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Increases in Seasonal Manatee (*Trichechus manatus latirostris*) Abundance Within Citrus County, Florida

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Abstract

Identified as critical winter manatee habitat, the U.S. Fish and Wildlife Service (USFWS) has documented a significant increase in peak and average Florida manatee (*Trichechus manatus latirostris*) counts during the winter months in Citrus County and Kings Bay, Florida. Manatees use the warm 22º C spring-fed waters of Kings Bay when water temperatures drop below 20º C in the Gulf of Mexico. The USFWS manages winter manatee sanctuaries positioned over and near the bay's warm-water springs. Simple linear regressions of aerial survey data collected between 1983 and 2012 indicate that the peak counts for the survey period were 654 manatees occurring on 5 January 2012 in Citrus County and 566 manatees occurring on 13 January 2010 in Kings Bay. The average winter count has increased from 102 ± 5 (1983) to 216 ± 49 (2012) in Citrus County and from 73 ± 6 (1983) to 148 ± 41 (2012) in Kings Bay. Summer surveys were conducted consistently between 2004 and 2012. No significant change in peak or average manatee abundance was detected during this period. The increase in winter manatee counts prompted the need to review existing manatee protection measures, including manatee use within the sanctuaries. Additional analysis of habitat quality (i.e., salinity, plant community, disturbance caused by human recreation) on the abundance and distribution of manatees in the bay is needed to promote adaptive manatee management in the bay.

Key Words: Sirenian, Kings Bay, Citrus County, springs, aerial surveys, Florida manatee, *Trichechus manatus latirostris*

Introduction

West Indian manatees (*Trichechus manatus*) range from Brazil north to Mexico and the southeastern United States, including the Caribbean Islands. This species includes two subspecies: the Antillean (*T. M. manatus*) and the Florida (*T. M. latirostris*) manatee. The Florida manatee is found in the southeastern United States, with the core of its range in Florida (U.S. Fish and Wildlife Service [USFWS], 2011). Throughout the year, Florida manatees utilize a variety of habitats, including rivers, estuaries, and coastal areas. Although freshwater is preferred, manatees frequently use salt and brackish waters for travel and feeding (Husar, 1978; Hartman, 1979; Powell & Rathbun, 1984).

Florida manatees are sensitive to cold water temperatures and move to warm-water sites when the water temperature drops below 20º C (Reynolds & Odell, 1991). When exposed to cold water for extended periods of time, manatees are susceptible to death from cold stress (Buergelt et al., 1984; Bossart et al., 2002). Warm-water discharges from man-made power plants and factories provide artificial refugia; however, natural refugia are most commonly provided by warm-water springs (Husar, 1978; Hartman, 1979; Laist & Reynolds, 2005).

Even though the temperature of inshore waters of the Gulf of Mexico can fluctuate frequently throughout the winter months (Hartman, 1979), the temperatures of warm-water springs remain constant at 22º C (Scott et al., 2004). While many manatees may overwinter within particular warm-water refugia, some individuals move to and from foraging sites during warm spells throughout the winter (King, 2002). Citrus County, specifically Kings Bay and the Crystal and Homosassa Rivers, are the principal warm-water refugia for manatees on the central west coast of Florida (Hartman, 1974; Powell & Rathbun, 1984; Rathbun et al., 1990).

Manatee numbers increase in Citrus County waters during the winter months (October through March for this analysis). Manatees return to the same wintering sites year after year, displaying strong patterns of site fidelity to individual refugia

or regional networks of refugia (Reid et al., 1991; Rathbun et al., 1995; Langtimm et al., 2004). Almost 90% of those manatees that have been identified by scar patterns in the Crystal River area return each winter (Powell & Rathbun, 1984; Reid et al., 1991; Langtimm et al., 2004).

Historically, the manatee's winter range was Charlotte Harbor on the Gulf coast and Sebastian Inlet on the Atlantic coast (Moore, 1951). This more southern winter range was prior to the construction of power plants, which serve as artificial warm-water sites (Reynolds & Wilcox, 1994; Laist & Reynolds, 2005). Now manatees are using wintering sites even further north, with hundreds of manatees wintering in natural springs in Crystal River and a few dozen manatees wintering at Wakulla Springs (Butler et al., 2011).

During the summer months (April through September for this analysis), manatee movements are not limited by water temperatures (Rathbun et al., 1990; Langtimm et al., 2011). When the waters of the Gulf of Mexico warm, manatees disperse from thermal sites like Kings Bay, but late cold fronts can draw many manatees back into the warm springs. As food resources are depleted in and around thermal sites, dispersing manatees travel along the Gulf coast in search of aquatic vegetation to regain weight lost during the winter months. Manatees have been documented moving from Kings Bay north to the Suwannee River and to a lesser degree southward to Tampa Bay during the spring, returning to Kings Bay in the fall and winter months (Rathbun et al., 1990).

