refuge occurs in Kings Bay, at the headwaters of the Crystal River on the Gulf coast of north-central Florida (Hartman 1974:18–19).

The number of manatees wintering in Kings Bay appears to have increased since the 1960's (Powell 1981), as has human use of the bay. Diving, boating, aquatic weed control, dredging, and construction have intensified to the point where conflicts with manatee conservation now exist. The objective of this study was to obtain baseline data on seasonal changes in the distribution and abundance of manatees in Kings Bay. This information will help resource managers coordinate human activities with manatee distribution in an area critical to the survival of manatees in northwestern Florida.

STUDY AREA AND METHODS

Kings Bay is located adjacent to the town of Crystal River in Citrus County, Florida. The bay is approximately 2 × 1 km and forms the headwaters of the Crystal River, which flows into the Gulf of Mexico 11 km to the northwest. Although Kings Bay is fed by at least 30 subaqueous springs (Rosenau et al. 1977:81), several large springs account for most of the discharge. The bay is shallow (1–3 m), with some of the larger springs reaching depths of 10 m or more. Water temperature at the springs is 23–24 C throughout the year and may be up to 7 C warmer than surrounding bay waters during cold winter periods (Hartman 1979:25). The Main Spring, located at the southern end of the bay, is the largest source of warm water and has attracted wintering manatees since at least the 1960's (Hartman 1979:7).

Manatee surveys (N = 181) were conducted at Kings Bay from November 1977 through October 1981. The bay was surveyed two to eight times per month ($\bar{x}$ = 4.7) from October through March and one to six times per month ($\bar{x}$ = 3.0) from April through September, with the exception of June 1979. Aerial surveys were done during daylight in a Cessna 172 at an approximate altitude of 170 m and air speed of 80 km/hour. Manatees were counted by one of two experienced observers from the right-front seat of the aircraft with the door removed to enhance visibility. Each of four sections of the bay was repeatedly circled until a consistent count was achieved. Flights were conducted only when the bottom of the bay could be seen from the air, so that manatee visibility was constant across all surveys. The location and number of manatees sighted during each survey were recorded on a study-area map overlaid with a grid scaled at 60 × 60 m.

Manatee counts were compared among months adjusted for year effects by the nonparametric method of m rankings (Benard and van Elteren 1953). This procedure uses rank scores and makes no assumptions about the distribution of the dependent variable. The m-rank technique is a generalization of the Friedman two-way ANOVA (Siegel 1956:166–173) and tests differences among groups adjusting for blocking variables. Multiple comparisons based on m rankings were done as pairwise tests

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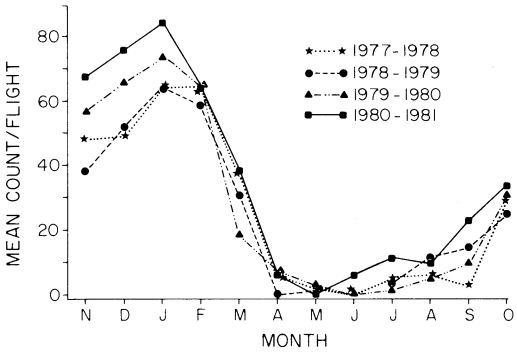

Fig. 1. Annual trend in manatee counts during 4 years of aerial surveys at Kings Bay, Crystal River, Florida.

between all pairs of the 12 months. The significance of each comparison was tested with standard-normal critical values determined by the Bonferroni inequality (Harris 1975:98–101) at an experimentwise error rate of $P \leq 0.05$. Analyses were performed using the MRANK procedure (Sarle 1983) of the Statistical Analysis System. The spatial distribution of manatees in Kings Bay was summarized monthly with computer-generated maps indicating the average number of animals counted in each grid cell during all aerial surveys for the month. Coordinates defining the outline of the bay and the location of manatees were taken from the study-area grid and mapped by the SYMAP program (Dougenik and Sheehan 1975).

RESULTS

Manatee counts ranked highest from November through February and lowest from April through September ($P < 0.05$) (Table 1). During March and October, survey results were variable and average counts were intermediate in rank. The seasonal distribution of manatees was similar during each of the 4 survey years (Fig. 1).

