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DISTRIBUTION AND ABUNDANCE OF MANATEES ALONG THE NORTHERN COAST OF THE GULF OF MEXICO

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Abstract: A review of historical and recent records of manatee (*Trichechus manatus*) sightings along the coast of the northern Gulf of Mexico indicates that their numbers have declined in Texas, but increased in Louisiana and Mississippi. This is due to their extirpation in Mexico and dramatic increase along the southern Big Bend coast of northwestern peninsular Florida. The distribution of manatees along the southern Big Bend coast is related to their need for warm water and the distribution of fresh water and submerged aquatic and marine food plants. The spring-fed headwaters of Crystal and Homosassa rivers are important warm water winter refuges; nearly 90% of the same individuals return each winter. The estuaries and grass beds associated with these two rivers and the Suwannee, Withlacoochee, and Chasshowitzka rivers are the principal summer habitats. The Suwannee and Crystal rivers are "high-use" rivers, whereas the other three are "low-use" rivers. Low human-caused mortality, high fecundity, some immigration, and high site fidelity are responsible for the increasing numbers of manatees using the southern Big Bend coast. Since this region of Florida has experienced relatively little development compared with the rest of the state, the best long-term future for this endangered marine mammal in the United States lies along the southern Big Bend coast.

INTRODUCTION

West Indian manatees (*Trichechus manatus*) are distributed along the northern Atlantic coast of South America, the Caribbean coasts of South and Central America, and the Greater Antilles. Though generally tropical in distribution, they are also found in the more temperate climate of Florida (Husar, 1977), where they utilize natural and artificial warm water refuges to maintain thermal homeostasis during cold weather (Hartman, 1974; Rose and McCutcheon, 1980; Irvine, 1983; Shane, in press).

Most of the information on the biology of the West Indian manatee has been collected from winter aggregations in Florida (Moore, 1956; Hartman, 1979;

Bengtson, 1981; Shane, in press). There are few data available on manatees when they move away from these winter refuges. This paper is the result of eight years (1975-1982) of research and observations of manatees in the northern Gulf of Mexico (Fig. 1). Our major emphasis has been on the population of manatees found along the southern Big Bend coast of western peninsular Florida (Dixie, Levy, Citrus, and Hernando counties; Fig. 2). The manatees along this coast spend each winter in the natural warm water refuges of Crystal River and Homosassa River. Hartman (1979) was the first to study the winter aggregation at Crystal River in the late 1960's and early 1970's. Our study builds on his foundation, with additional information about the use of the northern Gulf of Mexico coast by manatees, including a discussion of their historical and recent distribution, habitat requirements, and movements.

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Figure 1. Northern Gulf of Mexico, depicting the three principal areas in this study: northwestern Gulf of Mexico, northeastern Gulf of Mexico, and southern Big Bend coast (between dashed lines). Numbers refer to locations and sources (Table 1) of manatee sightings along the northern Gulf of Mexico coast between the Rio Grande, Texas, and the Suwannee River, Florida.

METHODS

Aerial Surveys

Manatee distribution data, gathered from ground and aerial surveys conducted along the southern Big Bend coast of Florida during the late 1960's and early 1970's (Hartman, 1979; Powell, 1981), were used to determine the aerial flight paths followed between 1979 and 1982. Rivers, canals, and nearshore areas about 1 km from shore were surveyed by air every 2 weeks from April through October (Fig. 2). The Waccasassa River was not flown regularly since Hartman (1974) determined that manatees did not use the river, probably because of the extensive shoals associated with Waccasassa Bay. During the cold season (November through March) the flight path north of the Withlacoochee River was discontinued and more time was spent circling aggregation sites at Crystal River and Homosassa River. Summer and

Figure 2. Southern Big Bend coast study area, depicting counties (dashed lines), principal waterways, and aerial survey flight path (April through October). The flight path north of the Withlacoochee River was discontinued between November and March. CFBC = Cross Florida Barge Canal. FPC = Florida Power Corporation power plant.

winter flights were about 3 hours in duration. In addition to the long flights, short one hour surveys were flown over Crystal River and Homosassa river after the passage of cold fronts. Occasional surveys were flown as far north as the Steinhatchee River and south to the Anclote River during the warm months, but manatees were rarely seen beyond the Suwannee River or Chassahowitzka River. The aerial surveys were conducted from a single engine high-wing aircraft at altitudes between 160 and 250 m and airspeeds of 80-100 km/hr. A single observer sat in the front right seat with the door removed for better visibility.

Habitat Analysis

Aerial survey data collected during April through October from 1979 through 1981 were analyzed to determine summer habitat preferences of manatees. Each river was divided into riverine habitat, estuarine habitat, and marine habitat within about 1 km of its mouth (U.S. Fish and Wildlife Service, 1982; Fig. 3). The effects of habitat and river system on the frequency of manatee sightings were evaluated by treating the survey flights as experimental units in a repeated measures analysis of variance (Winer, 1971). Survey flights were nested within each of 3 years and completely crossed with each river and habitat. This design was analyzed as a year x river x habitat factorial, with repeated measures on the last two factors. The number of manatee sightings per flight in each river x habitat combination served as the dependent variable and was transformed to square-root scale ($\sqrt{\text{count} + 0.5}$) before analysis.

Since a preliminary analysis indicated an extremely significant river x habitat interaction ($P \leq 0.0001$), subsequent analyses of habitat effects were simplified to a series of separate

Figure 3. Three ecological regions associated with the principal waterways along the southern Big Bend coast.

year x habitat factorials for each river, with repeated measures on the habitat factor. Similarly, variation among rivers was evaluated by summing manatee sightings over habitats and analyzing the counts as a year x river factorial, with repeated measures on the river factor. To adjust for the unequal number of survey flights in each year, significance tests for main effects and interactions were based on a complete least-squares analysis, implemented through the Type III sums of squares reported by the GLM procedure of the Statistical Analysis System (Helwig and Council, 1979; Freund and Littell, 1981). Multiple comparisons were conducted as pairwise linear contrasts between the adjusted means of the three habitats and six waterways. The significance of each contrast was based on the Bonferroni *post hoc* criterion (Harris, 1975) at an experimentwise error rate of $P \leq 0.05$.

Individual Identifications, Radio Telemetry, and Sightings

Underwater and surface observations of manatees were conducted in Crystal River nearly weekly during the winter, occasionally in Homosassa River during the winter, and other rivers during the summer from 1977 through 1982. Underwater notes of manatee behavior were made on white plastic slates with a graphite pencil. Sketches of scars were made on standard outlines of manatees on the slates. Underwater photographs were taken with a 35 mm Nikonos camera with a 28 mm wide-angle lens and Kodak Ektachrome 200 transparency film (use of trade names does not imply U.S. Fish and Wildlife Service endorsement of products). Color prints (4 x 10 cm) were made from the slides that best illustrated each animal's identifying traits. The photographs and information from the field notes were assembled into a photographic identification and sighting catalog.

Permanent identifying marks on manatees include wounds, scars, and mutilations caused by boat propellers and skegs, and morphological peculiarities such as skin folds, wrinkles, and medial tail notches (Hartman, 1979). At least two different types of marks were used to positively identify an animal. Single gross mutilations were distinctive enough to identify certain individuals. White, unpigmented scar tissue gradually darkened to gray over time (Fig. 4A,B); the rate and extent of the darkening depended on the severity, size, and location of the wound and the salinity of the water (abrasions and lesions tend to heal faster in saltwater; Hartman, 1974; Brownell *et al.*, 1981). Epidermal scrapes and scratches did not persist more than one winter season and often disappeared within 3 months. Scar tissue resulting from lacerations over about 2

Figure 4. Distinctive features, including natural notches, nicks, and wounds caused by boat strikes, were used to individually identify manatees over long periods of time. A. Piety (CR 71♀), with newly inflicted propeller wounds in winter 1973. B. Piety's 1973 healed wounds, with grey and white scar tissue, in August 1983. C. The dorsal tail surface of CR 18 ♂, with a congenital medial tail notch and several distinct nicks, in February 1979. D. New nicks and white scars on the tail of CR 18 ♂ in November 1982.

cm wide, or cuts that penetrated more than 1.5 cm deep into the dermal layer, remained the longest. Gross mutilations were essentially permanent. Sex was used to aid in identification. Skin coloration was not sufficient for long-term identification because it often was masked with a coat of algae (*Lyngbya*, *Compsopagon*) or diatoms (*Sygnema*, *Navicula*) (Hartman, 1979).

The reliability of natural marks to identify individual manatees over long periods of time depended on several factors. The marks needed to be distinct and unambiguous. If there were no permanent mutilations or morphological peculiarities, then wounds or scars were used that would persist for at least two seasons, permitting an update of the photographic catalog while the marks were still recognizable. Many manatees in Crystal River were hit and scarred by boats every year so that continuous updating of the catalog was necessary to provide an unambiguous record of each individual. It was imperative to examine closely each photograph of a seemingly new animal to be sure that it was not a previously identified animal with new marks or scars (Fig. 4C,D).

Eleven manatees were tagged with radio transmitters between January 1980 and March 1982, four during the first winter, three during the second, and four during the last. Ten of the units were designed and built by Cedar Creek Bioelectronics Laboratory, University of Minnesota. Each transmitter package was a 27 x 5 cm cylinder with a 40 cm long stainless steel whip antenna covered with plastic. The transmitters were fastened by stainless steel hose clamps to a belt made of 0.5 cm thick and 2.8 cm wide rubberized nylon machine belting covered with latex rubber surgical tubing. The tubing was impregnated with clear G.E. silicone rubber to prevent the

belting from twisting (Bengtson, 1981). The estimated life of the transmitters was 1 year. The belt was secured around the caudal peduncle of approachable, free-ranging manatees with a 1-inch delrin snap buckle (Tufbuc, Fastex Closure Products). The buckles were attached to the belting with steel bolts and brass nuts, which formed a corrodible link. The two metals corroded away, releasing the package from the animal in about 7-9 months. In practice, all of the plastic buckles broke before the link corroded. The eleventh transmitter was made by AVM Instrument Co., and measured 18 x 6 cm, had a predicted 2-year life, and less power than the Cedar Creek units. In other characteristics, it was similar to the Cedar Creek models.