West Indian manatees, including both subspecies, were listed as an endangered species in 1967 under the Endangered Species Preservation Act (PL 89-669). The Florida manatee and its habitat are currently protected under the Endangered Species Act, as amended (ESA; Title 16 U.S. Code, Sections 1531-1544); the U.S. Marine Mammal Protection Act of 1972, as amended (MMPA; Title 16 U.S. Code, Section 1361); and the Florida Manatee Sanctuary Act (CH 370.12(2), F.S.). Under the Endangered Species Act, a Florida Manatee Recovery Plan was developed and implemented with measures which focus on expanding our knowledge of the species through sound science in order to make informed, meaningful management decisions. A Citrus County Manatee Protection Plan was developed to reinforce and assist in the implementation of the Florida Manatee Recovery Plan (Citrus County Department of Development Services [CCDDS], 1998).

As part of the efforts to recover the Florida manatee, the Crystal River National Wildlife Refuge (NWR) was established for the protection of the Florida manatee in 1983. Seven seasonal federal manatee sanctuaries are managed under the refuge, which protect 16.2 ha of thermal refugia and foraging habitat (Figure 1). These sanctuaries were created between 1980 and 1998 and are set aside for manatees, with no human activities, such as swimming, snorkeling, diving, boating, or fishing, permitted. Manatees in the bay are protected with a variety of boating speed zones (idle and slow speed), some of which are implemented only during the winter months and others which are effective throughout the year.

Additional manatee protections were added in 2012 when a federal manatee refuge designation was approved for Kings Bay to help prevent manatee deaths from boat strikes (USFWS, 2012), one of the leading causes of manatee mortality (Florida Fish and Wildlife Conservation Commission [FWC], 2012). The new manatee refuge rules clearly list 12 prohibited activities which further defined appropriate human–manatee interactions, reduced the size of the bay's summer 30 mph water sports zone, and reduced the number of days this increased speed limit is in effect (White & Barrett, pers. comm., 2012).

To fulfill endangered species management and recovery goals, two primary objectives were identified by USFWS (2001). The first called for an increase in the total population of the West Indian manatee, with a corresponding reduction in threats to the species. The second objective called for the establishment of optimum sustainable populations in natural habitats throughout the manatee's historic range in the United States. Aerial manatee surveys were initially designed to provide data on the distribution and abundance of Florida manatees along the northern Gulf coast of peninsular Florida to measure the success of these two population objectives.

The USFWS has continued these aerial surveys to fulfill the management needs of Crystal River NWR under the guidelines of the Florida Manatee Recovery Plan. Tasks within the plan include (1) to continue and improve aerial survey techniques and analyze data to evaluate fecundity and determine distribution patterns; (2) to establish and evaluate manatee management programs at protected areas; and (3) to maintain, improve, and develop tools to monitor and evaluate manatee habitat.

Manatee survey data are maintained by USFWS; however, they have been used by other groups, including nonprofit conservation organizations, local governments, and state agencies. Distribution and count data have been used to establish the seven federal manatee sanctuaries within Kings Bay and to implement state boating speed zones. Data have also been used by both state and federal agencies, and conservation groups when commenting on proposed docks and marinas.