The spatial distribution of manatees varied seasonally and was strongly influenced by the location of springs (Fig. 2). Manatees were concentrated in the southern portion of Kings Bay from November through February. As the winters progressed, aggregations became larger and more localized around the Main Spring between Banana Island and Sunset Shores, while smaller groups formed in Magnolia Spring at the eastern end of the bay (Fig. 2A). Aggregations were generally smaller and more diffuse during March (Fig. 2B) and October (Fig. 2D). Low but consistent use of the area off the northern end of Banana Island (i.e., Tarpon Spring) was apparent from October through March. The relatively small number of manatees sighted from April through September avoided the major springs and occurred most frequently in the northern half of the bay (Fig. 2C).

Table 1. Monthly manatee counts (total per survey) during aerial surveys over Kings Bay, Crystal River, Florida, November 1977–October 1981.

Month[a]		N[b]	Avg[c]	Range
Jan	A	19	71.5	56–96
Feb	AB	17	62.8	17–76
Dec	ABC	17	60.6	37–97
Nov	ABC	14	52.6	31–76
Mar	BCD	22	30.8	1–59
Oct	CD	24	29.5	7–57
Sep	DE	14	12.3	0–31
Aug	DE	14	8.0	2–19
Jul	DE	12	5.2	1–15
Apr	DE	8	4.6	0–13
Jun[d]	E	7	2.0	0–7
May	E	13	1.3	0–5

[a] Months are ranked by average manatee count per survey to illustrate results of multiple comparisons. Manatee counts did not differ significantly among months followed by the same capital letter. Multiple comparisons were nonparametric rank-score tests (m rankings) adjusted for year effects performed at an experimentwise error rate of $P \leq 0.05$ (see Methods).

[b] Number of surveys summed over 4 years.

[c] Unweighted average for each month adjusted for unequal number of surveys per year. Monthly values are average of corresponding means from each of 4 survey years.

[d] No surveys were conducted in June 1979.

DISCUSSION

The spatial distribution of manatees in Kings Bay is influenced by several factors; most important is the location of artesian springs. The largest and earliest winter aggregations form in the warm-water area around the Main Spring (Fig. 2). Although November aggregations may be relatively diffuse, density around the Main Spring increases with the onset of colder weather. Smaller groups that develop at Magnolia Spring during January and February may be caused by human disturbance at the Main Spring (Hartman 1979:25). The low use of Tarpon Spring throughout the winter may relate to its smaller size and limited discharge. Other springs in the bay are associated with cul-de-sacs and narrow, shallow, or weed-choked passes; manatees generally avoid such conditions, especially in the presence of humans (Hartman 1979:36–41). Manatee use of specific sites may also be influenced by behavioral tradition (Bengtson 1981:100–102, Powell and Rathbun 1984), which may partially explain the