The frequencies of the transmitters were between 164 and 165 mHz. The radio receivers were 64 channel manual and scanning models constructed by Cedar Creek. Radio-tagged manatees were located by triangulation from a boat with a pole-mounted, hand-rotated yagi antenna or by a dual antenna system mounted on the wing struts of an aircraft (Bengtson, 1981). Manatees were radio-tracked during all aerial surveys after January 1980. Radio-tagging activities were carried out under Federal Wildlife Permits PRT2-4405 and PRT 2-8430.

Historical and recent information on manatee distribution was obtained from interviews and published literature. Sightings were solicited from the public between 1974 and 1979 by distributing posters and prepaid postcards along the Gulf coast from Florida to Texas.

Vegetation Analysis

Vegetation in Kings Bay (headwaters of Crystal River), Weeki Wachee Spring (Hernando Co.), Silver Spring (Marion Co.), and Alexander Spring (Lake Co.) was sampled once in August 1979

to compare the exotic dominated submerged vegetation of Kings Bay with spring runs that did not support any exotic plants. Ten sample plots, 30 m on a side, were chosen along the length of each spring run and 15 plots were chosen in Kings Bay (see Kochman, *et al.*, 1983). Each plot was randomly sampled 10 times. At each sample point, a staff with a sliding four-point cross, 1 m from tip to tip, was dropped to the surface of the vegetation (Osborne, 1981). The depth of water, height of vegetation, and species composition within 5 cm of the staff and the four points of the cross were measured at each sample point.

RESULTS

Manatee Distribution West of the Suwannee River

Historical Records

Before 1970, 15 records of manatee sightings, including 21 individuals, were reported along the coast from the Rio Grande, Texas to the Suwannee River, Florida (Fig. 1; Table 1). In Texas, Gunter (1941) reported one specimen from Copano Bay, one from Brazos, and another on the border of Louisiana in Sabine Lake. He presumed that these animals originated from Mexico. Two manatees were captured in the Rio Grande around 1914 and between 1911-1912 at least five manatees were

captured from the lower Laguna Madre for public display (Gunter, 1941). In Louisiana, one specimen was recovered from Calcasieu Lake in January 1929 (Lowery, 1974). There are no records known from Mississippi or Alabama before 1970. Mr. Silas Stearns (in True, 1884) stated that they occasionally were seen from Pensacola to New Orleans and had previously been more abundant. In 1880, Stearns saw a single animal in Santa Rosa Sound (Santa Rosa Co., Florida). Moore (1951) reported that the northern limit of the manatees' range on the western coast of Florida was Charlotte Harbor (Charlotte Co.). However, Moore had several confirmed sightings further north, including a butchered individual off Beacon Hill (Gulf Co.) and a sighting in the Wakulla River (Wakulla Co.). Hartman (1974) obtained several additional pre-1970 sightings from western Florida during his 1973 survey. These included four in Dixie Co., two in Wakulla Co., and one in Bay Co.

Recent Sightings

Since 1970, there have been 23 reports of manatee sightings from the northern Gulf of Mexico coast (Fig. 1; Table 1). One sighting in Texas was reported from Fish Pass near Corpus Christi (Nueces Co.) on 2 October 1979 (R.G. Whistles, pers. comm.). In Norco, Louisiana, a single adult was seen for

Table 1. Sources of manatee sightings from the northern coast of the Gulf of Mexico between the Rio Grande, Texas, and the Suwannee River, Florida, plotted in Figure 1.

Reference or Source	Sighting numbers reported in Figure 1		
	Pre 1970 Sightings	Post 1970 Sightings	Carcasses
True, 1884	8		
Gunter, 1941	1		3
Moore, 1951	10		
Lowery, 1974			4
Collard, <i>et al.</i> , 1976		7	
Gunter and Corcoran, 1981		5	6
Hartman, 1974, 1979	9	11	
Fish and Wildlife Service, Sirenia Project		2	

several days beginning on 8 April 1975 by employees at the Norco Shell Oil Plant. Another single animal was reported by Mr. Oscar Zeringue (pers. comm.) on 10 July 1976 in the Atchafalaya River Swamp, 7 km SW of Morgan City, Louisiana. A fisherman saw a manatee in water 14.6 m deep, 19 km west of Breton Island, Louisiana, on 4 July 1979 (Gunter and Corcoran, 1981).

In Mississippi, single sightings were reported on 31 December 1978 and 1 January 1979 in the Wolf River, near the Cueres Bridge. On 3 and 5 January 1979, single sightings were reported from the Gulfport Coast Guard Station and Gulfport Harbor, about 32 km by water from the Cueres Bridge sightings. A male manatee was captured by Sea World of Florida in Gulfport Harbor on 6 January 1979 (not 7 January 1979, as reported in Gunter and Corcoran, 1981). The captured animal was underweight and had difficulty breathing, so was taken to Sea World in Orlando, Florida, for recuperation (Federal Wildlife Permit PRT 2-3058; SWF-TM-901B, Beauraguard). The four sightings before the capture may represent more than one animal due to the distance (32 km) between the 1 January and 3 January records. According to Gunter and Corcoran (1981) single sightings were reported from the Pascagoula River, Mississippi, on 18 January 1979 and from the Gulf of Mexico south of Mississippi (Breton Island, Louisiana) on 4 July 1979. The seven sightings (including one confirmed by capture) from the vicinity of Mississippi indicate that there were at least two individuals in the area between December 1978 and July 1979.

Sixteen separate manatee sightings were made in the vicinity of Biloxi Bay, Mississippi, between 28 November 1979 and 19 January 1980 (G. Corcoran, pers. comm.). On 3 January 1980 a single female (230 cm long) was found dead on

Ship Island, Mississippi, 19.3 km south of Biloxi (Sirenia Project, salvage records; M-179). The cause of death was related to anorexia and probable cold stress. Three of the 16 sightings were made after the dead individual was found on Ship Island, indicating that there were at least 2 animals in the Biloxi Bay area. During this time the Gulf Coast Marine Laboratory initiated a local media campaign soliciting manatee sightings, which probably resulted in many sightings of only a few individuals. The most recent sighting was reported by a net fisherman, who caught and released a manatee about 1.8 m long near Graveline Bayou, Mississippi, on 3 December 1981 (G. Corcoran, pers. comm.; Gunter and Perry, 1983).

Based on reports and aerial surveys, the Suwannee River appears to be the present northern limit of the manatees' usual range on the Gulf coast of Florida. A sighting of a single animal was reported by Collard *et al.* (1976) from western Florida at Santa Rosa Sound (Santa Rosa Co.) on 30 June 1975. Manatees have been sighted between Panama City (Bay Co.) and the Suwannee River about three times a year (total 14) between 1976 and 1982: 3 in Bay Co., 4 in Gulf Co., 2 in Wakulla Co., 1 in Taylor Co., and 4 in Dixie Co.

The Manatee Population along the Southern Big Bend Coast

Recent History and Description of Study Area

Manatee distribution along the southern Big Bend coast has been affected by human activities and changes in coastal and fluvial habitats. During the late 19th and early 20th centuries, the Suwannee River was a major commercial shipping port for northern Florida (Vernon, 1951). The mouth was dredged to 2 m in 1909 to provide greater access to the river for large, deep-draft vessels.

However, due to the construction of railroads and highways, commercial traffic on the river has diminished and residential development and recreational boat traffic have increased.

Manatee Spring, 45 km from the mouth of the Suwannee River, apparently has been used as a "country swimming hole" since the late 1800's. Boats have been launched at the spring headwaters at least since the 1900's (Ellison Hardy, pers. comm.). The area was purchased by the State of Florida and incorporated into the state park system in 1949. Presently the park is used by the public for picnicking, swimming, and boating. The cement boat ramp near the headwaters and the wooden boardwalk leading down to the mouth of the spring were built in the mid-1950's.

The Withlacoochee River was dredged to 3 m in 1915 and, like the Suwannee River, was used heavily by commercial vessels in the early 1900's. Port Inglis was located at the mouth of the river and was a major port for the phosphate industry. The port no longer exists. The upper Withlacoochee River was dammed for hydroelectric power creating Lake Rousseau in 1907. The Florida Power Corporation (FPC) power plant at the present town of Inglis and the Tenneco petroleum storage facility located about 2.5 km downriver from the plant, were built in the early 1940's. Oil was delivered to both facilities by barges ascending the river. The power plant was closed in 1974, and oil deliveries to Tenneco were discontinued in June 1978.

The most dramatic changes to the coastline were caused by the construction of the FPC Crystal River power plant in 1957 and the Cross Florida Barge Canal (CFBC) between 1961 and 1968. The CFBC was designed to enable barges to cross Florida, thus avoiding the long trip around the peninsula.

However, the project was only partially completed when it was officially stopped in 1971. The 10 km long dredged canal from the lock at Lake Rousseau to the Gulf bisects the lower portion of the Withlacoochee River 14 km from its mouth. The water in the two sections of the river below the lake is controlled by spillways. The lower section is navigable from the mouth to a spillway near the lock, and the upper section is navigable from midway up the barge canal to the dam.