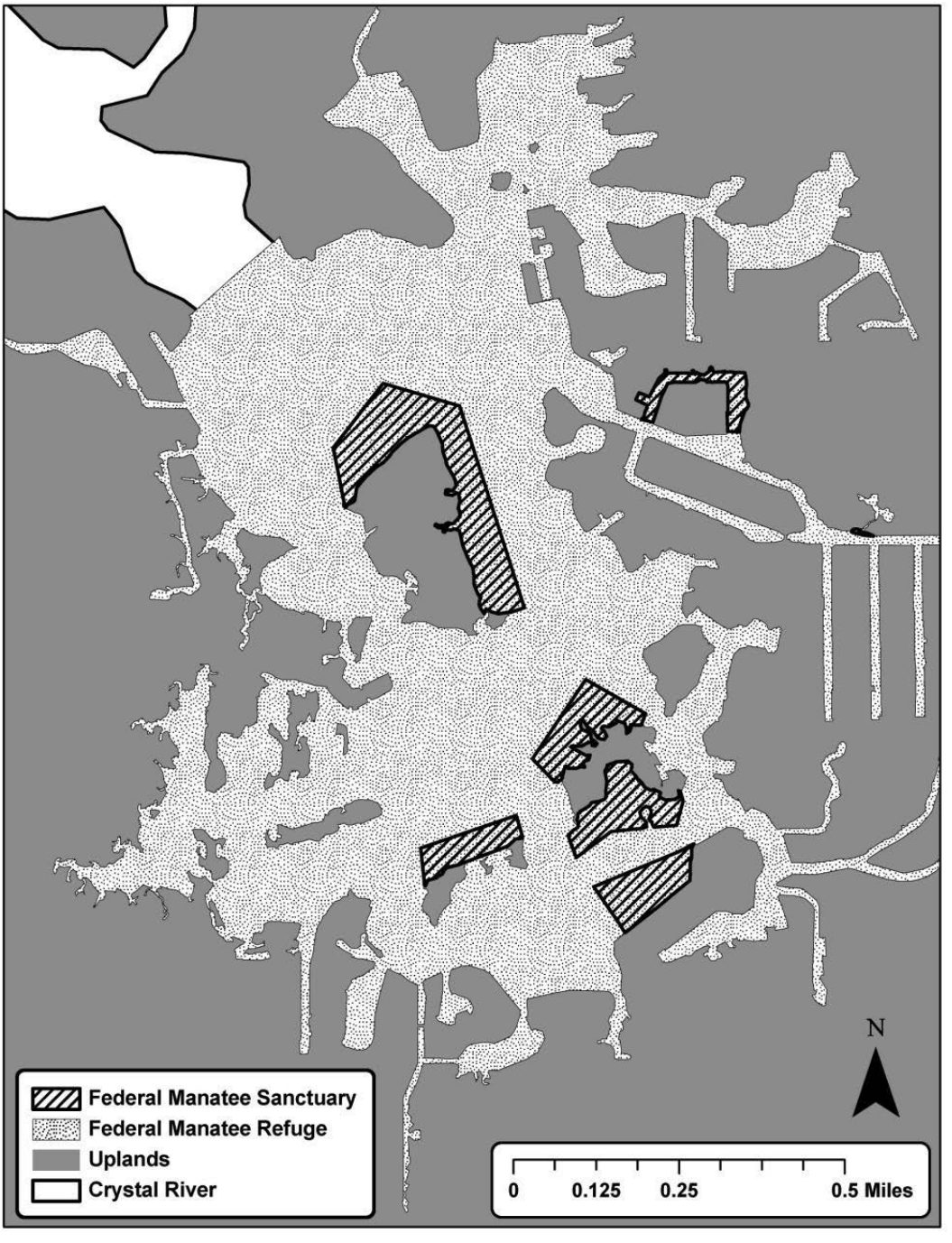

Figure 1. U.S. Fish and Wildlife Service (USFWS) manatee protection areas in Kings Bay, Citrus County, Florida

While the data have been useful in this capacity, results from these surveys have not been formally analyzed and made readily accessible to the general public and the scientific community since 1994 (Ackerman, 1995). The analysis of this long-term dataset will fill a significant gap in the understanding of manatee use of Citrus County and, more specifically, Kings Bay, Florida. In a time of

changing climate, increasing public use and ecotourism, and evolving manatee protections, survey data can facilitate discussion and development of protections for this endangered species.

Methods

Study Area

Located along the west coast of peninsular Florida approximately 104 km north of Tampa, Citrus County is characterized by several spring-fed rivers and creeks, freshwater bays, and brackish and saltwater marshes. Listed in order from northernmost extent south, the primary bodies of water surveyed include the Cross Florida Barge Canal, Crystal River nuclear power plant discharge canal, Crystal River, Kings Bay, Salt River, Homosassa River, and Chassahowitzka River. The coastal bays and waterways connecting these areas are also included in the survey. Winter warm-water refugia where manatees concentrate can be found at Duke Energy's Crystal River nuclear power plant discharge canal and the headsprings of the Homosassa River and Kings Bay (Hartman, 1979).

Kings Bay is located within the city of Crystal River, Citrus County, Florida, and forms the headwaters of the Crystal River, which flows 11 km to the Gulf of Mexico and provides bay access for manatees (Hartman, 1979). The bay is approximately 243 ha (Jones et al., 1998) and is fed by at least 70 warm-water springs (Rosenau et al., 1977; Flannery & Dewitt, 2009). The abundance of springs combined with high manatee use makes it the largest known natural thermal refuge for West Indian manatees (Hartman, 1979; Buckingham et al., 1999).

Aerial Surveys

Surveys were flown weekly or biweekly yearround using a Cessna 172 at an altitude of 304 m, traveling at 80 kts. Surveys were initiated between 0900 and 1100 h and averaged 1.7 h during the winter and 2 h in the summer, depending on the density of manatees present and the survey conditions. Variable survey start times are attributed to a minor change in the survey protocol in the 1980s and unfavorable survey conditions (e.g., ground fog, low cloud ceiling, etc.).

An experienced observer seated in the right-front seat of the aircraft plotted manatee locations on gridded maps with the density of animals at each location. The observer differentiated between calves and adult manatees when recording location data; calves were defined as approximately half the size or less of an adult in close proximity. The plane circled each area until the number of manatees counted remained constant or decreased. This methodology yielded a minimum count for the area (Packard et al., 1985). Where high densities of manatees occurred, photographs were taken, and later enlarged and viewed with the aid of a backlit table to verify the count.

The same flight path was flown on every survey, with minor deviations due to winds moving the plane off course. A variety of observers were used from 1983 through 1990. The same observer completed almost all of the surveys between 1990 and 2012. The same alternate observer was used during the entire survey period (1983 to 2012).

Additional data recorded during the surveys included date, survey start and end times, pilot and observer names, wind direction and velocity, percent cloud cover, air temperature, Gulf water temperature, tide height, and water clarity. Protocols for the survey conditions were limited to winds less than 17 kts/h, no precipitation, and no ground fog or cloud ceilings below 152 m.

