

Winter Movements and Use of Warm-water Refugia
by Radio-tagged West Indian Manatees
Along the Atlantic Coast of the United States

CHARLES J. DEUTSCH

Final Report Prepared for:
Florida Power and Light Company
and
U.S. Geological Survey

December 2000

Winter Movements and Use of Warm-water Refugia

by Radio-tagged West Indian Manatees

Along the Atlantic Coast of the United States

Charles J. Deutsch

U.S. Geological Survey, Florida Caribbean Science Center, Sirenia Project

412 NE 16th Ave., Rm. 250

Gainesville, FL 32601

and

U.S. Geological Survey, Florida Cooperative Fish and Wildlife Research Unit and

University of Florida, Department of Wildlife Ecology and Conservation

P. O. Box 110450, Gainesville, FL 32611

Present Address:

13905 NW 56th Ave.

Gainesville, FL 32653

Final Report Prepared for:

Florida Power and Light Company

Environmental Services Dept.

700 Universe Blvd.

Juno Beach, FL 33408

and

U.S. Geological Survey, Florida Caribbean Science Center, Sirenia Project

412 NE 16th Ave., Rm. 250

Gainesville, FL 32601

20 December 2000

How to Cite this Report:

Deutsch, C. J. 2000. Winter movements and use of warm-water refugia by radio-tagged West Indian manatees along the Atlantic coast of the United States. Final Report prepared for the Florida Power and Light Company and U.S. Geological Survey. 133 pp.

Additional Copies of this Report may be Requested from:

Florida Power and Light Company, Environmental Services Dept., 700 Universe Blvd., Juno Beach, Florida 33408.

or

U.S. Geological Survey, Florida Caribbean Science Center, Sirenia Project, 412 NE 16th Ave., Rm. 250, Gainesville, FL 32601

EXECUTIVE SUMMARY

The endangered West Indian manatee relies on a network of warm-water refugia along the coasts of Florida and Georgia to survive winter cold periods. Most of the sites where manatees aggregate during the winter months are industrial thermal discharges, primarily from power plants, including some that lie north of the species' historical winter range. The reliability of this refuge network may be jeopardized by future changes in the electric utility industry, including the retirement or intermittent operation of aging power plants.

Information on winter movements of manatees and their patterns of use of warm-water sources is valuable in developing management strategies and contingency plans to address this complex problem. This report summarizes findings from a 12-year radio-telemetry study conducted by the U.S. Geological Survey on winter movements, site fidelity, and use of warm-water refugia by 71 manatees tracked along the Atlantic coast between the Florida Keys and Savannah, Georgia.

Most manatees along the Atlantic coast migrated seasonally between a northerly warm season range and a southerly winter range, primarily in response to seasonal changes in temperature. All tagged manatees north of the Florida Keys were familiar with 2 or more warm-water refugia and used industrial effluents in every winter. Because of their long-distance migrations, most individuals visited refugia that were spread across an extensive geographic area. A variety of evidence indicates that a large number of manatees rely on man-made sources of warm water north of their historical winter range, principally in Brevard County, rather than migrating to southeastern Florida. These individuals may be particularly vulnerable to temporary disruption or elimination of industrial thermal discharges. Manatees exhibited strong site fidelity to 1 or 2 primary warm-water refugia by consistently returning to the same sites year after year. The most frequently used sites were the Brevard County and Port Everglades power plants.

The principal environmental factor affecting the frequency with which manatees used warm-water refugia was ambient water temperature. Manatees began to use power plant effluents when water temperature fell below 22 °C and use increased steadily with declining temperature. Manatees used warm-water refugia primarily during the coldest winter months of December through February and, to a lesser extent, during November and March. Their use of these sites was highest in northeastern Florida and Georgia and generally decreased to the south. Some warm-water aggregation sites possessed other features, such as freshwater sources and areas off-limits to watercraft, that may have also attracted manatees.

Individual manatees appear to possess the potential to shift overwintering sites, within the range of their experience, in response to changes in winter severity or power plant operation. The demonstrated tenacity of individuals to favored sites, however, is likely to result in their returning to traditionally used refugia, even after the warm water has ceased. Movement of manatees between sites is also constrained by their capacity to survive exposure to cold water temperatures while in transit. The manatee's vulnerability to changes in the availability of warm water means that sufficient time must be planned between the creation of alternative warm-water refugia and the elimination of existing ones.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	3
ABSTRACT	5
INTRODUCTION	7
Objectives	8
STUDY AREA	9
METHODS	10
Radio-tag Deployment and Tracking	10
Water Temperature Recording	11
Data Processing and Analysis	11
Number and Geographic Extent of Warm-water Refugia Used	12
Differential Use of Warm-water Refugia	13
Interannual Fidelity to Warm-water Refugia	13
Frequency of Use of Warm-water Refugia	14
RESULTS	14
Number of Warm-water Refugia Used	14
Geographic Extent of Warm-water Refuge Use	15
Differential Use of Warm-water Refugia	16
Interannual Fidelity to Warm-water Refugia	16
Frequency of Warm-water Refuge Use: Seasonal and Regional Variation	17
Frequency of Warm-water Refuge Use: Variation in Relation to Temperature	17
DISCUSSION	18
Use of the Network of Warm-water Refugia	18
Differential Use of Warm-water Refugia	19
Interannual Fidelity to Warm-water Refugia	20
Factors Affecting the Frequency of Warm-water Refuge Use	21
RECOMMENDATIONS FOR FURTHER ANALYSIS OF TELEMETRY DATA	23
ACKNOWLEDGMENTS	26
LITERATURE CITED	27
FIGURES	33
APPENDICES	74

ABSTRACT

The West Indian manatee's metabolic physiology constrains it to subtropical and tropical regions. In waters of the United States, a manatee's ability to find reliable warm-water refugia during winter cold periods is critical to its survival. This report documents how radio-tagged manatees used a network of 14 industrial and 3 "natural" warm-water sites along the east coast of Florida and Georgia during winter. Most industrial sites were power plant discharges but also included pulp mill effluents. The U. S. Geological Survey's Sirenia Project tracked 71 manatees over 12 winter seasons (1986-1998) using field-based VHF radio-telemetry and Argos satellite-based telemetry. Thirty-seven individuals were tracked over periods of at least 100 days between November and March of a given winter, many for multiple years. Presence at a warm-water refuge was defined as a location occurring within 200 m (for a VHF field observation) or within 1 km (for a satellite-determined location) of the site.

The network of warm-water refugia along the Atlantic coast that individual manatees utilized varied in extent from quite localized (<10 km) to widespread (>500 km). All tagged manatees north of the Florida Keys were familiar with multiple thermal refugia (mean = 4.3, SD = 1.9, maximum = 9 over tracking period) and they used one or more industrial effluents in every winter. Most individuals (84%) were located at warm-water sites spread across an extensive geographic area that included 2 or more defined regions (Fig. 1), but none traveled into the upper St. Johns River basin. Most manatees along the Atlantic coast migrated seasonally over large geographic areas between a northerly warm season range and a southerly winter range, primarily in response to seasonal changes in temperature (Deutsch et al. 2000a). There was relatively little overlap in the refuge network used by seasonal migrants between (1) the north and north-central (i.e., Brevard County) regions, and (2) the north-central or south-central and south regions. The seasonal movements of the latter group probably represent the traditional, historical pattern of migration. Half of the tagged manatees that used winter aggregation sites in Brevard County or in northeastern Florida and Georgia did not travel south of Brevard County during their tracking periods. These individuals may be particularly vulnerable to temporary disruption or elimination of industrial thermal discharges.

Manatees exhibited strong site fidelity to 1 or 2 primary warm-water refuge areas across multiple years. The most frequently used sites were the Brevard County and Port Everglades power plants. The vast majority of manatees consistently returned to the same southernmost warm-water destination year after year, if only for a brief duration. Some individuals showed interannual variation in the relative proportion of time spent at different warm-water sites within their annual range. This suggests that, within certain constraints, individual manatees possess the behavioral plasticity to adjust their winter movement patterns in relation to variation in winter severity or effluent operation. Constraints include (1) a spatial component—the geographic extent of an individual's annual range and its familiarity with thermal refugia within that range, and (2) a temporal component—the speed with which an individual can alter its migratory or sheltering behavior, especially when faced with severe cold.

Ambient water temperature strongly affected the frequency with which manatees used thermal refugia. Use of power plant effluents in Brevard County increased as mean daily water

temperature declined below 22 °C. Most seasonal migrants to southeastern Florida, however, responded to low temperatures in Brevard County by migrating south rather than by moving to the local power plants. Manatees overwintering in this region were located at the power plants on 84% of days when water temperatures averaged <16 °C. Manatees in northern Brevard County were frequently exposed to water temperatures that are known to increase energetic demands for maintaining core body temperature (66% of winter days <20 °C) and even to temperatures that can prove lethal over prolonged periods (21% of winter days <16 °C).

Seasonal and regional variation in warm-water use were largely accounted for by variation in temperature regime. Manatees utilized thermal refugia primarily during the coldest winter months of December through February and, to a lesser extent, during November and March. For all tagged manatees and regions pooled, 36% of manatee-days were spent at an identified warm-water site during those 3 winter months. In general, manatee use of warm-water refugia increased with latitude, being highest in northeastern Florida and Georgia (63% of manatee-days). The major exception to this pattern was the relatively high use of certain warm-water sites in southeastern Florida, which may have attracted manatees for reasons in addition to warm water, such as access to freshwater sources and to resting areas undisturbed by watercraft. The occurrence of mid-winter migrations from the southern region to central Florida during periods of mild weather may also have been a contributing factor.