The FPC Crystal River power plant, located on the coast of Citrus Co. 5 km north of the mouth of Crystal River, contains two fossil fuel generating units and one nuclear unit. Two additional fossil fuel units are under construction. The cooling water for the plant is drawn through an intake canal on the southern side of the plant and discharged into a separate canal on the northern side. The intake canal also is used by ocean-going barges for delivery of coal. The spoil areas created by the dredging of the intake and effluent canals form a spit extending 12 km into the Gulf (Fig. 2). Two gaps were left in the spits, 5 and 6 km from shore, allowing small fishing boats to pass.

The mouth of Crystal River was dredged to 2 m in 1906 and Homosassa River was dredged to 1.5 m in 1936. Both rivers have been used by a small fishing fleet and recreation boaters for the past 30 years. Since 1960, the human population in Citrus County has increased considerably, resulting in both rivers being further modified with adjoining canal systems, cement bulkheads, dredging and filling, and numerous boat ramps and multi-slip boat marinas.

The most obvious change in the ecology of the Crystal and Homosassa rivers has been the introduction of exotic aquatic vegetation, principally *Hydrilla*

verticillata, *Myriophyllum spicatum*, and *Eichhornia crassipes*. *Hydrilla* and *Myriophyllum* erupted to noxious levels in the two rivers in the early 1960's (Hartman, 1979), supposedly after a Miami based aquarium industry planted the exotics. Attendant with the eruptions have been various attempts to control the weeds by several agencies and methods. Before the introduction of the exotic weeds, the headwaters of the two rivers were typical of artesian spring runs in Florida. They had clear, low nutrient water with mixed stands of plants such as *Vallisneria americana*, *Ceratophyllum demersum*, and *Najas guadalupensis* (A. Carr, pers. comm.). These plants formed widely spaced beds interspersed with extensive areas of clean white calcareous sand with no vegetation. Unfortunately, there are no quantitative data on the abundance and distribution of native aquatic plants in the Crystal and Homosassa rivers before the introduction of exotics. An estimate of the changes that may have resulted from the proliferation of the exotics was obtained by sampling the species composition and abundance of vegetation in Kings Bay and three springs similar to Kings Bay, but not infested with exotics (Weeki Wachee Spring, Silver Spring, and Alexander Spring). In Kings Bay, the dominant plant was *Hydrilla* (55% of the sample points). The dominant plant(s) in the Weeki Wachee was *Najas* (40%); Silver Spring, *Vallisneria* (35%) and *Sagittaria* (20%); and in Alexander Spring, *Vallisneria* (20%) and various algae (20%). The abundance of vegetation in each of the three "natural" spring runs was less than in Kings Bay. The proportion of the bottom covered by aquatic plants in Kings Bay was 81%, compared with a mean of 60% for the three natural springs. The proportion of the water column occupied by vegetation was about

Figure 5. The relationship between the proportion of the water column occupied by vegetation and the proportion of the substrate covered by vegetation in four Florida artesian spring runs sampled in August 1979. Silver Spring (S), Alexander Spring (A), and Weeki Wachee River (W) did not have exotic plants species. Crystal River (C) contains exotic introductions.

2.5 times greater in Kings Bay than the average for the other three springs (Fig. 5). These data indicate that the standing biomass of aquatic vegetation in Kings Bay may have increased due to the presence of exotic forms, especially *Hydrilla*.

Historical Records

There are few records of manatees using the coast from the Suwannee River south to the Chasshowitzka River before the mid-1900's. Bartram (1791) reported that manatees used Manatee Spring on the Suwannee River during the winter in the mid-1770's. A single specimen in the U.S. National Museum (USNM 22773) was collected in the Homosassa river in 1879. Historical accounts written by sportsmen visiting the Crystal and Homosassa rivers on fishing and hunting expeditions in the late 19th and early 20th centuries make no mention of manatees (Hallock, 1876). These accounts included detailed and illustrative descriptions of the local wildlife and fish seen in the clear spring runs. Since the sportsmen usually visited these areas during the winter, and the articles were

written to lure their cohorts to Florida, presumably they would have mentioned anything as unusual as a manatee, but they did not. Moore (1951) found only a single record of a manatee in the Crystal River area and two other reports around 1950 from the Suwannee River. Dr. Paul G. Pearson and Mr. Kirk Strawn (in Moore, 1951) reported that Cedar Key was outside the manatee's range. Layne (1965) mentioned a single sighting in the Withlacoochee River in 1962 and Mr. Thomas Knotts (pers. comm.), whose family founded the fishing village of Yankeetown on the Withlacoochee River, first began to see manatees in the river around 1960. He could not remember anyone discussing their presence before that time. Based on discussions with local fishermen, guides, and residents, Hartman (1979) suggested that manatees began commonly using the headwaters of Crystal River and Homosassa River in the early 1960's.

The Crystal River and Homosassa River Thermal Refuges

The present abundance and distribution of manatees along the southern Big Bend coast is markedly different than that of 20 years ago. Manatees are now commonly seen along the coast, from the Suwannee River to the Chassahowitzka river, but their temporal distribution is associated closely with the seasons (Fig. 6). When the summer water temperatures of the Gulf (ca. 32°C) drop below about 20°C in the fall, manatees begin to move into the spring-fed headwaters of Crystal River and Homosassa River, where the water is a constant 23.5°C (Fig. 6 C,D). Large numbers remain in these winter refuges until dispersing along the Gulf with the onset of spring (Kochman *et al.*, 1983).

The total number of manatees using

Figure 6. Mean number of manatees seen in the Suwannee (A), Withlacoochee (B), Crystal (C), Homosassa (D), and Chassahowitzka (E) rivers during coastal surveys from January 1979 through December 1981. The Suwannee River was dropped from the surveys during November through February and not all rivers were flown equally. Vertical bars are monthly ranges of sightings in each river.

Crystal River as a refuge has increased markedly over the last 15 years. The largest aggregation counted on aerial surveys during the winter of 1967-68 was 38 (Hartman, 1979), whereas the 1981-82 maximum winter count was 116, a 205% increase (Table 2). The annual relative rates of increase over 5 consecutive years (aerial surveys beginning in 1977-78) were 2.5, 8.7, 13.8, and 17.2%, with an average of 10.5%. Although the percent growth rates have increased over 5 years, the relative differences between

Table 2. Winter manatee counts in the Homosassa River and Crystal River based on aerial surveys and individual identifications. A = flights flown during cold fronts, B = intermittent flights, C = flights flown twice a month, and D = flights flown at least weekly.

Season	Aerial survey maxima			Flight frequency	Individuals identified at			
	Homosassa	Crystal River			Crystal River			
	River	Calves	Total		Males	Females	Calves	Total
1967-68	8 ⁽²⁾	--	38 ⁽¹⁾	A	25 ⁽¹⁾	25 ⁽¹⁾	--	50
1968-69	--	--	44 ⁽¹⁾	A	23 ⁽¹⁾	25 ⁽¹⁾	--	48
1972-73	12 ⁽¹⁾	--	45 ⁽³⁾	A	16 ⁽³⁾	18 ⁽³⁾	4 ⁽³⁾	38
1973-74	18 ⁽¹⁾	--	44 ⁽³⁾	B	--	--	--	--
1974-75	--	--	47 ⁽³⁾	B	--	--	--	--
1975-76	--	--	51 ⁽³⁾	B	--	--	--	--
1976-77	--	--	37 ⁽³⁾	C	19 ⁽³⁾	20 ⁽³⁾	10 ⁽³⁾	49
1977-78	11	9	78	D	33 ⁽³⁾	43 ⁽³⁾	10 ⁽³⁾	86
1978-79	29	8	80	D	40	44	7	91
1979-80	16	10	87	D	32	49	8	89
1980-81	24	13	99	D	42	51	15	108
1981-82	20	10	116	A	35	45	12	92

(1) = Hartman, 1979.
(2) = Hartman, 1971.
(3) = Powell, 1981.

the yearly rates have decreased (mean = 1.4% per annum), indicating that the population is approaching a constant relative rate of increase. The number of reproductively active females identified in the population between 1976 and 1982 was high (35) as was the average annual percentage of calves (12.8%; Table 2). Many of the same manatees return to Crystal River each winter, and at least

six individuals have used the river for 14 years. The mean return rate for the four winters between December 1978 and March 1982 was 88.9%. Females had a greater average return rate (88.3%) than males (81.7%; Table 3). The high return rate suggests strong traditional use, which results in a fairly consistent and discrete group using Crystal River. The sex ratio of all manatees iden-

Table 3. Number and sex of individual manatees identified during winter season in Crystal River and yearly return rates. Percentage of total animals identified are in parentheses. Data do not include first year calves.

Season	Sex	Returns from previous year	Returns from any previous year	Newly identified	Total identified (column 2 + 3)
1978-79	♂	30	30	10	40
	♀	34	36	8	44
	Total	54 (73.0)	66 (89.2)	18 (24.3)	84
1979-80	♂	25	28	4	32
	♀	41	41	8	49
	Total	66 (81.5)	69 (85.2)	12 (14.8)	81
1980-81	♂	28	33	9	42
	♀	45	46	5	51
	Total	73 (78.5)	79 (84.9)	14 (15.1)	93
1981-82	♂	27	33	2	35
	♀	41	44	1	45
	Total	68 (85.0)	77 (96.3)	3 (3.8)	80

Table 4. Manatee sightings at Manatee Spring State Park. No corrections made for observation effort. Sightings were normally in the Suwannee River, at the mouth of Manatee Spring Run.