Data Analysis

Winter survey data were collected between 1 October and 31 March from 1983 through 2012. These survey data could be compared since the survey protocol and frequency were consistent throughout the 29-y survey period. Average manatee counts were calculated for each winter season, and the peak count for each season was used to compare maximum observed counts across time. A simple linear regression was used to test the alternate hypothesis that maximum observed and average seasonal manatee counts have increased with time (y = number of manatees; x = time). All tests were considered significant where $p < 0.05$. This was done for both Citrus County and Kings Bay.

Analysis of summer survey data, 1 April to 30 September, was limited due to changes in the frequency of surveys. Although counts by refuge staff have been completed to document manatee use of the survey area since 1983, the frequency of summer surveys was neither standardized nor sufficient to allow for analysis until 2004. Therefore, summer survey data were analyzed only for 2004 through 2011. Data were analyzed using the methods described for winter manatee data analysis.

Survey conditions were also examined using descriptive statistics. A simple linear regression was used to assess the change in Gulf water temperatures and water clarity within the bay and the county. An analysis of water temperatures was only completed for the winter season because water temperature is not a limiting factor for manatees during the summer months. Water clarity data were analyzed for the entire survey period, with no distinction between survey seasons.

Results

Winter Manatee Counts

Citrus County—Winter manatee counts in Citrus County increased significantly between 1983 and 2012, with significant increases in both average and peak observed manatee counts (Average: t_{29} = 9.32, r^2 = 0.76, β = 0.86, $p < 0.001$; Peak observed: t_{29} = 12.12, r^2 = 0.84, β = 14.72, $p < 0.001$). Winter use was variable. Extremes observed during the survey period included a minimum of 12 and a peak observed count of 654, with an average of 190 ± 5 manatees (Figure 2a).

Kings Bay—Manatee counts within Kings Bay during the winter months were similar to that of Citrus County. Increases in average counts and peak observed use were both significant (Average: t_{29} = 6.46, r^2 = 0.61, β = 3.61, $p < 0.001$; Peak observed: t_{29} = 6.57, r^2 0.63, β = 10.41, $p < 0.001$). When surveys began in November 1983, peak observed manatee events involved an addition of approximately 50 manatees during extreme cold temperatures. Recent peak events are of a greater magnitude, with peak observed usage involving an influx of more than 100 manatees in addition to the average winter population. The average

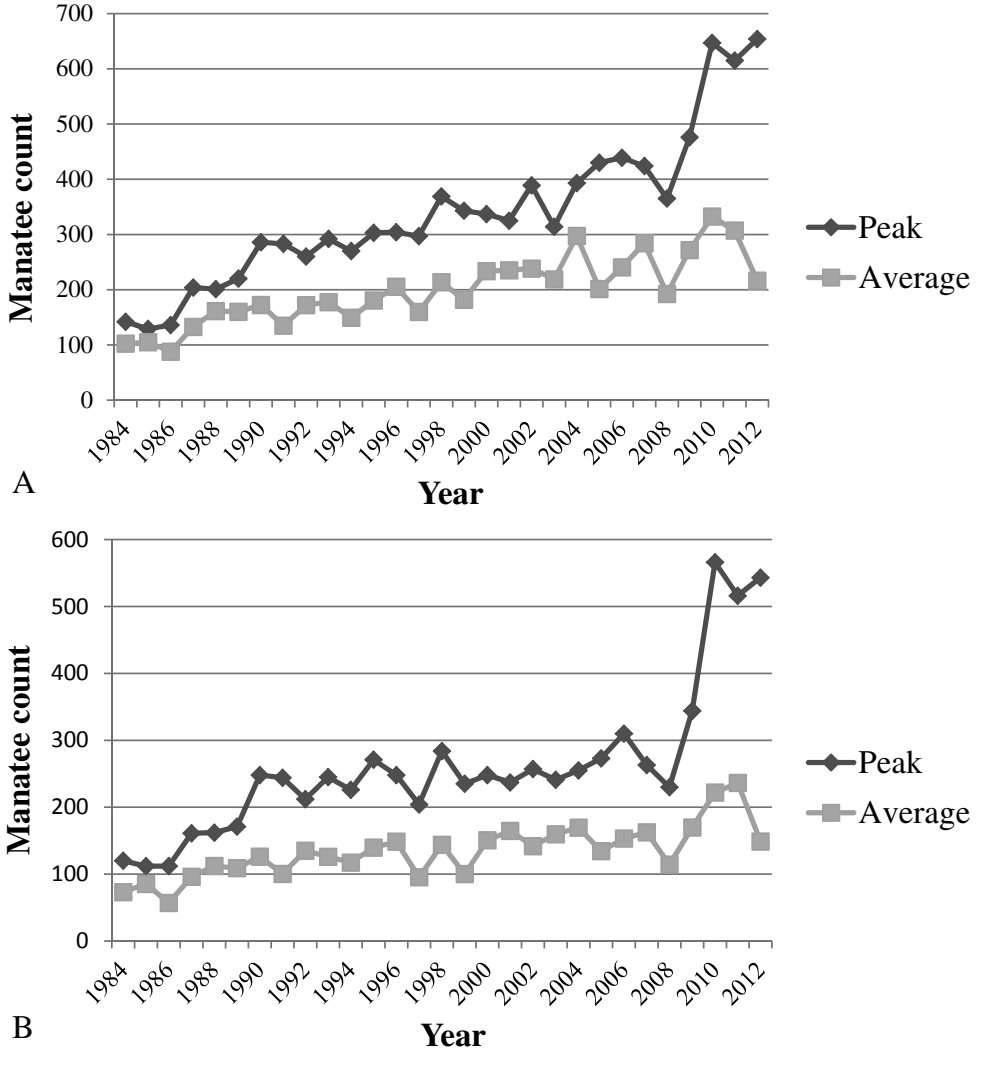

Figure 2. Peak and average manatee counts in winter from 1983 through 2012 in (A) Citrus County and (B) Kings Bay, Florida