INTRODUCTION

The peculiar metabolic physiology of the West Indian manatee (*Trichechus manatus*), including an extremely low metabolic rate and a high thermal conductance, limits its ability to thermoregulate in cold waters (Irvine 1983). Historically, this has restricted the extent of the manatee's winter distribution in the United States to southern peninsular Florida (Moore 1951a). Anecdotal accounts of manatee deaths associated with winter freezes have been reported for areas within their historical winter range, including Sebastian River, Palm Beach, Charlotte Harbor, and the Everglades (Bangs 1895, Cahn 1940, Moore 1951b, 1956). Over the past 50 years, however, the construction of electric power generating plants and other industrial facilities with warm-water outfalls has permitted manatees along the Atlantic coast to extend their winter range northward as far as Jacksonville, Florida and southeastern Georgia (Lefebvre et al. 1989, Zoodsma 1991). In some exceptionally cold winters, power plants in northeastern Florida were apparently unable to raise intake water temperature sufficiently to maintain adequate warmth for manatees, resulting in a high number of cold-related deaths, especially of subadults (Campbell and Irvine 1981, Buergelt et al. 1984, O'Shea et al. 1985; see Ackerman et al. 1995 for a review of "catastrophic" mortality events). Although the net effect of these artificial warm-water refugia on manatee population dynamics is unknown, they may have contributed to population growth by providing access to more habitat during winter and by reducing the extent of cold-related mortality in most winters.

The future of manatees in Florida may be jeopardized by changes in the electric utility industry, as well as other factors. Some aging power plants may be shut down and pending deregulation of the electric utility industry may eliminate or reduce the reliability of warm-water effluents that manatees depend on to survive winter cold periods (Rose 1997, U.S. Fish and Wildlife Service 2000). Increased competition within the industry may generate economic pressure to provide cheaper power, which may lead to unpredictable operation of existing power plants. The construction of "merchant" power plants in Florida may also reduce the need to operate the older, less efficient plants that manatees utilize. Temporary disruptions in heated effluents during winter have caused changes in local manatee distribution (Packard et al. 1989) and have been implicated in elevated numbers of deaths from cold stress (Campbell and Irvine 1981, but see O'Shea et al. 1985). The complete elimination of a warm-water refuge in northeastern Florida through diffusion of the heated effluent resulted in a shift in manatee distribution within the area and in substantial mortality of manatees that remained in the region (Deutsch et al. 2000b).

The uncertain future associated with potential changes in the electric utility industry, combined with the manatee's vulnerability to alterations in the operation of industrial warm-water discharges, have heightened concern among biologists, managers, environmental groups, and the utility industry about how best to manage the availability of these thermal sources. The urgency in addressing this issue was highlighted by estimates of Florida utility representatives at an August 1999 workshop (U.S. Fish and Wildlife Service 2000) that major change in their industry would likely occur sometime within the next 5 years. The development of effective solutions to this complex problem is crucial to the recovery of this endangered species, because

nearly all manatees on the east coast (excluding those in the Florida Keys and the upper St. Johns River) utilize industrial sources of warm water in winter. A catastrophic cold-related mortality event associated with intermittent operation or shutdown of a power plant effluent is a serious threat (Ackerman et al. 1995).

Numerous aerial survey studies have documented high winter use of warm-water aggregation sites by large numbers of manatees along the Atlantic coast (e.g., Reynolds and Wilcox 1994, Garrott et al. 1994). To understand how manatees might respond to temporary or permanent elimination of a thermal effluent, however, data are needed on the movements of individuals in relation to their environment. Resightings of distinctively scarred manatees through the use of photo-identification techniques demonstrated that some manatees migrate seasonally along the Atlantic coast, moving south for the winter and returning north for the warm season (Shane 1983, Reid et al. 1991). Reid et al. (1991) also obtained some evidence for interannual fidelity to specific warm-water sites, as well as movements among aggregation sites within and between winters. This approach provided valuable but incomplete sketches of manatee movement patterns at the individual level, because of the opportunistic nature of the methodology and long gaps between sightings.

The U.S. Geological Survey's Sirenia Project undertook a radio-telemetry study starting in 1986 to gather information on the spatial ecology, migratory behavior, and habitat use of manatees living along the Atlantic coast, including winter use of power plant effluents and other warm-water sources. Data from this study have been analyzed to estimate reproductive and survival rates (O'Shea and Langtimm 1995, Reid et al. 1995), and to describe seasonal movement patterns, migratory behavior, and fidelity to seasonal ranges (Deutsch 1996, Deutsch et al. 2000a), but no rigorous, quantitative analyses of manatee use of warm-water sources have been completed. This telemetry study was unique in the way in which it combined the strengths provided by a long-term perspective on individual behavior with the fine temporal resolution of within-winter movements.

Objectives

The purpose of this report is to provide government and electric utility industry managers with an analysis and summary of selected findings from a 12-year radio-telemetry study on winter movements, site fidelity, and use of warm-water sources by Florida manatees along the Atlantic coast of the United States. The following questions are addressed:

1. How have manatees used the network of warm-water refugia along the Atlantic coast of Florida and Georgia? Specifically, how many refugia did individual manatees visit within one winter season and across years, and across what geographic extent were they familiar with the locations of warm-water sites?
2. What patterns of interannual site fidelity did manatees show to warm-water refugia?
3. What environmental factors affected manatee use of warm-water sources during winter? In particular, how did the frequency with which tagged manatees used thermal refugia vary with season, with geographic region, and with ambient temperature?

STUDY AREA

These analyses assessed manatee movements among and use of 17 warm-water sources along the east coast of Florida and Georgia, including 14 industrial thermal effluents (9 power plants, 4 pulp mills, and 1 gypsum plant) and 3 “natural” sites (springs and thermally buffered waterways) (Fig. 1, Appendix A). Two sites in Jacksonville were adjacent to each other and their use could not be differentiated by satellite telemetry data; therefore, these 2 sites were treated as 1 site for the analyses. Bell (2000) reviews the characteristics of a number of these industrial thermal refugia. From north to south, the warm-water sites were:

1. Kemira gypsum plant, Savannah, GA (Fig. A-1).
2. Georgia-Pacific paper mill (GP-BR), Brunswick, GA (Fig. A-2).
3. Gilman pulp mill, St. Marys, GA (Fig. A-3).
4. Jefferson-Smurfit pulp mill (formerly Container Corp. of America) (JS-FB), Fernandina Beach, FL; warm-water refuge eliminated in November 1997 (Fig. A-4).
5. Jefferson-Smurfit pulp mill (formerly Alton Packing Corp.) (JS-JX), Jacksonville, FL; adjacent to JEA-KN, so it is not considered a separate site for the analyses (Fig. A-5).
6. Jacksonville Electric Authority J. D. Kennedy power plant (JEA-KN), Jacksonville, FL (Fig. A-5).
7. Jacksonville Electric Authority Southside power plant (JEA-SS), Jacksonville, FL (Fig. A-5).
8. Blue Spring, Deland, FL.
9. Orlando Utilities Commission Indian River power plant (OUC-IR), Titusville, FL (Fig. A-6).
10. Florida Power and Light Cape Canaveral power plant (FPL-CC), Titusville, FL (Fig. A-6).
11. North fork of the Sebastian River, Sebastian, FL (Fig. A-7).
12. Vero Beach municipal power plant, Vero Beach, FL (Fig. A-8).
13. Ft. Pierce Utilities Authority Henry D. King power plant, Ft. Pierce, FL (Fig. A-9).
14. Florida Power and Light Riviera power plant (FPL-RB), Riviera Beach, FL (Fig. A-10).
15. Florida Power and Light Port Everglades power plant (FPL-PE), Port Everglades, FL (Fig. A-11).
16. Florida Power and Light Fort Lauderdale power plant (FPL-FL), Fort Lauderdale, FL (Fig. A-11).
17. Coral Gables Waterway (CGW), Coral Gables, FL (Fig. A-12).

Temperature data, survey counts, and movements of manatees in relation to cold fronts clearly indicate that manatees seek shelter from low ambient temperatures in several “natural” warm-water refugia along Florida’s east coast, including Blue Spring, Sebastian River, and Coral Gables Waterway. Blue Spring is an artesian spring located approximately 240 km upstream from the mouth of the St. Johns River that produces a large volume of constant temperature water (22.5 °C) year-round (Hartman 1979, Bengtson 1981). Blue Spring run is the primary winter aggregation site in the upper (southern) St. Johns River, although several minor springs in the region are occasionally used by small numbers of manatees. Cold-induced aggregations of manatees form in a dredged canal off the north fork of the Sebastian River, which led to its designation as a no motorboat sanctuary. This waterway is thermally buffered by its depth and so cools more slowly than the shallow waters of the Indian River Lagoon (U.S. Geological

Survey, unpubl. data). Coral Gables Waterway is a dredged system of residential canals that is thought to have artesian springs or seeps of constant-temperature ground water that attracts manatees in cold weather (Kit Curtin and Kem Mayo, pers. comm.). Although there are no obvious surface boils of water (Kem Mayo, pers. comm.), one can observe water trickling out of the limestone rocks and down into the canal at low tide (Kit Curtin, pers. comm.). The mean $\pm$ SD water temperature in CGW during winter was 23.5 ± 1.2 °C for one satellite tag in which we independently calibrated sensor temperature; this excludes data from afternoon satellite passes which can be up to 2 °C higher due to solar heating. The temperature was fairly constant, generally between 23 - 24 °C, and averaged 3 - 4 °C warmer (max. = 6 °C) than Biscayne Bay, suggesting the presence of ground water inflow. Freshwater from a large stormwater outflow at the end of Riviera Drive also attracted manatees.

Other "natural" winter aggregation sites were not considered in these analyses, including two in particular that are worthy of mention here. Little River in northern Biscayne Bay is used regularly by many manatees in the area (U.S. Geological Survey, unpubl. data), with high counts of about 50 animals during winter (Kem Mayo, pers. comm.). However, Little River is generally only about 1 °C warmer than bay waters, so manatees disperse to other sites, especially FPL-PE, when water temperatures drop below about 21 °C (Kit Curtin, pers. comm.). Another winter aggregation site is the dredged harbor at the Harbor Branch Oceanographic Institution, located along the Indian River mid-way between Vero Beach and Ft. Pierce, where up to about 60 manatees have occasionally been counted (Steve McCulloch, pers. comm.). The tagged manatees in this study did not appear to use this site in cool temperatures, however, moving instead to the Ft. Pierce or FPL-RB power plants upon the arrival of a cold front.