Date	Total Number	Number of Calves	Individual Identification Number	Date	Total Number	Number of Calves	Individual Identification Number
9 Apr 1976	1			7 Aug 1982 a.m.	2		
10 Apr 1976	2			7 Aug 1982 p.m.	4		
6 Jul 1976	2		CR 71♀	8 Aug 1982	4		
17 Jul 1976	6			9 Aug 1982 a.m.	2		
18 Jul 1976	2			10 Aug 1982 a.m.	2		
13 Dec 1977	3	2		10 Aug 1982 p.m.	3		
31 Jan 1980	1			11 Aug 1982 a.m.	2		
11 Mar 1980	1			11 Aug 1982 p.m.	4		
30 Oct 1980	2	1		12 Aug 1982	2		
7 Nov 1980	2	1		15 Aug 1982	2		
12 Nov 1980	2	1		16 Aug 1982 a.m.	1		
16 Nov 1981	1			16 Aug 1982 p.m.	2		
2 Jan 1982	1			17 Aug 1982 a.m.	2		
18 Feb 1982	3			17 Aug 1982 p.m.	2		
29 Mar 1982	1			26 Aug 1982	2		
12 Apr 1982	3		CR#s 71♀, 104♀, 46♀	10 Sep 1982	5	1	
13 Apr 1982	3		CR#s 71♀, 104♀, 46♀	11 Sep 1982 p.m.	5		
14 Apr 1982	3		CR#s, 71♀, 104♀, 46♀	11 Sep 1982 p.m.	2		
31 Jun 1982	3			11 Sep 1982	4		
12 Jul 1982	2			12 Sep 1982	2		
13 Jul 1982	2			13 Sep 1982	2		CR 71♀
14 Jul 1982	3		CR 71♀	14 Sep 1982	2		
16 Jul 1982	3			15 Sep 1982 a.m.	2		
17 Jul 1982 a.m.	3			15 Sep 1982 p.m.	3		
17 Jul 1982 p.m.	3			17 Sep 1982 a.m.	2		
18 Jul 1982	2			17 Sep 1982 p.m.	2-3		
19 Jul 1982 a.m.	3			20 Sep 1982 a.m.	2		
19 Jul 1982	2		CR 71♀	20 Sep 1982 p.m.	1		
22 Jul 1982	3			21 Sep 1982	1		
23 Jul 1982	1			22 Sep 1982	3	1	CR 22♀
28 Jul 1982	3			25 Sep 1982	2		
2 Aug 1982	6	1		26 Sep 1982	2		
3 Aug 1982 a.m.	5			30 Sep 1982	4		
3 Aug 1982 p.m.	1			1 Oct 1982 a.m.	2		
3 Aug 1982 p.m.	2			1 Oct 1982 p.m.	3		
4 Aug 1982 a.m.	2		CR 71♀	2 Oct 1982	2		
4 Aug 1982 p.m.	2			14 Oct 1982	1		
5 Aug 1982	2			18 Oct 1982	2	1	
6 Aug 1982 a.m.	2-4						
6 Aug 1982 p.m.	2-4						

tified in Crystal and Homosassa rivers during six winters (1976-77 through 1981-82) was 1:1.02. However, the average yearly sex ratio for the six winters was 1:1.35. During any single winter, some males did not return, which resulted in more females using the refuge than males each winter.

Other Thermal Refuges

Six other sites besides Crystal and

Homosassa rivers have been identified along the southern Big Bend coast of Florida as winter refuges. These sites are not used continuously by manatees throughout the winter and appear to be only temporary sanctuaries. Manatees have been sighted sporadically in all seasons in Manatee Spring (Table 4). On 12 April 1982 three animals were identified in the run for 3 days during cool weather. Two (CR 71 ♀ and CR 104♀) were

Figure 7. Monthly mean number of manatees seen in the effluent of the Florida Power Corporation Crystal River power plant during aerial surveys ($n = 50$) conducted from January 1979 through December 1981. Vertical bars are monthly ranges.

last seen in Crystal River on 9 March 1982 and two (CR 71 ♀ and CR 46 ♀) were in late pregnancy. One of the animals (CR 104 ♀) was the four-year-old daughter of CR 71 ♀.

There is a small seep in the CFBC at the Inglis Lock, and manatees were reported using the seep in 1976 by the Inglis lockmaster. A manatee was seen in Rainbow River, a spring-fed tributary of the Withlacoochee River, during an aerial survey on 31 December 1976. To gain access to this site, it had to travel up the CFBC, through the Inglis lock, across Lake Rousseau, and up the Withlacoochee River past Dunnellon to the mouth of Rainbow River. It is possible that this animal was trapped above the Inglis Lock during winter.

Manatees use the FPC Crystal River power plant effluent during cool weather, but only for short periods of time, usually in the spring (Fig. 7). A single animal was reported using the headwaters of Chassahowitzka River during the winters of 1978 and 1979. In 1980 several manatees were reported in Jenkins Creek, a small spring-fed creek 6 km south of Weeki Wachee Spring, Hernando Co. There may be other temporary refuges along the southern Big Bend coast that have not been documented.

Summer Distribution and Ecology

Little information exists on the spring dispersal routes and destinations of known individuals from the Crystal River and Homosassa River winter refuges. Outside of these two rivers, 29 identifiable manatees have been located on 41 occasions. Seventeen sightings were from the Suwannee River, 18 from the Withlacoochee River, four from the Chassahowitzka River, and two from other areas (Table 5). All of the sightings were made from April through September 1976 through 1982. Radio-tagged animals could only be located when they ascended freshwater rivers due to salt-water attenuation of radio signals.

On 31 January 1980 a large male (CR 108 ♂; Gus) was tagged in Crystal River, where he had been seen during the previous six winters. He was last seen in the river in March. On 14 July 1980 his radio belt was found washed ashore at Bowman's Beach, on the Gulf of Mexico side of Sanibel Island, Lee Co., Florida. The plastic belt buckle had broken, but the transmitter was still functioning. Sanibel Island is over 300 km south of Crystal River and there are no currents that could have transported the negatively buoyant package there. It is likely that the animal lost its tag off Bowman's Beach on one of the submerged tree snags that are present (pers. obs.). On 24 November 1980, the male was again seen in Crystal River.

Several manatees have been sighted during spring and summer aerial surveys near the boat gap in the FPC power plant spit, and two were seen passing through the gap. One was seen traveling towards Cedar Keys on a straight line from Turtle Creek Point, about 11 km north of the Withlacoochee River (Fig. 8). At least one manatee (possibly two) was reported in the summer of 1976 about 8 km offshore of the Withlacoochee River, heading on a

Table 5. Manatees identified or radiotagged in Crystal River or Homosassa River that were found outside of these winter refuges between April and September. Eleven animals were radiotagged between January 1980 and April 1982. The number of sightings are given with the number of individuals involved in parentheses. There was no correction for search/observation effort.

Year	Location				Total
	Suwannee River	Withlacoochee River	Chassahowitzka River	Other	
1976	1 (1)	0	0	0	1 (1)
1977	0	1 (1)	0	0	1 (1)
1978	1 (1)	4 (3)	2 (1)	1 (1) ^{1/}	8 (6)
1979	0	0	1 (1)	0	1 (1)
1980	1 (1)	11 (7)	1 (1)	1 (1) ^{2/}	14 (10)
1981	3 (3)	2 (2)	0	0	5 (5)
1982	11 (5)	0	0	0	11 (5)
Total	17 (11)	18 (13)	4 (3)	2 (2)	41 (29)

^{1/} Cross Florida Barge Canal, Citrus Co.

^{2/} Sanibel Island, Lee Co.

straight course towards Cedar Keys (J.C. Dickinson, pers. comm.). When animals move north from Crystal River, they pass through the boat gap in the FPC spit and then either head directly towards Cedar Keys, or travel along the coast, passing near the Waccasassa River. From Cedar

Keys they probably move along the coast to the Suwannee River.

In February 1980, a radio-tagged manatee (CR 108 ♂, Gus) was followed at night during a high tide from Crystal River to within 6 km of Homosassa River, via Salt River. By dawn the next day, he had returned to Crystal River. We have never seen manatees offshore between Crystal River and Homosassa River (Fig. 8), indicating that they use the Salt River to travel between the two rivers. Battle Creek connects Homosassa River and Chasshowitzka River, but even at high tide it is too shallow for manatees to navigate. They probably travel offshore between the two rivers.

During the warm months (April through October), manatees disperse from the winter refuges and concentrate near and in the major waterways of the southern Big Bend coast, including the Suwannee River, Withlachoochee River, CFBC, Crystal River, Homosassa River, and Chassahowitzka River (Fig. 6). Based on summer aerial survey counts from 1979 through 1981 there was a significant difference ($P = 0.0001$) in manatee counts between the six waterways and these differences were consistent during the 3 years ($P = 0.83$). The frequency of sightings averaged significantly higher in

Figure 8. Manatee sightings greater than 1 km from a river mouth along the southern Big Bend coast. Data compiled from all aerial surveys from January 1978 through March 1981. Open circles = 1-2 sightings. Closed circles = 3-5 sightings. SW = Suwannee River. CR = Crystal River.

Table 6. Comparison of manatee aerial survey counts among six waterways on the southern Big Bend coast of Florida from April through October, 1979 through 1981.

River	Unweighted mean $\bar{y}$	Minimum count	Maximum count
Suwannee River	11.1 ^a	0	33
Withlacoochee River	2.6 ^b	0	20
Cross Florida Barge Canal	0.3 ^b	0	3
Crystal River	14.0 ^a	0	58
Homosassa River	2.3 ^b	0	15
Chassahowitzka River	2.4 ^b	0	8

^aMean number of manatees per flight per year averaged over 3 years ($n = 37$ flights). Means with same superscript are not significantly different ($P > 0.05$). Statistical analysis based on square root scale. Data presented in arithmetic scale.