annual count of manatees in winter was 129 ± 4, ranging from 5 to 566 animals (Figure 2b).

Summer Manatee Counts

Citrus County—Citrus County experienced no significant change in manatee counts during the summer months (Average: t_9 = -1.16, r^2 = 0.16, β = -1.44, p = 0.28; Peak observed: t_9 = -0.86, r^2 = 0.095, β = -2.50, p = 0.42). The average number of manatees observed throughout the 8 y of the survey was 61 ± 3 (Figure 3a). Observed manatee counts reached a peak of 188 and a minimum of 18 animals in the county.

Kings Bay—As with Citrus County, neither average nor peak observed manatee counts significantly increased in Kings Bay from 2004 to 2011 (Average: t_9 = -1.40, r^2 = 0.22, β = -1.34, p = 0.20; Peak observed: t_9 = -0.73, r^2 = 0.072, β = -0.52, p = 0.49). The annual peak number of manatees observed in Kings Bay during summer survey seasons averaged 75 ± 7 (Figure 3b). An average of 34 ± 2 manatees was observed within the 9 y of surveys, while as few as 11 and as many

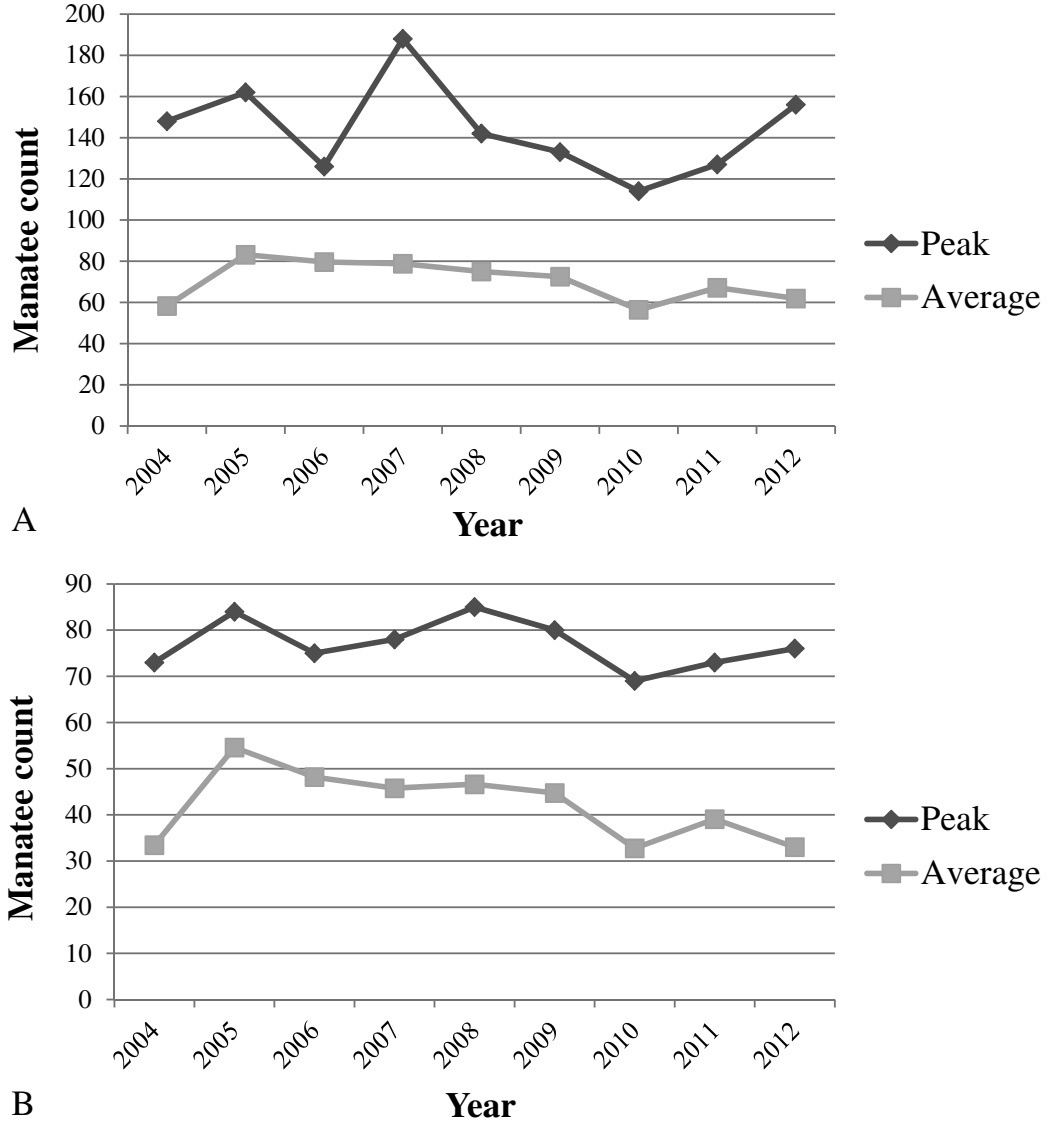

Figure 3. Peak and average manatee counts in summer from 2004 through 2012 in (A) Citrus County and (B) Kings Bay, Florida