Five regions were defined for analysis: (1) north (N) region (Savannah, GA to Flagler Beach, FL, including the lower St. Johns River), encompassing 7 industrial thermal effluents (6 sites); (2) north-central (NC) region (Flagler Beach, FL to Melbourne, FL), including 2 power plant discharges along the Indian River in Brevard County; (3) south-central (SC) region (Melbourne, FL to St. Lucie Inlet, FL), including the Sebastian River and 2 power plant outfalls; (4) south (S) region (St. Lucie Inlet, FL to southern Biscayne Bay), including 3 power plant discharges and Coral Gables Waterway; and (5) upper St. Johns River basin (south of Palatka, FL), including Blue Spring (Fig. 1). The latitudes of the regional boundaries were as follows: Flagler Beach (29.496° N), Melbourne (28.070° N), St. Lucie Inlet (27.138° N), southern Biscayne Bay (25.387° N), and Palatka (29.649° N). The presumptive historical winter range of the Florida manatee was south of the Sebastian River on the Atlantic coast (Moore 1951a) and is encompassed by the SC and S regions.

METHODS

Radio-tag Deployment and Tracking

Seventy-one manatees were radio-tagged and tracked over a 12-year period (8 May 1986 - 31 May 1998) along the Atlantic coast of the United States. Tagging occurred throughout the study area from the Florida Keys to Brunswick, GA, broken down by region as follows: 25

(35%) in the N region; 31 (44%) in the NC region (i.e., Brevard County); 3 (4%) in the SC region; 9 (13%) in the S region; and 3 (4%) in the upper Florida Keys. No manatees were tagged in the upper St. Johns River. Individuals born or raised in captivity and then radio-tagged upon their release into the wild were not included in this study.

Most tagged manatees ($N = 54$) were tracked remotely by satellite using the Argos data collection and location processing service (Fancy et al. 1988, Service Argos 1996). These animals carried tags containing a platform transmitter terminal (PTT) that sent UHF (ultra-high frequency) signals to 2 near-polar-orbiting NOAA weather satellites. The manatee PTTs were programmed with a duty cycle to transmit during the peak periods of satellite overpasses in Florida: 8 hr per day over 4 2-hr time periods, providing an average of nearly 4 locations per day (Deutsch et al. 2000a). Seventeen manatees carried only the smaller VHF (very high frequency) radio-tags throughout their tracking bouts. Both tag types consisted of buoyant cylindrical housings that were attached via a flexible nylon tether to a padded belt around the manatee's peduncle. The tether (1.3 - 2.0 m in length) permitted the tag to float at the surface and transmit in air while the animal was submerged at depths of up to 2 m. All manatees were located in the field about 1 - 3 times per week by homing in on the VHF signal using standard radio-tracking equipment, in order to assess activity, reproductive status, group size, and tag condition. Tag detachments were common, often resulting in interruptions of tracking bouts, but researchers often retagged study animals without recapture by quietly snorkeling up to them and attaching a new radio-tag and tether to the belt (Reid et al. 1995). Methods of capture, tagging, and tracking are described in Reid et al. (1995) and Deutsch et al. (1998).

Each record was assigned a location class (LC) code by Argos that denoted the relative accuracy of the location. According to Service Argos (1996), 68% of locations should lie within the following distances from the actual latitude and longitude of the radio-tag: LC3, 150 m; LC2, 350 m; and LC1, 1000 m. Locations with poorer accuracy (> 1000 m) were assigned LC0 or, starting in June 1994, LCA or LCB. Field experiments with manatee PTTs have shown that locational error, especially in longitude, is somewhat greater than expected (Deutsch et al. 1997).

Water Temperature Recording

Ambient water temperature was monitored continuously at sites in the Banana Creek and the northern Banana River of Brevard County, Florida from February 1988 through May 1998. The instruments (Tempmentor RTM 2000, Ryan Instruments, Richmond, WA; Stowaway and Tidbit, Onset Computer Co., Pocasset, MA) were anchored at a depth of approximately 1 m. They stored electronic records of hourly temperatures over several months and were periodically downloaded to computers. The manufacturer's stated accuracy was ± 0.2 °C.

Data Processing and Analysis

Database manipulation, statistical analyses, and preliminary data visualization were accomplished using SAS for Windows. ArcView GIS software was employed for spatial

analyses of telemetry data in relation to locations of warm-water refugia and temporal changes in ambient water temperature.

Presence at a warm-water refuge was defined as a VHF location occurring within 200 m or a PTT location (LC1, LC2, or LC3) occurring within 1 km of the discharge site. Maps of each of the winter refugia show the polygons used to determine manatee presence (Appendix A). At certain refugia where the area of warm water extended well beyond the immediate discharge sites (e.g., FPL-PE, FPL-FL) or that were not point sources (e.g., Coral Gables, Sebastian River), the polygons were larger in size than indicated by the above distances (Appendix A). Most polygons defined for analysis of PTT locations included some areas of habitat outside of warm-water influence; for example, the FPL-PE polygon included parts of the Intracoastal Waterway (ICW) and of the ocean. Presence at an identified industrial thermal refuge did not necessarily mean that warm water was being discharged at the time of the manatee's visit, because some facilities operated intermittently in some winters or were subject to unanticipated shutdowns. Known eliminations of warm-water refugia (JS-FB) and shifts in discharge sites (Gilman) have been taken into account, however.

Three tagged manatees that exclusively used the upper Florida Keys were excluded from most analyses. The winter movements of these individuals were restricted to a relatively small area in upper Key Largo. Manatees in this region frequently used deep residential canals that apparently intersected the ground water (Kit Curtin, pers. comm.). This may have provided a natural warm-water refuge during cool weather; a common aggregation area was located in canals in the northeast corner of Buttonwood Sound (this study; Kit Curtin, pers. comm.). Our data on PTT temperatures showed no evidence for higher temperatures at this site, but locational imprecision made this assessment inconclusive. Because of this uncertainty, manatees using this region were not included in analyses.

Number and Geographic Extent of Warm-water Refugia Used

For each tagged manatee in each year between 1 November and 31 March, the following calculations were made: (a) total number of days tracked (i.e., carrying a functioning radio-tag); (b) total number of days located (by Argos or in the field); and (c) number of days located at each warm-water refuge (Appendix Tables B-1 and B-2). These values were then summed across winters to yield cumulative numbers of days tracked, days located, and days at each refuge over an individual's entire tracking period (Tables B-3 and B-4). The number of refugia visited and the geographic extent of an individual's use of warm-water sites were also tabulated for each winter (Table B-1) and cumulatively over the entire tracking period (Table B-3).

For analyses of the number of warm-water refugia and geographic regions used by individuals, the data were censored to exclude records with insufficient data. The censor criteria were chosen empirically from a visual examination of the data. The number of refugia visited per winter increased with tracking duration (between Nov. - Mar.) up to about 100 days (Figs. 2 and 3). A similar pattern was shown for the number of geographic regions in which manatees visited warm-water sites. Subsequent analyses of these variables were restricted to records in which the manatee was tracked for at least 100 days, or about two-thirds of the 151-152 days

between November and March. The number of warm-water refugia that a manatee used over its entire tracking period, often including multiple winters, increased with cumulative tracking duration to about 150 days (Figs. 4 and 5); the number of regions in which individuals sought shelter at warm-water sites showed a similar pattern in relation to cumulative tracking duration. Six individuals that were tracked >500 days (4 - 8 winters) visited, on average, considerably more warm-water sites, however (Fig. 5). Analyses of warm-water refuge use over an individual's entire tracking history were limited to manatees that were tracked for a cumulative total of at least 150 days.

Differential Use of Warm-water Refugia

The relative importance of different warm-water sources to tagged manatees in this study was investigated with the aim of differentiating between "primary" refugia that manatees relied on during cold periods versus "secondary" refugia that they visited only briefly. Sites that were in close proximity to one another were combined into "warm-water refuge areas" for these analyses, as follows: the Gilman and JS-FB pulp mills along the Florida-Georgia border; the 2 JEA power plants and the JS-JX pulp mill in the lower St. Johns River; the 2 Brevard County power plants; and the 2 power plants at Port Everglades and Fort Lauderdale (Fig. 1). Tagged manatees have been located on the same day at both sites in all of these refuge pairs except for the JEA sites, which were rarely used. For each manatee and winter in which tracking duration was at least 100 days between November and March, the number of days located at each warm-water refuge area was determined and expressed as a percentage of the total number of days located at all warm-water sites. This provided a measure of an individual's relative allocation of time among the various thermal refuge areas in each winter. A "primary" warm-water refuge area was defined as a site that comprised $\geq 33\%$ of the days spent at all refugia by a given individual in a given winter; "secondary" refuge areas were used less often. The number of manatees that utilized each site as a primary or secondary refuge was tallied. In cases where an individual's use of a site was categorized as primary in one winter and secondary in another winter, it was counted just once as primary use for this analysis.

Interannual Fidelity to Warm-water Refugia

The degree to which individuals showed site fidelity to warm-water refuge areas from one year to the next was examined. Individuals were included in the analyses if they were tracked for two or more winters for at least 50 days during the 90-day period of December through February of each winter. For each manatee and winter meeting this criterion, the number and percentage of days located at each warm-water refuge area (Nov.-Mar.) was determined, as described in the section above. Because it was common for manatees to briefly stop at warm-water sites during their seasonal migrations, we focused the site fidelity analyses on those refugia that individuals used most frequently during the winter. The number and percentage of interannual comparisons (i.e., from one year to the next year meeting criteria) in which an individual used (a) all of the same primary refugia in both years, and (b) at least one of the same primary refugia across years, was calculated.

Frequency of Use of Warm-water Refugia

The frequency with which manatees utilized warm-water sources was analyzed in relation to season (i.e., month of the year), region along the Atlantic coast (Fig. 1), and ambient water temperature. Only satellite-determined locations (LC1-3) were included in these analyses because field observations were collected primarily during daylight hours (Deutsch et al. 1998) and were likely to be biased toward use of winter aggregation sites. A manatee was considered to have visited a warm-water site on a given day if at least 1 location on that day was within the site's defined polygon, as described above. The percentage of days in which manatees visited thermal refugia was calculated from the pooled data across individuals, according to the following categories: month (all regions combined), region (Dec-Feb), month by region, and ambient water temperature. The mean daily water temperature in northern Brevard County was calculated from 24 hourly measurements per day (see above). The frequency of use of the 2 Brevard County power plants in the NC region was computed for 1-°C categories of ambient water temperature over the months of November through March.