Crystal River and Suwannee River than in the other rivers and the CFBC ($P < 0.05$), resulting in low-use and high-use systems (Table 6). The mean number of manatees that used the Suwannee River and Crystal River during the summer was not significantly different ($P > 0.05$), although the monthly pattern in each river was distinct. Manatees used the Suwannee River heavily all summer, whereas Crystal River was used mostly during late summer (Fig. 6). The Homosassa River was similar to the Crystal River pattern of use, whereas the Withlacoochee and Chassahowitzka rivers were more similar to the Suwannee (Fig. 6).

Based on an ANOVA of data gathered during aerial surveys of the southern Big Bend coast from April through October 1979 through 1981, the frequency of manatee sightings in river, estuarine, and marine habitats in each of the five river systems (CFBC is not included) was significantly different ($P < 0.05$, Table 7). The pattern of habitat use between rivers also was different, as indicated by the significant river $\times$ habitat interaction ($P \leq 0.0001$) of the preliminary analysis. The year $\times$ habitat interaction was not significant ($P > 0.12$) for all rivers except the Chassahowitzka River ($P = 0.038$). Yearly variation also was not significant ($P > 0.25$).

Manatees in the vicinity of the Suwannee River were seen principally in large groups at the mouths of North Pass, West Pass, and East Pass (Fig. 9) feeding on beds of *Ruppia maritima* that grow on sandbars adjacent to channels.

Figure 9. Manatee sightings in the Suwannee River and within 1 km of its mouth. Data compiled from all aerial surveys from January 1978 through March 1981 ($n = 36$). A = North Pass. B = West Pass. C = East Pass.

In the Withlacoochee River they were seen frequently feeding on *Ruppia* or *Halodule wrightii* growing on sandbars adjacent to the main channel at the river's mouth and just offshore of the mouth (Fig. 10). They also were seen

Table 7. Comparison of manatee aerial survey counts among three habitats within five rivers on the southern Big Bend coast of Florida from April through October, 1979 through 1981.

River (No. flights)	Habitat	Unweighted mean ^y	Minimum count	Maximum count
Suwannee (38)	Estuarine	10.2 ^a	0	33
	Riverine	1.1 ^b	0	7
	Marine	0.1 ^b	0	1
Withlacoochee River (39)	Estuarine	1.4 ^a	0	14
	Riverine	1.2 ^{a,b}	0	8
	Marine	0.4 ^b	0	7
Crystal River (38)	Riverine	10.6 ^a	0	57
	Estuarine	3.1 ^b	0	11
	Marine	0.3 ^c	0	5
Homosassa River (38)	Riverine	2.0 ^a	0	15
	Estuarine	0.3 ^b	0	7
	Marine	0.03 ^b	0	1
Chassahowitzka River (38)	Estuarine	1.8 ^a	0	8
	Riverine	0.6 ^b	0	5
	Marine	0.02 ^b	0	1

^yMean number of manatees per flight per year averaged over 3 years. Means with same superscript are not significantly different ($P > 0.05$). Statistical analysis based on square root transformation. Data presented in arithmetic scale.

resting and feeding in the vicinity of Bird Creek and in the area where the dredged residential canals at Yankeetown meet the river (Fig. 10). Few sightings were made in the Withlacoochee River

Figure 10. Manatee sightings in the lower Cross Florida Barge Canal, lower Withlacoochee River, and within 1 km of the river's mouth. Data compiled from all aerial surveys from January 1978 through March 1981 ($n = 46$). A = mouth of Withlacoochee River. B = Bird Creek. C = Yankeetown.

Figure 11. Manatee sightings in the upper Cross Florida Barge Canal and upper Withlacoochee River. Data compiled from all aerial surveys from January 1978 through March 1981. ($n = 46$). A = U.S. Highway 19 bridge over the Withlacoochee River. B = Upper Cross Florida Barge Canal. C = Canal boat lock. D = Dam on the Upper Withlacoochee River and Lake Rousseau.

between Yankeetown and the CFBC, in the CFBC itself, in the Withlacoochee River between the CFBC and Lake Rousseau (Fig. 11), or the FPC intake canal (Fig. 12). The distribution of sightings in the lower reaches of Crystal River was influenced greatly during the spring and fall by the large number of

Figure 12. Manatee sightings in the Florida Power Corporation Crystal River power plant (A) intake and discharge canals. Data compiled from all aerial surveys from January 1978 through March 1981 ($n = 46$).

Figure 13. Manatee sightings in the Crystal River and within 1 km of its mouth. Data compiled from all aerial surveys from January 1978 through March 1981 ($n = 48$). Sightings in Kings Bay (D, upriver of dashed line) are too numerous to be plotted (see Kochman *et al.*, 1983). A = North Pass at mouth of Crystal River. B = The Rocks. C = Confluence of Crystal and Salt rivers. D = Kings Bay.

Figure 14. Manatee sightings in the Homosassa River and within 1 km of its mouth. Data compiled from all aerial surveys from January 1978 through March 1981 ($n = 46$). Sightings in headwaters (C) are too numerous to be plotted (see Table 2). A = Mouth of Homosassa River. B = Confluence of Homosassa and Salt rivers. C = Homosassa River headwaters.

animals coming and going from Kings Bay. Manatees frequently used those areas of the river that had vegetated, shallow shelves or sandbars next to a channel, such as the *Ruppia* beds near the confluence of Salt River, an area 0.5 km downriver from "The Rocks", and around North Pass at the mouth of the river (Fig. 13). In the Homosassa River, manatees frequently were seen feeding on *Ruppia* and *Halodule* growing on sandbars at the river's mouth (Fig. 14). They also were seen feeding on *Hydrilla* and resting near the river's headwaters. Manatees in the Chassahowitzka River were seen resting, and feeding on *Rup-*

Figure 15. Manatee sightings in the Chassahowitzka River and within 1 km of its mouth. Data compiled from all aerial surveys from January 1978 through March 1981 ($n = 47$).

pia, along the channels and around the islands in the estuary at the mouth (Fig. 15). Animals rarely were seen in the Gulf of Mexico further than one kilometer from the mouth of a river (Fig. 8), with the exception of the shallow flats offshore of the Withlacoochee River, where they were occasionally observed moving slowly through the area. When seen in open Gulf waters between rivers they were always traveling.

Mortality Records

The manatee carcass salvage program of the Sirenia Project, U.S. Fish and Wildlife Service, has recovered and necropsied 28 animals from Citrus, Dixie, and Levy counties from April 1974 through June 1982 (O'Shea *et al.*, in

press). No recoveries were made from Hernando Co. The causes of death were boat/barge, 5; navigation lock, 1; other human related, 1; dependent calf, 14; undetermined, 6; and other natural, 1. Three of the boat kills were recovered from the Withlacoochee River in 1975 and two from Crystal River. One manatee was killed by the Inglis Lock on the CFBC. Dependent calves were recovered from all major river systems except the Homosassa River (Table 8).

DISCUSSION

Manatee Distribution West of the Suwannee River

Manatees have been found along the entire coast of the northern Gulf of Mexico (Fig. 1). However, there is a spatial and temporal pattern to their distribution. Sightings along the northwestern Gulf, from Texas to Louisiana, have declined since the early part of this century and they all have occurred during the summer. Gunter's (1942) suggestion that these manatees originated from Mexico is probably correct. The recent decline of sightings from Texas probably is due to the extirpation of animals in northern Mexico (Alvarez, 1963). In contrast, the number of animals sighted along the northeastern Gulf has increased recently, particularly in Mississippi. These extralimital sightings probably are due to animals moving north and west along the coast from the southern Big Ben coast, where their numbers have increased considerably in the past 20 years (Table 2).

Along the northwestern Gulf coast, the sequence of sightings seems to indicate a historical movement pattern very similar to that found along the Atlantic coast of Florida, where manatees make a north-south seasonal migration in response to low winter

Table 8. Southern Big Bend manatee mortality, April 1974 through June 1982. Data from Sirenia Project manatee salvage program, U.S. Fish and Wildlife Service.