as 85 manatees were recorded during the individual surveys.

Survey Conditions

Gulf of Mexico Water Temperatures—The annual minimum Gulf water temperature during the winter season has significantly decreased since surveys began in 1983 (t_{21} = -0.32, r^2 = 0.48, β = -0.17, p = 0.029). The minimum winter Gulf water temperature was 13° C in 1991 and 9° C in 2011, with a 29-y average of 13.3° C ± 0.48. The average Gulf water temperature within the winter season has not significantly changed over the 29 y of surveying (t_{21} = -0.11, r^2 = 0.088, β = -0.017, p = 0.70). The average winter water temperature in the Gulf was 19.06° C ± 0.20.

Water Clarity—Water clarity has not significantly changed over the 29-y survey period (t_{28} = -0.62, r^2 = 0.12, β = -0.081, p = 0.54). Average water clarity, ranked on a scale of 1 (poor) to 5 (excellent) in the survey protocol, was 2.38 ± 0.10 (fair to good) over the 29 y of surveying.

Discussion

Over a period of 29 y, Citrus County and Kings Bay, Florida, have experienced a continuous increase in manatee use during the winter months. Manatee sightings in the Crystal River area along the Gulf coast of Florida were documented as rare in the 1940s and earlier, prior to the establishment of federal manatee sanctuaries (Moore, 1951; Ackerman, 1995). Beginning in the 1960s, increases in the Crystal River population were documented by Hartman (1979), Powell & Rathbun (1984), O'Shea (1988), and Rathbun et al. (1990). Although there was a noted increase in the Crystal River manatee population throughout the 1960s (Hartman, 1974), the first aerial surveys to document manatees in this area began in 1967. Hartman (1979) identified a total of 63 different manatees in Kings Bay using scar patterns and a maximum of 38 manatees during the first season of aerial surveys in the winter of 1967-1968 (Hartman, 1974). By 1980, the wintering manatee population in the Kings Bay area increased to 99 animals (Powell & Rathbun, 1984); and in the winter of 2011-2012, similar aerial surveys documented 546 individual manatees within the bay.

Since 1967, except for three winter seasons from 1969 to 1971, aerial surveys have been conducted in the coastal waters of Citrus County, Florida, to determine the distribution and abundance of endangered Florida manatees (Powell, 1981; Kochman et al., 1985; Packard et al., 1986). USFWS began conducting aerial surveys in 1976; however, the protocol for data collection was not standardized until 1983 when Crystal River NWR was established for the protection of the Florida manatee. The continued monitoring of manatee distribution and abundance within the survey area is recommended by the USFWS Manatee Recovery Plan, which also details the required survey protocol (USFWS, 1990, unpub. report; USFWS, 2001).

Irvine & Campbell (1978), Shane (1981), Kinnaird (1985), and Packard et al. (1985) agreed that aerial surveys are considered to be the most accurate method of counting manatees, although some manatees are undoubtedly missed (Rathbun, 1988; Langtimm et al., 2011). Marsh & Sinclair (1989) documented two types of visibility bias: (1) perception bias (proportion of the target species present and visible in the survey area but not observed) and (2) availability bias (proportion of the target species present but not visible; Lefebvre et al., 1995). Another possible source of bias is that larger groups may have a higher probability of detection than smaller groups or individuals (Langtimm et al., 2011). Visibility may be reduced by a variety of factors, including deep and/or turbid water, ripples on the surface of the water, cloud cover which reduces the sun's penetration into the water, or full sun which can cause glare on the water's surface.

As USFWS has limited aerial survey data predating the current manatee protections (speed zones and sanctuaries), we assume that the continued increase in the Citrus County and Kings Bay population has paralleled the increase in manatee protections in the area. Protective provisions within the bay were initiated in 1980 with the establishment of the first three federal manatee sanctuaries within Kings Bay. Three years later, Crystal River NWR was established to provide habitat protection and staffing for the recovery of the Florida manatee population. Since then, local manatee protections have grown to include speed zones, winter manatee sanctuaries, and a special federal designation of a Kings Bay Manatee Refuge (50 C.F.R. 17.104) (USFWS, 2012).