RESULTS

Number of Warm-water Refugia Used

We radio-tracked 71 manatees along the east coast of Florida and Georgia during winter months over the course of this 12-year study. Thirty-seven radio-tagged manatees (69 manatee-winters) met the criteria (see Methods) for inclusion in analyses of single winter use of the network of warm-water refugia along the Atlantic coast north of the Florida Keys. They were tracked for a mean $\pm$ SD of 135.8 ± 16.2 days (range = 100 - 152 days) and located on 111.6 ± 25.8 days (range = 45 - 151 days) during the months of November through March of a given year. The manatees used a mean $\pm$ SD of 3.2 ± 1.4 identified refugia per winter, with most individuals visiting an average of 2 to 4 sites (Fig. 6). One individual (TPE-01) used only 1 warm-water refuge in 2 winters, but she visited an average of 1.8 sites per winter over 5 years. Eight individuals visited 5 or more warm-water sites in at least 1 of the winters that they were tracked. Adult female TNC-13 visited 8 thermal refugia—the highest number by any manatee in a single winter—during her southward migration from Savannah, GA to Port Everglades, FL; this does not include her brief visit to the pulp mill in Fernandina Beach, whose warm-water effluent had been diffused about 1 month before her arrival. All tagged manatees north of the Florida Keys utilized industrial warm-water sites (mean $\pm$ SD = 2.9 ± 1.3 , range = 1 - 7) in each winter that they were tracked.

Analyses of manatee use of the warm-water refuge network over their entire tracking periods were conducted for 32 tagged individuals that met the criteria (see Methods). They were radio-tracked for a mean $\pm$ SD of 334.2 ± 239.1 days (range = 151 - 1047 days) and located on 281.4 ± 198.9 days (range = 103 - 827 days) during the months of November through March over periods covering 1 to 8 winters. The manatees visited a mean $\pm$ SD of 4.3 ± 1.9 refugia over their tracking histories, with most individuals using 3 or 4 sites (Fig. 7). Many of these animals (53%) visited one or both of the 2 "natural" warm-water sites included in the analyses.

Most of the individuals that migrated south of Brevard County for the winter (73% of 22) used the Sebastian River for brief periods.

Geographic Extent of Warm-water Refuge Use

For a single winter season, manatees used thermal refugia that were spread over a mean $\pm$ SD of 1.9 ± 0.8 regions (range = 1 - 4, N = 37). Most tagged individuals (51%) visited warm-water sites in an average of 2 regions, but 30% of individuals restricted their use of these refugia to a single region (Fig. 8). Two long-distance migrants, whose annual range extended over 500 km between southeastern Florida and northeastern Florida or further north, used warm-water sites in all 4 regions in a single winter.

Over their entire tracking periods, individual manatees found warm-water refugia in a mean $\pm$ SD of 2.2 ± 0.9 regions (range = 1 - 4, N = 32). Most tagged manatees (84%) were familiar with warm-water sites in multiple regions (Fig. 9). Of the 5 individuals that were located at thermal refugia in only 1 region, 3 were seasonal migrants between the N region in the warm season and the NC region (i.e., Brevard County) in the winter; the other 2 were year-round residents within a region (1 in Brevard County and 1 in the Florida-Georgia border area). Three of the 4 individuals that used warm-water sites in all 4 regions were long-distance seasonal migrants along the Atlantic coast of Florida and Georgia; the other animal typically migrated seasonally between the NC and S regions, but also visited a power plant in the lower St. Johns River for 1 day early in 1 winter. Manatees visiting refugia in 2 regions fell into 1 of 2 distinct groups: those using the SC and S regions (N = 14), and those using the N and NC regions (N = 4).

For manatees using thermal refugia in a particular region, we asked what percentage of these animals also used refugia in each of the other regions at any time during their winter tracking periods? About 90% of tagged manatees using warm-water sites in the N region were familiar with the Brevard County power plants (i.e., north-central region), and nearly half also used refugia further south (Fig. 10). Most manatees (59%) observed using the NC sites also visited industrial warm-water effluents in the N region, and almost half used thermal refugia to the south. Ninety-five percent of manatees located at warm-water sites in the SC region also visited sites in the S region, and the converse was also true (Fig. 10). For both regions, 36% of the individuals also visited the Brevard County power plants and 23% used sites in the N region. Approximately one-quarter of the manatees that utilized the power plants in Brevard County were not observed to visit warm-water sites outside of this region during their tracking periods. Although sample sizes are small, this appeared to differ from the other 3 regions, where 0 - 9 % of individuals were restricted to a single region (Fig. 10). Of 23 manatees that used thermal refugia in the S or SC regions, 61% did not use industrial warm-water effluents in Brevard County or further north, even though most of these individuals spent the warm season in Brevard County. More importantly from a conservation standpoint, 50% of the manatees using warm-water sites in the N or NC regions (N = 18) were never observed to travel south of Brevard County.

None of the 71 manatees tracked along the Atlantic coast during winter visited Blue Spring or traveled south of Palatka, FL into the upper St. Johns River basin. The 3 manatees tracked in the upper Florida Keys during the 1993-94 winter did not use industrial warm-water refugia and did not travel north of the Keys into Biscayne Bay. One of these individuals (TFK-03) had been photo-identified in Biscayne Bay in three previous winters, however, including 2 sightings in Coral Gables Waterway (U. S. Geological Survey, unpublished data).

Differential Use of Warm-water Refugia

The various thermal refugia along the Atlantic coast differed in their relative importance to tagged manatees. The power plants in the Indian River of Brevard County and at Port Everglades and Fort Lauderdale attracted the greatest number of manatees, approximately 80% of which relied on them as primary refuge areas (Fig. 11). All 24 manatees using the Brevard County power plants visited both effluents, which were located about 3 km apart: 14 individuals used FPL-CC more often, 9 used OUC-IR more often, and 1 spent the same number of days at both plants. In contrast, use of the power plant discharge canals in the Port Everglades and Fort Lauderdale refuge area was not equal: all 17 individuals utilized FPL-PE, but only 5 visited FPL-FL; 2 manatees spent slightly more days at FPL-FL than at FPL-PE. The 4 warm-water sites located between Brevard County and Port Everglades were also visited by a large number of individuals, most (67-85%) of which used them as secondary refugia (Fig. 11). The northerly sites and CGW were used by relatively few tagged manatees. The Kemira gypsum plant, the GP-BR paper mill, and the industrial facilities in the St. Johns River were minor sites that were visited briefly, mostly at the start or end of the winter season (i.e., November and March). The Gilman and JS-FB pulp mills, on the other hand, attracted a small number of manatees that relied on them for their primary source of warmth through all or much of the winter (Fig. 11). Other manatees that appeared to use these pulp mills as secondary refugia during their northward migration in March were not tallied because they did not meet the tracking duration criterion (see Methods).

Interannual Fidelity to Warm-water Refugia

Seventeen manatees were tracked for 2 or more winters (maximum = 7) that met the censor criteria (total $n = 56$ manatee-winters). Most tagged manatees were remarkably consistent in their use of primary warm-water sites across years (Fig. 12). Some individuals returned to the same primary thermal refuge area year after year (e.g., Fig. 12A, B, H), while others regularly returned to the same 2 such areas (e.g., Fig. 12C, D, G, I, K). In 20 (51%) of 39 year-to-year comparisons, all primary refuge areas were shared from one year to the next. At least 1 primary refuge area was shared from one year to the next in 79% (31/39) of the cases and for 82% (14/17) of the individuals. Three of the 8 exceptions were generated by interannual variation in primary warm-water refuge use of adult female TBC-03: Port Everglades power plant in 1987-88, Sebastian River in 1988-89, Brevard County power plants in 1990-91 and 1992-93, and Port Everglades in 1993-94 (Fig. 12E). Two other exceptions were from adult male TFP-02: Vero Beach and Riviera Beach power plants in 1990-91, Sebastian River in 1991-92, and Riviera Beach in 1992-93 (Fig. 12L). Note that the relative symbol sizes in Figure 12 do

not represent the number of days at warm-water refugia, but rather the proportional allocation of time among refugia within a winter. During the 1990-91 winter, for example, individual TFP-02 was located at thermal refugia on only 4 days (2 at VB and 2 at FPL-RB, for 50% each, Fig. 12L), even though he was tracked the entire winter and located on 142 days between November and March.

The southernmost warm-water refuge that a manatee visited was consistent across years for 82% (14/17) of the individuals, including all 5 of those tracked for at least 5 winters (Fig. 12). This held true even for those manatees that exhibited interannual variation in the location of their primary refuge areas; TBC-03, for example, utilized the Port Everglades power plant effluent 8 winters in a row, although the allocation of time there relative to other refugia varied across years (Fig. 12E). The one individual that showed a major change in southerly winter destination was adult female TNC-10, a long-distance migrant that spent the warm season in the N and NC regions; she traveled to Port Everglades in one year but overwintered in Brevard County during the subsequent year (Fig. 12J).

Frequency of Warm-water Refuge Use: Seasonal and Regional Variation

Locational data were obtained on 58 manatees tracked with satellite-monitored PTTs north of the Florida Keys, yielding 21,475 manatee-days with locations (LC1-3) throughout the year. Tagged manatee use of warm-water refugia along the Atlantic coast showed a clear seasonal pattern: increasing in November, peaking in the coldest months of December through February, and decreasing in March (Fig. 13). Manatees visited thermal refugia on 36.2% of 5297 manatee-days during the main winter period (Dec-Feb). Use of these sites was low during the warm season (1.5 - 6.3% of manatee-days per month, April to October, Fig. 13).