County	Date	Field No.	Location	Cause of Death
Dixie	16 Jan 80	M 180	Suwannee, at mouth of the Suwannee River	Undetermined
	29 May 80	M 193	Suwannee River, Suwannee, ca. 1 km downstream of Lock Creek	Dependent calf
Levy	20 Mar 75	M 8	Withlacoochee River at marker 43	Boat/barge
	20 Mar 75	M 9	Withlacoochee River, 100 m upstream of marker 43	Boat/barge
	24 Oct 75	M 14	Withlacoochee River, drifted 2 mi down river from the boat marina, Yankeetown	Boat/barge
	13 Apr 76	M 22	Manatee Springs, in mouth of Manatee Springs Run at its confluence with Suwannee River	Dependent calf
	8 Apr 78	M 113	Withlacoochee River, Yankeetown, 0.5 km east of Yankeetown Boat Company	Dependent calf
	3 Jul 80	M 196	East pass of the Suwannee River, just W of the mouth	Undetermined
	2 Nov 80	M 212	Inglis, Cross Florida Barge Canal, Inglis Lock, immediately downstream of west gate	Gate/lock
	7 Dec 80	M 214	Cedar Key, found floating offshore between markers 16 and 18	Dependent calf
	15 Mar 81	M 228	Inglis, Cross Florida Barge Canal, Inglis Lock, immediately downstream of SW end of lock	Dependent calf
	7 Mar 82	M 274	Barge Canal, Inglis Lock, on S side, outside of the downstream gate	Dependent calf
Citrus	25 Dec 74	M 2	Crystal River, Bagley Cove	Boat/barge
	29 Jan 76	M 16	Crystal River, King's Bay, S tip of Buzzard Island	Undetermined
	5 Jan 77	M 40	S side of Crystal River, 1 km downstream from conjunction with Salt River	Other human
	26 Jan 77	M 43	Crystal River, King's Bay, W shore of Buzzard Island	Undetermined
	4 Sep 77	77 43	Crystal River, King's Bay, in creek on SW bank of bay	Undetermined
	16 Oct 77	M 92	Crystal River, King's Bay	Undetermined
	11 Jan 78	M 97	Crystal River, canal running parallel to Palm Drive	Dependent calf
	31 Aug 78	M 126	Junction of Salt and Crystal rivers across from Twin Rivers Marina	Boat/barge
	8 Feb 79	M 135	Chassahowitzka River, 300 yds E of Crawford Creek	Dependent calf
	16 Mar 79	M 141	Crystal River, Kings Bay, S shore of Three Grassy Islands, W of Banana Island	Dependent calf
	21 Feb 80	M 185	Crystal River, W bank of main channel of Crystal River, just S. of Bagley Cove, adjacent to Indian mounds	Dependent calf
	27 Feb 80	M 187	Crystal River, King's Bay main boil	Other/natural
	22 May 81	M 241	St. Martins River at Ozello	Dependent calf
	22 Feb 82	M 269	South shore of the Barge Canal, approx. 1 km downstream of Inglis Lock, in bay E of Dolime Mineral Plant	Dependent calf
	28 Feb 82	M 271	South bank of the Withlacoochee River, between the Barge Canal and the Withlacoochee Dam	Dependent calf
	4 Mar 82	M 272	Crystal River, Kings Bay, in cove SW of Warden Key	Dependent calf

temperatures (Moore, 1951; Rathbun *et al.*, 1982; Shane, 1983). Although there is no historical evidence for manatee

migration along the eastern Gulf coast (Moore, 1951), manatees presently using Crystal River and Homosassa River as

winter refuges seasonally disperse as far north as the Suwannee River and south at least to the Chassahowitzka River (Table 5). If the number of animals continues to increase along the southern Big Bend coast, resources may become limited, forcing spring migration further afield. Two factors probably act to inhibit long distance movements to the north or south. First, the northwestern coast of Florida does not have a sheltered, continuous series of estuaries and bays connected by an intracoastal waterway along its entire length, as occurs along the Atlantic coast. The protected intracoastal waterways are favored by manatees (Hartman, 1974) and provide ideal corridors of travel. Secondly, Crystal River and Homosassa River provide large, reliable, and natural sources of warm water that free manatees from the necessity of moving south during the cold winter months.

The winter range of manatees will probably not extend further north than Crystal River, or perhaps Manatee Spring, because they are sensitive to cold temperatures (Irvine, 1983; Shane, in press). The minimum suitable water temperature is about 20°C, and feeding may be inhibited at temperatures approaching 16°C (Campbell and Irvine, 1981; Irvine, 1983). Even though the Mississippi and Louisiana coasts are at about the same latitude as Jacksonville, Florida (30-31°N Lat.), where manatees often overwinter in warm water industrial outfalls (Hartman, 1974), the average winter Gulf water temperature in Mississippi in January 1982 was 3.3°C lower than in Jacksonville (National Oceanic and Atmospheric Administration, 1982). Industrial and electric generating plants along the northern Gulf coast do not raise the ambient water temperature sufficiently for wintering manatees. For example, the J. Watson

Power Plant in Biloxi, Mississippi, reported an average daily discharge temperature of only 15°C during January 1980 (E. J. Holt, pers. comm.), the same month when animals were sighted in the vicinity of Biloxi. The dead and cold-stressed manatees found in Mississippi give further evidence that winter conditions are too cold along the northern Gulf coast.

Manatee Abundance and Distribution Along the Southern Big Bend Coast

Although Moore (1951) considered the southern Big Bend coast of Florida outside of the normal range of the manatee, there is considerable evidence that during the period of Indian dominance, animals populated this coast in sufficient numbers to be hunted. Manatee kill sites have been identified on the Santa Fe River (off of the Suwannee River), Withlacoochee River, and Crystal River (Cumbaa, 1980). Bone fragments with cuts and scrapes have been found in the Waccasassa River (pers. obs.). Presumably Manatee Spring was named because manatees were hunted in the spring run during the winter (Bartram, 1791). Although the evidence indicates that manatees were once abundant enough to be hunted by Indians, their numbers probably were kept at low levels. In the mid-19th century the southern Big Bend coast was occupied by white settlers. The Indians and first settlers probably found the animals wintering in the clear headwaters of Manatee Spring, Crystal River, and Homosassa River easy prey, which they subsequently hunted to near extinction. Thus, with the exception of Bartram's (1791) account, reference to manatees on the southern Big Bend coast virtually disappeared from the literature until the mid-1900's (Moore, 1951; Layne, 1965).

The recent population increase

along the southern Big Bend coast can be attributed to several factors. Most important has been the reduction of hunting and poaching due to the enactment of strong protective laws and the emergence of a conservation ethic. Mr. T. R. Hodges (in Moore, 1951) remarked: "... they became almost extinct years ago . . . A law was passed prohibiting anyone from killing a manatee except for scientific purposes . . . the enforcement of this law was under my jurisdiction for fifteen years and was rigidly enforced, and the manatee became very plentiful . . ." Another factor has been the low mortality in recent years compared with other areas of the state (Irvine *et al.*, 1981; Beck *et al.*, 1981; O'Shea *et al.*, in press). Large boats have been identified as a major cause of manatee mortality in Florida (Beck *et al.*, 1982), but due to the shallowness of the southern Big Bend coast (Vernon, 1951) and the absence of an intracoastal waterway, relatively few large vessels use the area and few boat kills have been identified. An exception to this was the death of at least three animals in the Withlacoochee River in 1975 (Table 8), during the period when oil was being carried upriver by barges. There have been no boat mortalities reported in the Withlacoochee River since the barge traffic stopped.

The low manatee mortality and large proportion of calves in the Crystal River population compared with other areas of the state (Irvine and Campbell, 1978; O'Shea *et al.*, in press) suggests that the population increase probably has primarily been due to intrinsic growth (Table 2). However, every year a few adult manatees, with large, old, and distinct scars, are identified in Crystal River for the first time (Table 3; Hartman, 1979; Powell, 1981). These animals must be emigrating from the south, possibly due to human encroachment of their habitat

(Hartman, 1979) and the destruction of seagrass beds (Phillips, 1960). The introduction of exotic macrophytes in the Crystal River (Hartman, 1979) is probably another factor contributing to an increase in manatee abundance. Our vegetation surveys (Fig. 5) suggest that before the introductions, there may not have been enough submerged vegetation to support the number of animals presently wintering in Crystal River.

It is difficult to estimate the current number of manatees using the southern Big Bend coast because of the mostly turbid waters and the complex labyrinth of passes, islands, and creeks in the region. However, since manatees form winter aggregations in the Crystal and Homosassa rivers, a minimum population estimate of 136 animals can be obtained from the maximum aerial counts made in these two rivers during 1981-82 (Table 2). Alternatively, a minimum estimate of 132 animals can be obtained by counting the total number of individuals identified at Crystal River during the winters of 1978-79 through 1981-82 (U.S. Fish and Wildlife Service, unpubl. data). Based on these two similar estimates, and the knowledge that not all manatees are seen during aerial surveys or are individually identifiable, we think there were at least 150 animals using the southern Big Bend coast during the 1981-82 winter. Hartman (1974) and Brownell *et al.* (1981) suggested a Florida population of at least 800 to 1000 manatees. If this estimate is correct, then the number of animals inhabiting the southern Big Bend coast may represent a considerable proportion (ca. 17%) of the total Florida (= United States) population.

The five principal rivers along the southern Big Bend coast have distinctive characteristics that influence the seasonal distribution of manatees (Fig.

6). Crystal River, Homosassa River, and Chassahowitzka River are unique in that they are spring fed and are relatively short in length. The Crystal and Homosassa rivers are fed by numerous large springs that have a constant temperature (23.5°C) throughout the year (Rosenau *et al.*, 1977), and have channels that are greater than one meter deep, enabling manatees to reach the headwaters. The Chassahowitzka River, however, is fed by small springs (Rosenau *et al.*, 1977) and its upper channel is normally too shallow for manatees (Hartman, 1979). Crystal River and Homosassa River are unique in that they form large, natural sources of warm water, whereas most other winter refuges in Florida are man-made, usually at electric generating plants (Hartman, 1974). The Suwannee and Withlacoochee rivers are not spring fed and become too cold for manatees during the winter.

Manatees used the FPC Crystal River power plant effluent and other smaller springs as temporary "safe spots" and transition areas. The greatest number were seen in the plant's warm water effluent during the early spring as they exited from Crystal River, and to a lesser degree in the fall when they returned (Fig. 7). Presumably they used the plant until the coastal water warmed sufficiently for their dispersal, or as immediate shelter during cold fronts before their arrival at Crystal River. The power plant and the other temporary refuges probably will not become established as permanent winter sanctuaries due to a lack of freshwater or adequate food, as well as their small size and difficulty of access.

During the warm months the five major rivers along the southern Big Bend coast form high-use (Suwannee and Crystal rivers) and low-use (Withlacoochee, Homosassa, and Chassa-

howitzka rivers) systems (Table 6). This dichotomy is related to the different characteristics of the riverine, estuarine, and marine habitats of each river and the habitat requirements of manatees.