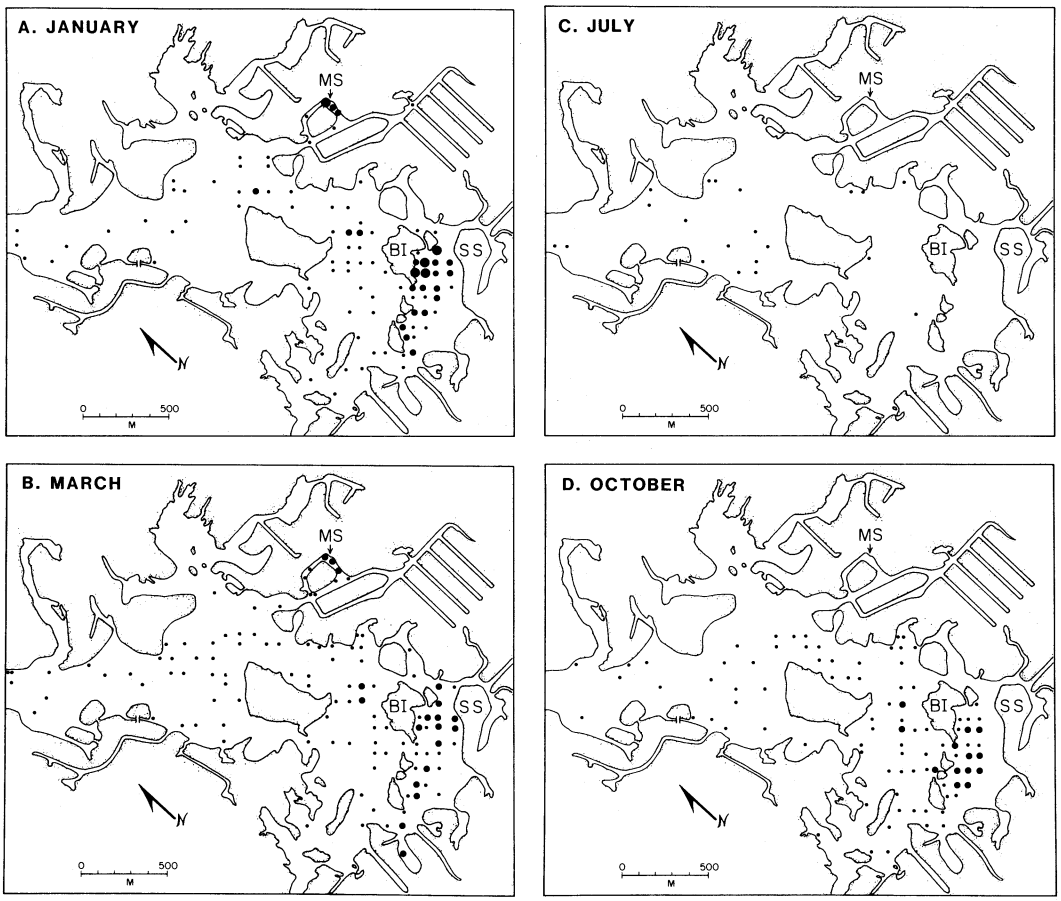

Fig. 2. Spatial distribution of manatees in Kings Bay during 4 representative months. Dot size represents average number of animals per survey at each location during all aerial surveys for the month (small = <0.5, medium = 0.5–4.5, large = 4.5–8.5). A = January 1978–80 (N = 11 surveys), B = March 1978–80 (N = 16 surveys), C = July 1978–80 (N = 10 surveys), D = October 1978–79 (N = 14 surveys). The Main Spring is located between Banana Island (BI) and Sunset Shores (SS). MS = Magnolia Spring.

consistent location of winter aggregations and avoidance of other potential aggregation sites. In March and October (Fig. 2), aggregations are generally not prominent and manatees may be dispersed throughout the bay, but relatively large aggregations can form in response to sudden cold weather. During spring and summer, the springs remain colder than surrounding bay waters and are usually avoided by the few animals present.

The seasonal distribution of manatees in Kings Bay corresponds to changes in Gulf coastal water temperatures (Hartman 1979:18–20). Wintering manatees are attracted to Kings Bay when nearshore and river waters become colder than the Kings Bay springs. Animals begin to leave the bay and disperse along the coast during March (Hartman 1979:29, Powell and Rathbun 1984) and gradually return in October. The seasonal use of Kings Bay by wintering manatees is similar to annual trends at other warm-water refuges in Florida (Powell and Waldron 1981, Shane 1983).

Although manatees appear to require unlimited access to warm water while wintering in Kings Bay, they frequently leave the springs and temporarily disperse to colder areas. Wintering manatees were routinely seen at feeding sites in colder water north of Banana Island (Fig. 2A) and have been reported from water as cold as 14–16 C (Hartman 1979:22–23, Shane 1981:68). Although the limits of manatee tolerance to cold are unknown, hypothermia appears to be a major cause of mortality in Florida

during unusually severe winters (O'Shea et al. 1985). Considering their large body size and corresponding thermal inertia, it is unlikely that manatees are stressed by brief exposure to cold water, as long as warmer areas are readily accessible (Irvine 1983).

Kings Bay is now crucial to the survival of manatees inhabiting the northwestern coast of peninsular Florida. A maximum aerial count of 97 manatees during the winter of 1980–81 implies an actual winter population exceeding 100 animals. With up to 10% of the U.S. manatee population (see Brownell et al. 1981) wintering in Kings Bay, the potential for catastrophic losses is apparent. Winter aggregations can be disrupted by adjacent human activity, such as boat traffic and SCUBA divers, dispersing the animals into colder water for prolonged periods of time (Hartman 1979:25–26, Powell 1981). The timing and location of human activities at Kings Bay and at other warm-water refuges in Florida (see Hartman 1974:13–28) should be coordinated with manatee distributions to minimize adverse impacts on vulnerable winter aggregations.

Acknowledgments.—We thank T. J. O'Shea and R. K. Bonde for reviewing an earlier draft of the manuscript and A. R. Brand for editorial assistance. M. J. Borcheller, T. E. Davis, and J. M. Evans piloted the aerial surveys.

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Received 21 May 1984.
Accepted 23 January 1985.