The frequency with which tagged manatees used warm-water refugia varied greatly among regions. Restricting the analyses to the winter months of December through February, visitation of warm-water sources was highest in the N region (63.0% of manatee-days) and declined to the south (33.3% and 22.3% for NC and SC regions, respectively), although use was relatively high in southern Florida (39.6%) (Fig. 14). These regional differences in warm-water use were largely maintained throughout the winter (Fig. 15). The SC region experienced the lowest winter use of thermal refugia (Figs. 14 and 15), but it had the highest warm season use of these sites (6.1 - 14.2%), mainly because manatees continued to visit the north fork of the Sebastian River throughout the year.

Frequency of Warm-water Refuge Use: Variation in Relation to Temperature

Manatees' daily use of the Brevard County power plant effluents in the NC region increased as ambient water temperature declined (Fig. 16), as expected. Manatee use of these refugia started to increase at temperatures below 22 °C (Fig. 16). About half of the manatees in the NC region visited the power plants when the water temperature was between 16.0-16.9 °C and use reached 80.0% on the coldest days (<14 °C). This relationship between refugia use and water temperature was complicated, however, by the different responses of manatees with different migratory patterns to cool weather. Tagged manatees that overwintered in the NC

region, including 2 year-round residents and 12 seasonal migrants between the N and NC regions, visited the power plants much more often for a given temperature than did manatees that migrated south for the winter (Fig. 17A). Most individuals that overwintered in the NC region occupied the northern Indian River lagoon in the general vicinity of the power plants, whereas most migrants to southern Florida occupied the Banana River and were never observed to visit the Brevard County power plants. Restricting the analysis to the 21 individuals known to be familiar with these power plants elevated the frequency of use for the migrants to southern Florida, but it still remained less than that of individuals overwintering in the NC region (Fig. 17B).

DISCUSSION

Use of the Network of Warm-water Refugia

Most West Indian manatees along the Atlantic coast of the United States undertake seasonal migrations between northerly warm season and southerly winter ranges, primarily in response to seasonal changes in temperature (Reid et al. 1991, Deutsch et al. 2000a). Their principal winter destinations during cold weather center around a network of industrial and natural warm-water sites (Fig. 1). This radio-telemetry study demonstrated that all tagged manatees north of the Florida Keys were familiar with multiple thermal refugia (Fig. 7) and used industrial effluents in every winter. The only individuals completely independent of industrial sites occupied winter ranges in Key Largo (N = 3 manatees in 1 winter). For most individuals (84%), these refugia were spread across an extensive geographic area including 2 or more defined regions (Fig. 9). No tagged animals traveled into the upper St. Johns River basin, however. Given the manatee's long lifespan (Marmontel et al. 1996), wide-ranging movements (Deutsch et al. 2000a), and relatively narrow band of habitat in the intracoastal waters, it seems likely that individuals were familiar with most or all warm-water sites within their annual range. The annual ranges of manatees along the Atlantic coast vary greatly, from year-round residents whose movements are restricted to a particular region, to long-distance migrants that travel several hundred km across all 4 coastal regions (Deutsch et al. 2000a). Individuals with more extensive ranges over the annual cycle and, hence, having experience with a larger number of refugia, may have greater flexibility in adapting to changes in the locations and operation of man-made warm-water sources than those with more limited ranges.

There was little overlap in the network of thermal refugia used by two distinct groups of seasonal migrants: (1) those migrating between the N and NC regions relied principally on the Brevard County power plants and some also used northern sites; and (2) those migrating between central (NC or SC) and S regions utilized a variety of warm-water sites, primarily in the S region, but secondarily in the SC and NC regions. The seasonal movements of the latter group probably represent the traditional pattern of migration that existed historically, except for the presence of large, cold-induced aggregations of manatees around power plants. The entire year-round range of the former group was north of the presumptive historical winter range of Florida manatees on the east coast. Half of the tagged manatees that visited warm-water refugia in the N

or NC regions were never observed at refugia to the south or even to travel south of Brevard County during their tracking periods. Likewise, 24% of over 200 distinctively scarred manatees known to have used the Brevard County power plants during winter have never been sighted at a thermal refuge to the south (Beck 2000). Thus, both tracking and photo-identification studies indicate that a large component of the Atlantic coast population does not migrate to the historical winter range in southeastern Florida, but instead relies on man-made sources of warm water to sustain them through cold periods in more northerly areas. Those individuals that migrate seasonally between the N and NC regions, or that occupy year-round ranges within 1 of these 2 regions, are particularly vulnerable to disruption or termination of these thermal discharges.

In the northern portion of the Florida manatee's range, cold winter temperatures have been a serious cause of mortality on an episodic basis. An average of 10% of all deaths and 22% of winter deaths in northeastern Florida, including Brevard County, were attributed to cold stress during 1986 - 1992 (Ackerman et al. 1995). Exceptionally high cold-related mortality in Florida occurred during 4 winters between 1974 - 1992 (Campbell and Irvine 1981, O'Shea et al. 1985, Ackerman et al. 1995). In all cases, the subadult size class suffered the greatest mortality. The most severe cold-related mortality event occurred during the 1989-90 winter, when at least 61 manatees died of cold stress, including 50 along the Atlantic coast; all but one of these 50 carcasses were recovered north of Vero Beach (Ackerman et al. 1995). The 2 power plants in Brevard County were apparently unable to produce sufficiently warm water to keep all manatees using them alive; ambient water temperatures dropped to lows of about 8 °C at the plant intakes and 4 °C elsewhere in the Indian River lagoon system. The OUC-IR plant essentially shut down about 1 week after the arrival of the severe cold front, when intake temperature was still only 13.3 °C. A similar event took place in January 1977, when intake water temperature at the FPL-CC plant fell to 8 °C and discharge temperatures were as low as 11 °C and 13 °C after 2 partial shutdowns (i.e., only 1 generating unit was operating) (Campbell and Irvine 1981). Unusually high winter mortality of tagged and untagged manatees in northeastern Florida and Georgia, presumably from cold stress, was associated with the elimination of a regionally important warm-water refuge created by the JS-FB pulp mill outfall (Deutsch et al. 2000b).

Differential Use of Warm-water Refugia

Most tagged manatees (79% of 38) utilized the Brevard County power plants, the FPL-PE power plant, or both as primary warm-water refugia during winter. These sites have produced a large volume of heated effluent fairly consistently throughout the study period. A majority (55%) of individuals used the 4 intervening sites but mostly for brief periods as secondary refugia (Fig. 11). Sebastian River and the intracoastal waters between Ft. Pierce and Vero Beach have been identified as important stopover sites for manatees during their seasonal migrations (Deutsch et al. 2000a), which explains the present finding. The Ft. Pierce plant has operated intermittently during some winters of the study. The northern refugia were used by relatively few tagged manatees; these sites were located in waters where the average winter temperature was well below the species' thermoneutral zone. The relative use of the different warm-water sites should be interpreted cautiously because our tagged animals did not represent a random

sample of the Atlantic coast population. The general concordance of these results with those from aerial survey counts (Reynolds and Wilcox 1994, Ackerman 1995, Reynolds 1996) and photo-identification sightings (Reid et al. 1991, Beck and Reid 1995), however, provides some assurance that the ranking of relative importance of the various warm-water refugia to Atlantic coast manatees was not biased much by the distribution of tagging locations.

Interannual Fidelity to Warm-water Refugia

Manatees exhibited strong site fidelity to 1 or 2 primary warm-water refuge areas across multiple years (Fig. 12). Some individuals also showed consistency in their use of secondary refugia from one year to the next; for example, TBC-24 was located in the Sebastian River sanctuary in 5 of 6 years (Fig. 12C) and TBC-09 visited the Vero Beach power plant in 6 of 8 years (Fig. 12A). Such regular visits to these warm-water sites typically occurred as brief migratory stopovers during seasonal and mid-winter migrations (Deutsch et al. 2000a). The vast majority of manatees consistently returned to the same southernmost warm-water destination year after year, if only for a brief duration (e.g., Fig. 12E). Exceptions to this generalization (Fig. 12J, K, O) included 1 long-distance migrant (TNC-10) that shifted overwintering areas from Port Everglades to Brevard County. Given the wide interannual fluctuations in winter aerial counts of manatees at the Brevard County power plants (Reynolds and Wilcox 1994, Ackerman and Reynolds 2000), I suspect that year-to-year shifts between NC and S regions may be more common than indicated in this study. Yet many tagged individuals did show interannual variation in the relative allocation of time among the warm-water sites within their annual range (e.g., Fig. 12E).

This variability suggests that individual manatees possess the behavioral plasticity to adjust their winter movement patterns in relation to variation in winter severity or effluent operation across years. The degree to which manatees are able to respond adaptively to changes in the availability of warm water is subject, however, to a number of constraints. One obvious constraint is the geographic extent of an individual's annual range and its familiarity with thermal refugia within that range. Manatees that have no experience south of Brevard County might not migrate south if the 2 local power plants were retired. They would probably be even less likely to leave if the plants continued to generate warm water intermittently through the winter, leaving them susceptible to cold-related illness. Another important constraint is the speed with which an individual can alter its migratory or sheltering behavior, especially when faced with severe cold. Ambient water temperatures in the shallow estuaries and lagoons of northeast and central Florida can cool rapidly with the passage of major cold fronts: Banana Creek temperature during the March 1993 "Storm of the Century," for example, dropped 10.2 °C in a 24-hr period! Familiarity with several sites within the network of warm-water refugia is helpful only if the animal is able to survive exposure to cold temperatures while in transit between sites. Relatively little is known about how long free-ranging manatees can tolerate low temperatures and how this varies with size and nutritional status. So while their experience with multiple thermal refugia will help manatees survive future changes in the spatial and temporal availability of warm water, it should not generate complacency on the part of managers. The

threat of catastrophic mortality associated with the shutdown or intermittent operation of an industrial thermal discharge during a prolonged hard freeze is very real.