Estuarine conditions in the rivers of the southern Big Bend coast are created by several important physiographic features. Oyster bars form fringing reefs at the mouths of the Suwannee, Withlacoochee, Crystal, and Homosassa rivers. The bars at the mouth of the Suwannee River trap fresh water from the river and create the large, protected estuary that is heavily used by manatees during the warm season (Fig. 9, Table 7). The small estuary formed by large, marshy islands at the mouth of the Chassahowitzka River is also regularly used during this period (Fig. 15). Estuarine conditions in the Withlacoochee, Crystal, and Homosassa rivers are limited to relatively small portions of their channels upstream from their mouths. The rate of water flow is much less than that of the Suwannee River (EPA, unpubl. data) and the channels have been dredged at the mouths, which prevents freshwater from becoming impounded by the fringing oyster bars. This results in the large, shallow flats between the oyster bars and mouths of these three rivers being principally marine and infrequently used by manatees.

The riverine habitats of Crystal River and Homosassa River are used significantly more than the estuarine and marine habitats (Table 7), because animals begin to aggregate in both rivers during late September and early October in anticipation of cold weather (Fig. 6). This increases the average warm season counts. The riverine habitats of the Suwannee River and Chassahowitzka River are used significantly less than the estuarine habitats (Table 7). The channel

in the Chassahowitzka River is well vegetated, but is normally too shallow for manatees to navigate, whereas the channel in the Suwannee River is deeper and wider, but supports little submerged vegetation suitable for feeding. The water of the Suwannee River is turbid, which prevents rooted submerged aquatic plants from growing, and the swift current prevents large mats of floating vegetation from forming along the banks. These conditions are not present in Manatee Spring, however, where the water is clear and several species of submerged aquatic plants attract manatees (Table 4).

Manatees are rarely seen in purely marine habitats along the southern Big Bend coast (Fig. 8). This is due to their habitat requirements, which probably relate to their phylogeny and physiological limitations. Domning (1982) presented evidence that the genus *Trichechus* (Family Trichechidae) evolved relatively recently (Pliocene) in freshwater habitats in the Amazon Basin of South America. He also suggested that the Amazonian Manatee (*Trichechus inunguis*) is restricted to fresh water rivers because it is unable to osmoregulate in saltwater. Another sirenian, however, the Dugong (*Dugong dugon*; Family Dugongidae), is strictly marine, and presumably does not require access to fresh water (Bertram and Bertram, 1973). West Indian manatees that occur in salt water habitats are frequently seen drinking from fresh water sources, such as sewer effluents, offshore artesian springs, and water hoses (Morison, 1942; Hartman, 1974; Belitsky and Belitsky, 1980; Powell *et al.*, 1981; Shane, 1983). Hartman (1974, 1979) first proposed that the frequent association of manatees with fresh water in Florida was related to their poor osmoregulatory abilities. Manatees do not occur regu-

larly around Caribbean islands that lack reliable sources of fresh water, such as the Lesser Antilles and Bahamas (Husar, 1977). In Florida (Hartman, 1974; Irvine and Campbell, 1978), Cuba (Cuni, 1910), Puerto Rico (Powell *et al.*, 1981), and Honduras (Rathbun, *et al.*, 1983) manatees are normally found in association with fresh water. Our data confirm this pattern on the southern Big Bend coast (Figs. 6 and 8). Clinical studies by Irvine *et al.*, (1980) suggest that manatees have at least a limited ability to excrete salt while occupying marine habitats. Although the circumstantial evidence for fresh water dependency is strong, the extent of their dependency will remain speculative until appropriate physiological studies are completed.

The southward summer movement of Gus (CR 108♂) to Sanibel Island and then his return in the fall to Crystal River is intriguing for several reasons. First, it suggests a strong traditional use of the winter refuge. When Gus was at Sanibel Island he was within 30 km of the Florida Power and Light Co. Ft. Myers power plant, the largest known winter aggregation site on the west coast (Rose and McCutcheon, 1980). Rather than remain for the winter at this nearby warm water site, he traveled over 300 km north to Crystal River. This northward movement is opposite to what might be expected as a response to impending cold weather and is the converse of the migratory movements on the east coast. Secondly, his summer movement out of the southern Big Bend coast may illustrate how reproduction influences male movements. Gus is a large male that had been seen participating in several mating herds during the previous six seasons. Bengtson (1981) found that males in the St. Johns River moved more frequently and further afield than females. This suggests that Gus's movement to Sanibel

Island was related to his search for reproductive females, rather than a movement to avoid adverse seasonal temperatures or a limited resource, such as food.

Packard (in press) has shown that manatees on the east coast of Florida feed on dense beds of *Syringodium filiforme*, *Thalassia testudinum*, and *Halodule wrightii* and in some areas they entirely remove these species by excavating the substrate. Birch (1975) carried out some chemical analyses of several marine angiosperms in Australia, including *S. isoetiofolium*, *T. hemorichii*, and *H. uninervis*, and found that the sodium content of the plants (2.8% to 7.8%, dry weight) often exceeded that of sea water. Birch (1975) calculated that an average-sized dugong feeding on these marine angiosperms would consume about 62 g of sodium per day. This requires a considerable ability to eliminate salt. Fresh water macrophytes, such as *Hydrilla verticillata*, *Ceratophyllum demersum*, *Vallisneria americana*, and *Najas guadalupensis*, have low sodium concentrations (less than 1.5% dry matter; Easley and Shirley, 1974) compared with marine plants. The estuarine plant *Ruppia maritima* is tolerant of a wide range of salinity, and its sodium content is intermediate to the marine and freshwater angiosperms (1-3% dry weight; Walsh and Grow, 1972).

Vast seagrass beds, dominated by *T. testudinum*, *S. filiforme*, and *H. wrightii*, extend up to 25 km offshore along the southern Big Bend coast (Phillips, 1960; U.S. Fish and Wildlife Service, 1982). These three species have different tolerances to fluctuating salinities and exposure to air during low tides, which results in their zonation (Strawn, 1961). *Halodule* grows nearest to shore and around the mouths of the rivers, whereas *Thalassia* and *Syringodium* are

found in deeper water further from shore, often outside the fringing oyster bars (pers. obs.; Strawn, 1961). *R. maritima* is most tolerant of fluctuations in salinity and is abundant in the estuarine habitats at the mouths of the Suwannee and Chassahowitzka rivers, and in the estuarine habitats of the lower Withlacoochee, Crystal, and Homosassa rivers (pers. obs.; Hartman, 1979). Manatees along the southern Big Bend coast frequently were seen feeding on *Ruppia* and *Halodule* in and near the estuarine habitats at the mouths of the rivers during the summer, and in freshwater during the winter. They rarely were seen in association with the off-shore beds of marine angiosperms. These observations are consistent with the hypothesis that manatees have poor abilities to osmoregulate and thus feed on plants with low salt concentrations (such as *Ruppia*) or on marine angiosperms that grow near fresh water (such as *Halodule*). Not enough is known about the distribution of manatees, food plants, and freshwater along the east coast of Florida to explain Packard's (in press) observations.

If the West Indian manatee has difficulty in excreting salt obtained by feeding on sodium-rich marine plants, then they might be expected to remain in the headwaters of the Crystal and Homosassa rivers year round in order to feed on fresh water macrophytes with a low sodium content. There are two principal reasons why they do not. First, both rivers are urbanized with considerable recreational boat traffic during the summer. Manatees may avoid these activities when they are not seeking the warm spring water during the winter. The second and most important factor is the manatee's need to conserve body heat. During the warm months, the temperature at the headwaters of the two spring-

fed rivers can be 13°C lower than the temperature of the rivers, or Gulf. Since these animals have relatively low metabolic rates and high heat conductances (Irvine, 1983) they would be expected to favor warmer water.

The Future of Manatees Along the Southern Big Bend Coast

We have presented data on the distribution and abundance of manatees that suggest that the population along the southern Big Bend coast has increased substantially in the last two decades. Human-caused mortality has been low compared with the eastern and southwestern regions of the state (O'Shea *et. al.*, in manuscript). Manatees along the southern Big Bend coast are doing well because large sections are relatively unpopulated, undisturbed, and undeveloped compared with other areas of the state (Fernald, 1981). Consequently, we believe that the best hope for the long-term existence of this endangered species in Florida is along the Big Bend coast. However, this could easily and rapidly change if the region develops without regard to the needs of the manatees. It is the responsibility of the various local, state, and federal governmental agencies, conservation organizations, and private companies to ensure tht the Big Bend coast develops in harmony with manatees. This may be the last opportunity in the United States to use foresight to conserve manatees. The alternative is to mimic past efforts and implement remedial actions based on hindsight.