Powell & Rathbun (1984) and Rathbun et al. (1990) suggest the increase in the Citrus County manatee population may have been a combination of local recruitment and immigration from areas further south. High levels of local recruitment are supported by population modeling (Langtimm et al., 2004). The northwest Florida population of Florida manatees, which includes Citrus County, has a higher growth rate than other parts of the species' range (Langtimm et al., 2004). This higher rate has been attributed to lower human impacts than in heavily developed areas in the southern parts of the state and Atlantic coast; manatee use of warm-water springs for overwintering sites; and the strong management efforts to protect the

manatee in this region (Langtimm et al., 2004). With higher reproduction and survival rates, an increase in manatee use of Kings Bay would again suggest that these provisions are creating a safer, higher quality habitat for manatees during the winter months.

Other factors which must be considered include habitat conditions outside of Kings Bay. This would primarily be the change in water temperatures in the Gulf of Mexico. Average Gulf water temperatures have not significantly decreased. With an average temperature of 19.06° C ± 0.20, it has remained cold enough during the winter seasons to move manatees into warm-water habitats. A notable relationship is the increase in peak observed manatee events occurring during the winter months. These might be related to the minimum Gulf water temperatures, which have significantly decreased from 13° C in 1991 to 9° C in 2011.

Hartman (1979) noted that even within the spring-fed waters of the bay, temperatures could vary by as much as 7° C between the King Spring (23.7° C) and the head of Crystal River and, on cold mornings, differences between the surface and bottom waters in the spring run could be as high as 5° C. If this still holds true, the importance of warm-water habitat would be increased today as temperatures can be significantly colder than at the time of that study. Hartman (1979) hypothesized that the surfacing and submerging of manatees had the potential to mix these cooler and warmer waters when several animals were present. If this was occurring it could have a significant effect on water temperature on days with extreme low temperatures as the sanctuaries and springs currently attract several hundred manatees at times.

Although the use of Kings Bay is largely attributable to warm-water springs, manatees were regularly observed in low densities in other county waters throughout the year. Manatee counts within Kings Bay have been shown to be proportional to the air temperature and, as the Gulf of Mexico's waters warm, manatees leave aggregation sites around springs and move to surrounding waters such as the Crystal and Salt Rivers in search of food and other resources not abundant within Kings Bay (Hartman, 1979; Kochman et al., 1985; Rathbun et al., 1990; King, 2002).

Quality foraging sites are found extensively along the coast of Citrus County, Florida. Hartman (1979) noted the Crystal River area's abundant food supplies may have resulted in a higher immigration rate compared to other winter sites, especially with the introduction of exotic vegetation in the mid-1960s. This is especially important because even with some of the sanctuaries providing protected foraging habitat within Kings Bay, food resources are noticeably depleted as the winter progresses and the density of manatees increases within the bay. Eventually, with the decline of exotic vegetation in Kings Bay, individuals initially attracted to the site for those food resources may remain due to site fidelity, loss of other quality wintering habitat, or more extreme winter temperatures.

Manatees have been frequently observed feeding in the waters adjacent to the salt marshes of the county. These marshes are very heterogeneous and include shallow coves, small lagoons, and tidal creeks (Hartman, 1979). Such areas provide important habitat for manatees throughout the year. Once the Gulf water temperature is high and stable enough to allow manatees to leave the bay for the summer, they disperse along the coast to utilize the rich food resources available. Without the restriction of cold water temperatures, manatees can travel long distances to forage during the summer. This migration away from thermal sites for food resources explains low summer counts. Although submerged aquatic vegetation is available within the coastal waters of Citrus County, manatees are not limited by water temperatures and, therefore, can travel to other areas of high-quality forage. Peak usage in Kings Bay during the summer months is typically due to late cold fronts, which can bring an influx of manatees returning to the springs during late spring and early summer.

Within Kings Bay and the Crystal River, food resources have likely experienced shifts in their abundance, variety, and distribution over the past 30 y. Salinity can significantly affect the plant community as some species of submerged aquatic vegetation are less salt tolerant than others (Hoyer et al., 2001; Frazer et al., 2006). An increase of salinity by two or three practical salinity units (psu) has been suggested as a threshold for causing significant reductions in plant biomass within Kings Bay (Hoyer et al., 2001). Frazer et al. (2001) documented bottom salinities ranging from 0.74 to 15.36 psu within 1 y of monitoring in Kings Bay, with a mean salinity of 2.1 psu. These levels suggest a long-term increase in salinity within the bay. Significant declines in total plant biomass could have resulted from such a shift (Frazer et al., 2001, 2006).

With increases in salinity in Kings Bay, gradual changes in the vegetation from fresh water tolerant plants (exotics like *Hydrilla verticillata*) to salt tolerant plants (exotic *Myriophyllum spicatum*) is also occurring (Frazer et al., 2001, 2006). This change in vegetation may be affecting the distribution and abundance of manatees within Kings Bay and Citrus County. Changes within the bay

could decrease the value of sanctuaries established within the last 30 y to provide food resources. A combination of record high manatee use and reduced vegetation could result in increased stress to wintering manatees that would force them to leave the safety of warm-water habitat to seek food resources in local rivers and the Gulf or remain in the springs at the risk of illness from lack of food. If total vegetation biomass does decline in Kings Bay, Crystal River, and other habitats within Citrus County, more manatees may disperse from the county during the summer months when they are not limited by cold temperatures. The effects of continued sea level rise on manatees and the continued increase in the salinity of Kings Bay and the associated coastal waters of Citrus County will need to be closely monitored.