Long-term fidelity of distinctively scarred Florida manatees to winter aggregation sites at natural artesian springs has been well-documented using photo-identification techniques (Powell and Waldron 1981, Powell and Rathbun 1984, Rathbun et al. 1990, 1995, O'Shea and Hartley 1995) and radio-telemetry (Bengtson 1981). Some individuals have been resighted at these same springs over a span of at least 15 years (O'Shea and Hartley 1995, Rathbun et al. 1995). The phenomenon of interannual fidelity to man-made warm-water sites was first noted in the early 1950's, when Moore (1956) identified several manatees in more than 1 winter, and up to 5 years apart, aggregating around the same industrial effluent in the Miami River. A long-term, intensive photo-identification study along Florida's east coast began to reveal the complex nature of manatee winter movements and use of thermal refugia (Reid et al. 1991). The authors found clear evidence for interannual site fidelity (i.e., at least 1 sighting in each of 2+ years) to all of the major winter aggregation areas, particularly FPL-PE, FPL-RB, and the Brevard County power plants. Unlike our telemetry findings, however, only 6% of 237 cataloged and resighted manatees were observed at more than 1 warm-water site within a winter (Reid et al. 1991). Forty-one individuals (17%) in their study were resighted at different aggregation sites in different years, suggesting a possible shift in their overwintering area. Radio-telemetry research has since demonstrated the dynamic nature of manatee winter movements along the Atlantic coast (Deutsch et al. 2000a, this study), and indicates that interpretation of individual movements and shifts in overwintering areas based on resighting data must be done with caution. Deutsch et al. (2000a) found strong interannual fidelity to winter ranges, irrespective of warm-water refugia, based on cluster analyses of locational data from this long-term telemetry study: the median distance between winter range centers (within the same region) from 1 year to the next was 3.4 km, and 76% of the individuals returned to within 10 km of the previous year's range center. Most individuals tracked over multiple years remained faithful to the same winter ranges (Deutsch et al. 2000a), and this is reflected in the high fidelity to specific warm-water aggregation sites demonstrated in this report.

Factors Affecting the Frequency of Warm-water Refuge Use

The principal environmental factor affecting the frequency with which manatees used thermal refugia was ambient water temperature (Fig. 16). This was expected based on knowledge of the species' metabolic physiology (Irvine 1983) and of the well-documented inverse relationship between winter aerial counts at power plants and ambient temperature (Rose and McCutcheon 1980, Packard and Mulholland 1983, Shane 1984, Garrott et al. 1994). The mean daily water temperature at which tagged manatees in Brevard County began to show a behavioral response was 22 °C: they rarely visited the power plants above this threshold, and their use of these sites increased steadily with declines below 22 °C (Fig. 16). Manatees initiated their southward autumn migration or initial move to the local power plants in Brevard County in response to cold fronts that dropped water temperature to an average of 19 °C, but there was considerable variation among individuals (Deutsch et al. 2000a). The temperature threshold of 22 °C corresponds to the upper limit of response shown by some individuals that

appeared to be more sensitive to cold. These results are concordant with previous studies which found that manatees start to arrive at warm-water refugia in autumn or early winter when ambient water temperature drops to approximately 20-22 °C (Hartman 1979, Bengtson 1981, Powell 1981, Powell and Waldron 1981, Shane 1984). The lower critical limit (T_{lc}) of the thermoneutral zone for adult Florida manatees was estimated to be about 24 °C by Irvine (1983), but more extensive measurements by Worthy et al. (2000) placed the T_{lc} at 20 °C, below which the animal's metabolic rate increases by 50-100%. Visits to warm-water sources allow manatees to reduce cold-related energetic demands in winter and to perfuse skin tissues following periods of peripheral vasoconstriction while in cooler waters (Worthy et al. 2000). This is particularly important in the northern portion of the Florida manatee's range where ambient water temperatures frequently drop below the adult thermoneutral zone. In northern Brevard County (Banana Creek and Banana River), for instance, the mean daily water temperature was <20 °C on an average of 66.5% of the days between December and February (1988 - 1998, this study). Water temperatures to the north are, of course, even cooler in winter (Irvine 1983, Deutsch et al. 2000a). Powell and Waldron (1981) found that interannual variation in use of Blue Spring by resident manatees correlated with average water temperature of the St. Johns River during winter: individuals visited the run on an average of 30% of days in a mild winter (mean temperature = 19.4 °C), 44% of days in a cooler winter (17.4 °C), and 74% of days in the exceptionally cold winter of 1976-77 (16.1 °C). The frequency of use for 2 of the 3 years at Blue Spring was similar to that found for the NC region in this study.

Anecdotal evidence from captive manatees suggests that feeding may become irregular at water temperatures of 18-19 °C and may cease entirely at or below 16 °C (Moore 1951, citing a letter from L. Leigh; Brownell et al. 1981, citing a statement made by Jenkins at a workshop; Campbell and Irvine 1981, citing a pers. comm. from C. Walker). Yet free-ranging manatees have been observed to make feeding forays from warm-water aggregation sites into 15 °C waters (Hartman 1979, Bengtson 1981). In the present study, the mean daily water temperature in the shallow waters of Brevard County dropped below 16 °C on an average of 21.2% of winter days (Dec.-Feb., 1988-1998); the lowest mean temperature recorded was 6.3 °C during the hard freeze of December 1989. Tagged manatees in the NC region visited the Brevard County power plants on nearly half of the days when the mean daily water temperature was 16.0-16.9 °C (Fig. 16). Pooling data from manatees following different seasonal movement patterns, however, obscured the actual relationship between refuge use and ambient temperature. Manatees overwintering in the NC region visited the power plants on 69% and 84% of days when water temperatures averaged 16.0-16.9 °C and <16 °C, respectively; comparable figures for manatees that overwintered in the S region were 20% and 24%, respectively, while they resided in the NC region (Fig. 17A). This low use of the Brevard County power plants during cold weather by southerly migrants resulted from two main factors: (1) most (59% of 22) of these migrants never used either of the 2 local power plants during their tracking periods and may not even have been familiar with them; and (2) most responded to declining water temperatures by migrating south out of the NC region rather than by moving to the local power plants, thus leaving the most cold-tolerant of migrants in the region during periods of low temperatures. Deutsch et al. (2000a) found that the most cold-tolerant individuals remained on their warm season range until the water temperature dropped to an average of 16 °C. They hypothesized that manatees not seeking

shelter at industrial sites when water temperatures became cool (16 - 20 °C) on their warm season range were able to behaviorally thermoregulate by moving to warmer, deep-water habitats (e.g., dredged basins or canal systems) that cooled more slowly than the more extensive shallows.

Seasonal and regional variation in warm-water use were largely accounted for by variation in temperature regime. Manatees utilized thermal refugia primarily during the coldest winter months of December through February and, to a lesser extent, during the transitional months of November and March (Fig. 13). The mean monthly ambient water temperature in Brevard County during this study was <20 °C only for the 3 winter months, but temperatures often dropped this low also during the 2 transitional months. The seasonal pattern of use of warm-water sites by tagged manatees was very similar to that found in aerial surveys of manatees at power plants along the Atlantic coast (Rose and McCutcheon 1980, Shane 1983). Visits to these sites during the warm season (April to October) were infrequent in all regions, but one may wonder why there was any use at all when manatees were not thermally stressed. Manatees may have visited some of these sites during the warm season for access to freshwater or to a protected resting area (e.g., Sebastian River); researchers have observed manatees in the intake canals of Brevard County power plants year-round, especially during the warm season (Rose and McCutcheon 1980, Shane 1981). Some "use" may also have represented animals traveling by the sites (<1 km) or may have been a consequence of Argos locational error (Deutsch et al. 1997).

Latitudinal variation in average winter temperatures along the Atlantic coast (see Fig. 4 in Irvine 1983) accounts for the general pattern of increasing use of warm-water refugia with increasing latitude (Fig. 14 and 15). The frequency with which tagged manatees utilized thermal refugia in the SC region was particularly low, perhaps because most retreated to the FPL-RB power plant or other sites in the S region during very cold weather. In fact, only 1 tagged individual (TBC-36, 1992-93) spent the entire winter in the SC region; most overwintered in either the S or NC regions and a few remained in the N region (Deutsch et al. 2000a). The major exception to the pattern of increasing refuge use with latitude was the relatively high use of warm-water sites in the S region (Fig. 14). One behavioral characteristic that undoubtedly contributed to this anomaly was the occurrence of mid-winter migrations from the S region to the SC and NC regions during periods of mild weather, followed by return movement to the S region upon the passage of the next major cold front (Deutsch et al. 2000a). Consequently, the percentage of days at thermal refugia was elevated in the S region and lower in the SC and NC regions. Manatees may have also utilized certain southern refugia—particularly the Port Everglades power plant's effluent canal and Coral Gables Waterway—for reasons in addition to warm water, such as access to freshwater sources and undisturbed resting areas. Since boaters were prohibited from portions of these waterways during winter, manatees were able to rest, nurse their young, and socialize with conspecifics free of disturbance from watercraft.

RECOMMENDATIONS FOR FURTHER ANALYSIS OF TELEMETRY DATA

Radio-telemetry is the principal means by which we can investigate detailed movements of manatees within a winter in relation to the distribution of warm-water sources, ambient water temperatures, and other environmental variables. The long-term Atlantic telemetry databases store a wealth of information that is available from no other source. With the exception of the use-temperature relationship for the Brevard County power plants (Fig. 16 and 17), analyses conducted to date have focused on manatee utilization of the network of warm-water refugia over broad spatial (e.g., regional) and temporal (e.g., seasonal) scales. The following analyses of the existing databases need to be carried out for a full understanding of how environmental factors affect manatee use of warm-water sources during winter: (1) The relationship between manatee use of thermal refugia and ambient water temperature needs to be quantified for each of the other regions, and the effects of previous days' temperatures should be statistically analyzed. Geographic or site-specific differences in this relationship may yield insights into the effects of other contributing environmental variables. (2) The temperature, volume, and operating schedule of industrial discharges clearly affect the attractiveness of a warm-water site to manatees, but the relationships have not been characterized. For a given ambient temperature range, is manatee use positively correlated with discharge temperature above a certain threshold (e.g., 20 °C)? Archived data on intake and discharge water temperatures (minimum and maximum each day) and operating hours (total per day) for FPL power plants are available, albeit incomplete. (3) Manatees have been found to exhibit a diel pattern of use of warm-water springs and other natural aggregation sites in winter (Bengtson 1981, Rathbun et al. 1990, Deutsch et al. 1998). If the same holds true for manatee use of industrial thermal effluents, it has important implications for the interpretation of aerial survey counts at power plants. Preliminary examination of telemetry data in the Indian River of Brevard County suggests that manatees show a diel pattern of power plant utilization at cool ambient temperatures (16-20 °C), with highest use in the afternoon and least at night (Deutsch 2000). Less frequent operation of the utility at night may account for this pattern, but it has not been investigated. Lower manatee counts at the Brevard County power plants in the early morning relative to the late morning have been attributed to poorer visibility conditions and manatee resting behavior (Reynolds and Wilcox 1994), but diel variation in manatee movements may also contribute to the observed difference. The Sirenia Project tracked several focal individuals for 36-hr periods throughout the winter of 1987-88 with VHF telemetry, but these data were not incorporated into the main VHF telemetry database. Quantitative analysis of this specialized VHF database, in addition to the large Argos telemetry database accumulated over 12 years, would shed light on the diel pattern of warm-water use in Brevard County. Similar analyses should be conducted at other major winter aggregation areas, such as Port Everglades power plant. (4) Manatees behave as central-place foragers when the ambient water temperature is generally <20 °C; they make feeding forays out from a warm-water refuge and then return. An analysis of the maximum distance that individuals move away from a refuge in relation to temperature would complement the above analyses of environmental factors affecting presence/absence at refugia.