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LITERATURE CITED

- Alvarez, T. 1963. The recent mammals of Tamaulipas, Mexico. Univ. Kansas Publ. 14: 363-473.
- Bartram, W. 1791. Travels of William Bartram. James and Johnson, Philadelphia. Dover reprint edition, 1955, 414 p.
- Beck, C., R.K. Bonde, and D. K. Odell. 1981. Manatee mortality in Florida during 1978. P. 76-85, in Brownell, R.L., Jr., and K. Ralls (eds.) The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, FL, 27-29

- March 1978. Florida Dept. of Natural Resources, Tallahassee, 154 p.
- _____, and G.B. Rathbun. 1982. Analysis of propeller wounds on manatees in Florida. *J. Wildl. Manage.* 46: 531-535.
- Belitsky, D.W. and C.L. Belitsky. 1980. Distribution and abundance of manatees, *Trichechus manatus*, in the Dominican Republic. *Biol. Conserv.* 17: 313-319.
- Bengtson, J.L. 1981. Ecology of manatees (*Trichechus manatus*) in the St. Johns River, Florida. Ph. D. Thesis, University of Minnesota, 126 p.
- Bertram, G.C.L. and C.K. Ricardo Bertram. 1973. The modern Sirenia: their distribution and status. *Biol. J. Linn. Soc.* 5: 297-338.
- Birch, W.R. 1975. Some chemical and calorific properties of tropical marine angiosperms compared with those of other plants. *J. Appl. Ecol.* 12: 201-212.
- Brownell, R.L., Jr., K. Ralls, and R.R. Reeves. 1981. Report of the West Indian manatee workshop. P. 3-16 in Brownell, R.L., Jr. and K. Ralls (eds.), *The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, FL. 27-29 March 1978.* Florida Dept. of Natural Resources, Tallahassee, 154 p.
- Campbell, H.W. and A.B. Irvine. 1981. Manatee mortality during the unusually cold winter of 1976-1977. P. 86-91 in Brownell, R.L., Jr. and K. Ralls (eds.), *The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida, 27-29 March 1978.* Florida Dept. of Natural Resources, Tallahassee, 154 p.
- Collard, S.D., N.I. Rubenstein, J.C. Wright, and S.B. Collard, III. 1976. Occurrence of a Florida manatee at Pensacola Bay. *Fl. Sci.* 39: 48.
- Cumbaa, S.L. 1980. Aboriginal use of marine mammals in the southeastern United States. *Southeastern Archaeological Conference Bulletin* 17: 6-10.
- Cuni, L.A. 1910. Contribution al estudio de mamiferos acuaticos observados en las costas de Cuba. Publicada en la "Revista de la Facultad de Letras y Ciencias", Habana, Cuba. 43 p.
- Domning, D.P. 1982. Evolution of manatees: a speculative history. *J. Paleontol.* 56: 599-619.
- Easley, J.R. and R.L. Shirley. 1974. Nutrient elements for livestock in aquatic plants. *Hyacinth Control J.* 12: 82-85.
- Fernald, E.A., ed. 1981. *Atlas of Florida.* Florida State Univ. Foundation, Tallahassee. 276 p.
- Freund, R.T. and R.C. Littell. 1981. SAS for linear models. A guide to the ANOVA and GLM procedures. SAS Institute, Inc., Cary, NC, 231 p.
- Gunter, G. 1941. Occurrence of the manatee in the United States, with records from Texas. *J. Mammal.* 22: 60-64.
- _____. 1942. Further miscellaneous notes on American manatees. *J. Mammal.* 23: 89-90.
- _____ and G. Corcoran. 1981. Mississippi manatees. *Gulf Research Reports* 7: 97-99.
- _____ and A. Perry. 1983. A 1981 sighting of *Trichechus manatus* in Mississippi. *J. Mammal.* 64:513.
- Hallock, C. 1876. *Camp Life in Florida.* Smith and McDugal, New York, NY. 348 p.
- Harris, R.J. 1975. *A primer of multivariate statistics.* Academic Press, NY. 332 p.
- Hartman, D.S. 1971. Behavior and ecology of the Florida manatee, *Trichechus manatus latirostris* (Harlan), at Crystal River, Citrus County. Ph.D. Thesis, Cornell University, Zoology. 185 p.
- _____. 1974. Distribution, status, and conservation of the manatee in the United States. *U. S. Fish and Wildlife*

- Service, Nat'l. Fish and Wildlife Lab. Contract Report No. 14-16-0008-748, NTIS Publ. No. PB81-140725, 246 p.
- _____. 1979. Ecology and behavior of the manatee (*Trichechus manatus*) in Florida. Amer. Soc. Mammalogists Special Publ. No. 5, 153 p.
- Helwig, J.T. and K.A. Council (eds.). 1979. SAS User's Guide, 1979 edition. SAS Institute, Inc., Raleigh, NC, 494 p.
- Husar, S.H. 1977. The West Indian manatee (*Trichechus manatus*). U.S. Dept. Interior, Fish and Wildlife Service, Wildlife Research Report No. 7, 22 p.
- Irvine, A.B. 1983. Manatee metabolism and its influence on distribution in Florida. Biol. Conserv. 25: 315-334.
- _____. and H.W. Campbell. 1978. Aerial census of the West Indian manatee, *Trichechus manatus*, in the southeastern United States. J. Mammal. 59: 613-617.
- _____, F.C. Neal, P.T. Cardeilhac, J.A. Popp, F.H. White, and R.L. Jenkins, 1980. Clinical observations on captive and free-ranging West Indian manatee, *Trichechus manatus*, in Florida. Aquatic Mammals 8: 2-10.
- _____, D.K. Odell, and H.W. Campbell. 1981. Manatee mortality in the southeastern United States from 1974 through 1977. p. 67-75 in Brownell, R.L., Jr. and K. Ralls (eds.), The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, FL, 27-29 March 1978. Florida Dept. of Natural Resources, Tallahassee, 154 p.
- Kochman, H.I., G.B. Rathbun, and J.A. Powell. 1983. Use of Kings Bay, Crystal River, Florida, by the West Indian manatee (*Trichechus manatus*). p. 60-124, in Packard, J. M. (ed.), Proposed Research/Management Plan for Crystal River Manatees. Vol. III. Compendium. Florida Cooperative Fish and Wildlife Research Unit, University of Florida, Gainesville, FL. Technical Report No. 7. 346 p.
- Layne, J.N. 1965. Observations on marine mammals in Florida waters. Bull. Florida St. Mus., Biol. Sci. 9: 131-181.
- Lowery, G.H., Jr. 1974. The mammals of Louisiana and its adjacent waters. Louisiana State Univ. Press, 565 p.
- Moore, J.C. 1951. The range of the Florida manatee. Quart. Jour. Florida Acad. Sci. 14: 1-19.
- _____. 1956. Observations of manatees in aggregations. Amer. Mus. Novit. 1811: 1-24.
- Morison, S.E. 1942. Admiral of the Ocean Sea, A Life of Christopher Columbus. Little, Brown, and Co., Boston, MA.
- National Oceanic and Atmospheric Administration. 1982. Oceanographic Monthly Summary. U.S. Dept. of Commerce, Wash., D.C. Fig. 20-21.
- Osborne, J.A. 1981. Macrophyton. p. 983-995, in Greenberg, A.E., J.A. Connors, and D. Jenkins (eds.). Standard methods for the examination of water and waste water, 15th edition. Amer. Public Health Assoc., Wash., D.C. 134 p.
- O'Shea, T.J., C.A. Beck, R.K. Bonde, H.I. Kochman, and D.K. Odell. In press. An analysis of manatee mortality patterns in Florida, 1976-1981. J. Wildl. Manage.
- Packard, J.M. In press. Impact of manatees (*Trichechus manatus*) on seagrass communities in eastern Florida. Acta Zool. Fennica.
- Phillips, R.C. 1960. Observations on the ecology and distribution of the Florida seagrasses. Florida State Board of Conservation, Marine Laboratory, Professional Papers Series No. 2, 72 p.
- Powell, J.A. 1981. The manatee population in Crystal River, Citrus County, Florida. p. 33-40, in Brownell, R.L., Jr. and K. Ralls (eds.), The West Indian manatee in Florida. Proceedings of a

- workshop held in Orlando, FL, 27-29 March 1978. Florida Dept. of Natural Resources, Tallahassee, 154 p.
- _____, D.W. Bellitsky, and G.B. Rathbun. 1981. Status of the West Indian manatee (*Trichechus manatus*) in Puerto Rico. J. Mammal. 62: 642-646.
- Rathbun, G. B., R. K. Bonde, and D. Clay. 1982. The status of the West Indian manatee on the Atlantic coast north of Florida. p. 152-165, in Odom, R.R. and J.W. Guthrie (eds.), Proceedings of the nongame and endangered wildlife symposium, Georgia Dept. Natural Resources, Game and Fish Division, Tech. Bull. WL 5, 179 p.
- _____, J.A. Powell, and G. Cruz. 1983. Status of the West Indian manatee in Honduras. Biol. Conserv. 26: 301-308.
- Rose, P.M. and S.P. McCutcheon. 1980. Manatees (*Trichechus manatus*): Abundance and distribution in and around several power plant effluents. Final report prepared for the Florida Power and Light Co., Miami, FL, Contract No. 31534-86626, 128 p.
- Rosenau, J.C., G.L. Faulkner, C.W. Hendry, Jr., and R.W. Hull. 1977. Springs of Florida. Florida Dept. of Natural Resources Bulletin 31, 461 p.
- Shane, S.S. 1983. Abundance, distribution, and movements of manatees (*Trichechus manatus*) in Brevard County. Florida. Bull. Marine Sci. 33: 1-9.
- _____. In press. Manatee use of power plant effluents in Brevard County, Florida. Florida Scientist.
- Strawn, K. 1961. Factors influencing the zonation of submerged monocotyledons at Cedar Key, Florida. J. Wildl. Manage. 25: 178-189.
- True, F. 1884. The Sirenians or sea cows. The Fishery Industry of the U. S., Section 1, Natural History of Useful Aquatic Animals, Part I, Art. C, p. 114-135, Pls. 33, 34.
- U. S. Fish and Wildlife Service. 1982. Gulf Coast Ecological Inventory, 1: 250,000-Scale maps, Gainesville and Tarpon Springs, Florida. U. S. Fish and Wildlife Service, FWS/OBS 82/55.
- Vernon, R.O. 1951. Geology of Citrus and Levy Counties, FL. Fl. Geol. Surv., Bull. 33: 256 p.
- Walsh, G.E. and T.E. Grow. 1972. Composition of *Thalassia testudinum* and *Ruppia maritima*. Quart. J. Florida Acad. Sci. 35: 97-108.
- Winer, B.J. 1971. Statistical principles in experimental design. McGraw-Hill Book Co., NY. 907 p.