We propose that increased manatee survival and population growth and increasingly severe winter events have led to the high winter manatee abundance in Kings Bay. Population growth has been observed to be at a higher rate in an area which includes Citrus County and Kings Bay as compared to other parts of the Florida manatee's range (Eberhardt & O'Shea, 1995; O'Shea & Ackerman, 1995; Runge et al., 2007a). While the numbers of manatees that utilize the resources of the bay continue to increase, they must not only compete with higher densities of manatees, but with increasing numbers of visitors and boaters as well. Even in the 1960s and 1970s, Hartman (1979) noticed the rarity of seeing a manatee free of propeller scarring in Citrus County and attributed a significant amount of manatee harassment to boats and divers, both of which have been shown to negatively influence manatees and increase their use of sanctuaries (Buckingham et al., 1999; King, 2002; King & Heinen, 2004). As the number of manatees continues to increase, so does the ecotourism demand within Kings Bay. Visitation to Crystal River NWR has increased from 100,000 people in 2004 to 150,000 in 2011 (I. Vicente, pers. comm., 2012).

Kings Bay and its associated waters are internationally recognized and continue to experience an increase in visitors for their unique value to ecotourism, which attracts snorkelers, scuba divers, paddlers, pleasure-boaters, photographers, and videographers (Buckingham et al., 1999). In 2011, dive shops reported guiding or renting equipment for watching and swimming with manatees to 93,099 tourists. Fifty-four percent of those visitors came during the winter manatee season (I. Vicente, pers. comm., 2012). Additionally, residents and tourists bring their personal watercraft to recreate in the bay throughout the year.

Warm-water springs appear to be the best natural winter habitat for Florida manatees in the northern two-thirds of Florida (Laist & Reynolds, 2005). With the importance of springs for wintering manatees strongly supported by the literature (Hartman, 1979; King, 2002; King & Heinen, 2004; Laist & Reynolds, 2005) and increasing demands on these natural resources, protection is critical. Laist & Reynolds (2005) identified only four warm-water springs with winter congregations of 50 or more manatees in Florida, many of which face reduced flow rates from increased demands on groundwater. Two of these four springs were in Citrus County, including the Kings Bay/Crystal River spring complex and the Homosassa Springs complex. Statewide survey data suggest that the population supported within Citrus County and the rest of the Big Bend coast (Dixie, Levy, Citrus, and Hernando Counties) may represent a significant proportion of the Florida manatee's population (Powell & Rathbun, 1984; Kochman et al., 1985; Ackerman, 1995).

A "core biological model" was developed by Runge et al. (2007a) to describe Florida manatee life history and predict future population dynamics using the best data currently available. The probability of extinction in the core biological model assessed the role of five threats to manatees: (1) watercraft-related mortality, (2) loss of warm-water habitat in winter, (3) mortality in water-control structures, (4) entanglement, and (5) red tide (Runge et al., 2007b). Watercraft-related mortalities were identified as having the greatest impact on manatee populations in Florida (Runge et al., 2007a). Runge and colleagues' (2007a) model predicted that the northwest region's population, which includes Citrus County, will increase over time until manatee carrying capacity in warm water is reached and then growth will slowly decline. A long-term population decline is predicted for the other regions.

The USFWS currently protects seven manatee sanctuaries, enforces idle and slow boating speed zones, and enforces the Kings Bay Manatee Refuge. The continuation of aerial manatee surveys within the survey area will be critical in monitoring the effectiveness of the new federal manatee refuge in Kings Bay. This unique federal designation is separate from the national wildlife refuge designation. Unlike a national wildlife refuge, the manatee refuge provides added protection for manatees not through the physical acquisition of habitat but by the designation of the public waters of Kings Bay as a manatee refuge, which are subject to more rigorous regulations for human–manatee interaction. These special regulations help clarify what constitutes harassment of this endangered species for swimmers, paddlers, and watercraft operators.

Further analysis of the existing data is needed to evaluate the current use of the seven sanctuaries. While the data have been internally analyzed and used in the creation of the new Kings Bay Manatee Refuge, the spatial distribution of wintering manatees within the bay should be examined to assess the effectiveness of the current sanctuary sizes and locations. Some sanctuaries may need to be relocated, such as Warden Key, as the distribution of resources utilized by manatees has changed. Evaluating the reason behind any shift in distribution of manatees from older sanctuaries (Warden Key) to newer sanctuaries (Three Sisters Springs) is also needed. For example, this shift may be due to an increase in salinity in Kings Bay and a movement of manatees to fresher waters or higher quality food resources.

Identified as critical winter manatee habitat, USFWS surveys have documented a significant increase in manatee use during the winter months in Kings Bay, Florida. We recommend a more detailed analysis of aerial manatee survey data, including the effects of altered habitat (i.e., salinity, plant community, and protected areas) and human recreation (i.e., boating, swimming, etc.) on the abundance and distribution of manatees in the bay to guide the recovery and conservation of this endangered species.

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