The frequency with which tagged manatees visited warm-water refugia appeared to vary among individuals, although variation among years and among regions in temperature regime

may be confounded with inter-individual variation. If sample sizes are sufficient, it would prove useful to examine whether this variation is related to individual attributes, such as sex, body size, or reproductive status. Some individuals were nearly independent of industrial thermal sources in some years: adult male TFP-02, for example, spent only 4 days at warm-water refugia in 1990-91 even though he was tracked for the entire winter and located on 142 days between November and March, mostly in the SC region between Jupiter and Ft. Pierce. Likewise, some manatees that primarily occupied the Banana River in Brevard County survived cool temperatures without resorting to industrial warm-water effluents, at the same time that many manatees in the Indian River visited the power plant (Fig. 17). A more detailed analysis of the movements and habitat selection of tagged individuals that did not always use power plants in response to cold may reveal alternative strategies for survival and may point to management actions that could potentially reduce manatee dependence on industrial thermal effluents. This type of investigation would also be valuable to managers challenged with developing a network of non-industry-based winter refugia—an alternative that is being studied by some manatee researchers (Reynolds 2000) and supported by the Florida Power and Light Company.

This report provides a summary of interannual site fidelity to warm-water refugia but does not quantify the degree to which manatees showed fidelity to particular sites within a winter season. That is, did individuals exhibit a preference for just 1 or 2 warm-water sources within a winter, or did they spend similar amounts of time at multiple sites? Did manatees that used multiple refugia frequently move back and forth among them within a winter? If so, this may indicate that animals continue to assess the relative quality of the different sites. Some manatees tracked over multiple winters varied in the relative proportion of time spent in different regions and at different refugia. Can environmental correlates, such as winter severity or power plant operation, be identified that might account for such temporal variation? For example, mild temperatures in the winter of 1988-89 apparently led to a number of tagged manatees spending considerable time in the Sebastian River. How did the migratory and sheltering behavior of these manatees differ from other winters?

Many other questions regarding manatee use of warm-water refugia could be posed. How manatees respond to disruptions in industrial thermal effluents is a critical issue. A review of the power plant temperature databases may provide specific instances of such disruptions, and these could be used to select specific areas and time periods for closer scrutiny of available data on movements of tagged individuals. The Atlantic coast telemetry databases represent a virtual goldmine of information awaiting the posing of innovative questions. It is my view that the application of rigorous analyses to this unique long-term data set will continue to enhance our understanding of manatee behavioral ecology and shed light on crucial management problems.

ACKNOWLEDGMENTS

This study was conducted by the Sirenia Project, Florida Caribbean Science Center, U. S. Geological Survey (USGS), which provided essential base funds for the work. Additional funding was provided by the U. S. Fish and Wildlife Service (USFWS), Florida Department of Environmental Protection (FDEP), Georgia Department of Natural Resources (GDNR), National Fish and Wildlife Foundation, Lockheed Space Operations Company, Port Everglades Authority, Florida Power and Light Company (in cooperation with Florida Audubon Society), the Army Corps of Engineers, the U. S. Marine Mammal Commission, Port of Fernandina, the U.S. Navy, and Save the Manatee Club. The Florida Power and Light Company provided funding for the preparation of this report and I thank Winifred Perkins for making this possible.

Colleagues who have been instrumental in this study and who will be coauthors on future publication of this work include Bob Bonde, Dean Easton, Howard Kochman, Tom O'Shea, and Jim Reid, all with USGS. Over the 12 years and the great distances spanned by these research efforts, numerous other individuals provided valuable technical, logistic, or field assistance; they worked for a number of agencies and organizations, including: USGS, USFWS (especially Merritt Island National Wildlife Refuge), FDEP, GDNR, National Park Service Cooperative Research Unit at the University of Georgia, Florida Cooperative Fish and Wildlife Research Unit, Telonics, Inc., Service Argos, Inc., and Dynamac Corporation (NASA contractor). For their considerable time spent radio-tracking in the field, I especially thank Kevin Abbott, Bob Bonde, Susan Butler, Kit Curtin, Dean Easton, Maria Okoniewski Eifler, Jim Reid, Martha Suarez, Sharon Tyson, and Barb Zoodsma. Assistance with handling and release of rehabilitated captive manatees was provided by Sea World of Florida, Miami Seaquarium, Lowry Park Zoo, and FDEP. This project was also supported in part by Cooperative Agreement No. 14-45-0009-1544 (Research Work Order No. 163) through the Florida Cooperative Fish and Wildlife Research Unit (USGS, University of Florida, Florida Fish and Wildlife Conservation Commission, and Wildlife Management Institute cooperating). I thank Susan Butler, Dean Easton, and Howard Kochman for assistance with database management; Kit Curtin and Kem Mayo for information on manatee use of aggregation sites in southeastern Florida; Bob Bonde, Dean Easton, Jim Reid, and Jim Valade for help with determining coordinates of warm-water discharges; Lynn Lefebvre for her instrumental role in continuing the manatee tracking studies; H. Franklin Percival for administering the work order; Barbara Fesler and Karen Ahlers for administrative support; and Winifred Perkins, Lynn Lefebvre, and Bob Bonde for comments on an earlier draft of the report. Permission to conduct the activities outlined in this report was granted under the authority of U.S. Fish and Wildlife Service Federal Wildlife Permits PRT-684532 and PRT-791721.

LITERATURE CITED

- Ackerman, B. B. 1995. Aerial surveys of manatees: a summary and progress report. Pp. 13-33 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technology Report 1.
- Ackerman, B. B. and J. E. Reynolds, III. 2000. Manatee use of power plant effluents as shown by winter aerial surveys. Pages 56-61 in U. S. Fish and Wildlife Service. Florida manatees and warm water: Proceedings of the warm-water workshop, Jupiter, Florida, August 24-25, 1999.
- Ackerman, B. B., S. D. Wright, R. K. Bonde, D. K. Odell, and D. J. Banowetz. 1995. Trends and patterns in mortality of manatees in Florida, 1974-1991. Pages 223-258 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technology Report 1.
- Bangs, O. 1895. The present standing of the Florida manatee, *Trichechus manatus latirostris* (Harlan) in the Indian River waters. Amer. Nat. 29: 783-787.
- Beck, C. A. 2000. Winter use of warm water sites by photographically identified manatees. Pages 65-66 in U. S. Fish and Wildlife Service. Florida manatees and warm water: Proceedings of the warm-water workshop, Jupiter, Florida, August 24-25, 1999.
- Beck, C. A. and J. P. Reid. 1995. An automated photo-identification catalog for studies of the life history of the Florida manatee. Pages 120-134 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technology Report 1.
- Bell, J. T. 2000. Characterization and analysis of artificial warm-water refugia and their use by the Florida manatee, *Trichechus manatus latirostris*, on the east coast of Florida. Master's Thesis. Duke University. 55 pp. + appendices.
- Bengtson, J. L. 1981. Ecology of manatees (*Trichechus manatus*) in the St. Johns River, Florida. Ph.D. Thesis, University of Minnesota. 126 pp.
- Brownell, R. L., Jr., K. Ralls, and R. R. Reeves. 1981. Report of the West Indian manatee workshop. Pages 3-16 in R. L. Brownell, Jr., and K. Ralls, eds. The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida, 27-29 March 1978. Florida Department of Natural Resources, Tallahassee, FL.

- Buergelt, C. D., R. K. Bonde, C. A. Beck, and T. J. O'Shea. 1984. Pathologic findings in manatees in Florida. *Journal of the American Veterinary Medical Association* 185: 1331-1334.
- Cahn, A. R. 1940. Manatees and the Florida freeze. *J. Mamm.* 21: 222-223.
- Campbell, H. W. and A. B. Irvine. 1981. Manatee mortality during the unusually cold winter of 1976-1977. Pp. 86-91 in R. L. Brownell, Jr., and K. Ralls, eds. *The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida, 27-29 March 1978.* Florida Department of Natural Resources, Tallahassee, FL.
- Deutsch, C. J. 1996. Movements and spatial use patterns of radio-tagged West Indian manatees (*Trichechus manatus*) along the Atlantic coast of Florida and Georgia: A progress report. Unpublished report for RWO No. 125. Sirenia Project, National Biological Service and Florida Cooperative Fish and Wildlife Research Unit, University of Florida and National Biological Service. Gainesville, FL. 93 pp.
- Deutsch, C. J. 2000. Winter use of thermal refugia by radio-tagged manatees along the Atlantic coast. Pages 62-64 in U. S. Fish and Wildlife Service. *Florida manatees and warm water: Proceedings of the warm-water workshop, Jupiter, Florida, August 24-25, 1999.*
- Deutsch, C. J., R. K. Bonde, and J. P. Reid. 1998. Radio-tracking manatees from land and space: Tag design, implementation, and lessons learned from long-term study. *Marine Technology Society Journal* 32: 18-29.
- Deutsch, C. J., D. E. Easton, H. I. Kochman, and J. P. Reid. 1997. Locational accuracy of the Argos satellite telemetry system in a marine environment: Implications for spatial data analysis and wildlife management. Forum on wildlife telemetry: Innovations, evaluations, and research needs. 21-23 September 1997, Snowmass Village, Colorado. Program and Abstracts. U.S. Geological Survey and The Wildlife Society. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. <http://www.npwrc.usgs.gov/resource/tools/telemetry/argos.htm>
- Deutsch, C. J., J. P. Reid, R. K. Bonde, D. E. Easton, H. I. Kochman, and T. J. O'Shea. 2000a. Seasonal movements, migratory behavior, and site fidelity of West Indian manatees along the Atlantic coast of the United States as determined by radio-telemetry. Final Report. Research Work Order No. 163. Florida Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey and University of Florida. 254 pp. + xii.
- Deutsch, C. J., J. P. Reid, L. W. Lefebvre, D. E. Easton, and B. J. Zoodsma. 2000b. Manatee response to elimination of a thermal refuge in northeastern Florida: A preliminary report of results. Pages 71-73 in U. S. Fish and Wildlife Service. *Florida manatees and warm water: Proceedings of the warm-water workshop, Jupiter, Florida, August 24-25, 1999.*

- Fancy, S. G., L. F. Pank, D. C. Douglas, C. H. Curby, G. W. Garner, S. C. Amstrup, and W. L. Regelin. 1988. Satellite telemetry: a new tool for wildlife research and management. U.S. Fish and Wildlife Service, Resource Publication 172:1-54.
- Florida Department of Environmental Protection, Florida Marine Research Institute. 1998. Atlas of Marine Resources, version 1.2 (CD-ROM).
- Garrott, R. A., B. B. Ackerman, J. R. Cary, D. M. Heisey, J. E. Reynolds III, P. M. Rose, and J. R. Wilcox. 1994. Trends in counts of Florida manatees at winter aggregation sites. J. Wildl. Manage. 58: 642-654.
- Hartman, D. S. 1979. Ecology and behavior of the manatee (*Trichechus manatus*) in Florida. Amer. Soc. Mammalogists Spec. Pub. No. 5. 153 pp.
- Irvine, A. B. 1983. Manatee metabolism and its influence on distribution in Florida. Biological Conservation 25: 315-334.
- Lefebvre, L. W., T. J. O'Shea, G. B. Rathbun, and R. C. Best. 1989. Distribution, status, and biogeography of the West Indian manatee. Pages 567-610 in C. A. Woods, ed. Biogeography of the West Indies: past, present, and future. Sandhill Crane Press, Gainesville, FL.
- Marmontel, M., T. J. O'Shea, H. I. Kochman, and S. R. Humphrey. 1996. Age determination in manatees using growth-layer-group counts in bone. Mar. Mamm. Sci. 12: 54-88.
- Moore, J. C. 1951a. The range of the Florida manatee. Quarterly Journal of the Florida Academy of Sciences 14: 1-19.
- Moore, J. C. 1951b. The status of the manatee in the Everglades National Park, with notes on its natural history. J. Mamm. 32: 22-36.
- Moore, J. C. 1956. Observations of manatees in aggregations. American Museum Novitates 1811: 1-24.
- O'Shea, T. J., C. A. Beck, R. K. Bonde, H. I. Kochman, and D. K. Odell. 1985. An analysis of manatee mortality patterns in Florida, 1976-81. J. Wildl. Manage. 49: 1-11.
- O'Shea, T. J. and W. C. Hartley. 1995. Reproduction and early-age survival of manatees at Blue Spring, upper St. Johns River, Florida. Pages 157-170 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technology Report 1.

- O'Shea, T. J. and C. A. Langtimm. 1995. Estimation of survival of adult Florida manatees in the Crystal River, at Blue Spring, and on the Atlantic Coast. Pp. 194-222 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technology Report 1.
- Packard, J. M., R. K. Frohlich, J. E. Reynolds, III, and J. R. Wilcox. 1989. Manatee response to interruption of a thermal effluent. *J. Wildl. Manage.* 53: 692-700.
- Packard, J. M and R. Mulholland. 1983. Analysis of manatee aerial surveys: A compilation and preliminary analysis of winter aerial surveys conducted in Florida between 1977 and 1982. Manatee Population Research Report No. 2. Technical Report No. 8-2. Florida Cooperative Fish and Wildlife Research Unit. University of Florida, Gainesville, FL. 119 pp.
- Powell, J. A. 1981. The manatee population in Crystal River, Citrus County, Florida. Pages 33-40 in R. L. Brownell, Jr., and K. Ralls, eds. The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida, 27-29 March 1978. Florida Department of Natural Resources, Tallahassee, FL.
- Powell, J. A. and G. B. Rathbun. 1984. Distribution and abundance of manatees along the northern coast of the Gulf of Mexico. *Northeast Gulf Science* 7: 1-28.
- Powell, J. A. and J. C. Waldron. 1981. The manatee population in Blue Spring, Volusia County, Florida. Pages 41-51 in R. L. Brownell, Jr., and K. Ralls, eds. The West Indian manatee in Florida. Proceedings of a workshop held in Orlando, Florida, 27-29 March 1978. Florida Department of Natural Resources, Tallahassee, FL.
- Rathbun, G. B., J. P. Reid, R. K. Bonde, and J. A. Powell. 1995. Reproduction in free-ranging Florida manatees. Pp. 135-156 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technology Report 1.
- Rathbun, G. B., J. P. Reid, and G. Carowan. 1990. Distribution and movement patterns of manatees (*Trichechus manatus*) in northwestern peninsular Florida. *Fl. Mar. Res. Publ.* 48: 1-33.
- Reid, J. P., R. K. Bonde, and T. J. O'Shea. 1995. Reproduction and mortality of radio-tagged and recognizable manatees on the Atlantic Coast of Florida. Pages 171-191 in T. J. O'Shea, B. B. Ackerman, and H. F. Percival, eds. Population biology of the Florida manatee (*Trichechus manatus latirostris*). National Biological Service, Information and Technical Report 1.

- Reid, J. P., G. B. Rathbun, and J. R. Wilcox. 1991. Distribution patterns of individually identifiable West Indian manatees (*Trichechus manatus*) in Florida. *Mar. Mamm. Sci.* 7: 180-190.
- Reynolds, J. E., III. 1996. Distribution and abundance of Florida manatees (*Trichechus manatus latirostris*) around selected power plants following winter cold fronts: 1995-1996. Final Report, Florida Power and Light Company, North Palm Beach, FL. Contract Number B93135-00139.
- Reynolds, J. E., III. 2000. Possible locations for long-term, warm-water refugia for manatees in Florida: Alternatives to power plants. Report to Florida Power and Light Company. 68 pp.
- Reynolds, J. E., III and J. R. Wilcox. 1994. Observations of Florida manatees (*Trichechus manatus latirostris*) around selected power plants in winter. *Mar. Mamm. Sci.* 10: 163-177.
- Rose, P. M. 1997. Manatees and the future of electric utilities deregulation in Florida. *Sirennews* 28: 1-3.
- Rose, P. M. and S. P. McCutcheon. 1980. Manatees (*Trichechus manatus*): Abundance and distribution in and around several Florida power plant effluents. Final Report. Prepared for the Florida Power and Light Co. Contract No. 31534 86626. 128 pp.
- Service Argos, Inc. 1996. User's manual. Service Argos, Inc., Landover, MD. 176 pp.
- Shane, S. H. 1981. Abundance, distribution, and use of power plant effluents by manatees in Brevard County, Florida. U.S. Fish and Wildlife Service, National Fish and Wildlife Laboratory Contract Report No. 61552-86540 to Florida Power and Light Company. National Technical Information Service, #PB81-147019, Springfield, VA. 244 pp.
- Shane, S. H. 1983. Abundance, distribution, and movements of manatees (*Trichechus manatus*) in Brevard County, Florida. *Bull. Mar. Sci.* 33: 1-9.
- Shane, S. H. 1984. Manatee use of power plant effluents in Brevard County, Florida. *Florida Scientist* 47: 180-188.
- U. S. Fish and Wildlife Service. 1996. Florida Manatee recovery plan, second revision. U. S. Fish and Wildlife Service, Atlanta, GA. 160 pp.
- U. S. Fish and Wildlife Service. 2000. Florida manatees and warm water: Proceedings of the warm-water workshop, Jupiter, Florida, August 24-25, 1999. 109 pp.

Worthy, G. A. J., T. A. Miculka, and S. D. Wright. 2000. Manatee response to cold: How cold is too cold? Pp. 17-22 *in* U. S. Fish and Wildlife Service. Florida manatees and warm water: Proceedings of the warm-water workshop, Jupiter, Florida, August 24-25, 1999.

Zoodsma, B. J. 1991. Distribution and behavioral ecology of manatees in southeastern Georgia. Master's Thesis, University of Florida. Gainesville, FL. 202 pp.

FIGURES

Figure 1. Locations of warm-water refugia along the east coast of Florida and Georgia.

Boundaries of the 5 regions defined for analysis are also shown. Abbreviations are as follows: CGW = Coral Gables Waterway; FPL-CC = Florida Power and Light Canaveral power plant; FPL-FL = Florida Power and Light Fort Lauderdale power plant; FPL-PE = Florida Power and Light Port Everglades power plant; FPL-RB = Florida Power and Light Riviera Beach power plant; GP-BR = Georgia Pacific pulp mill in Brunswick, GA; JEA = Jacksonville Electric Authority Kennedy and Southside power plants; JS-FB = Jefferson-Smurfit Corp. pulp mill in Fernandina Beach, FL; JS-JX = Jefferson-Smurfit Corp. pulp mill in Jacksonville; Kemira = Kemira gypsum plant; OUC-IR = Orlando Utilities Commission Indian River power plant; PM = pulp or paper mill; and PP = electric utility power plant.

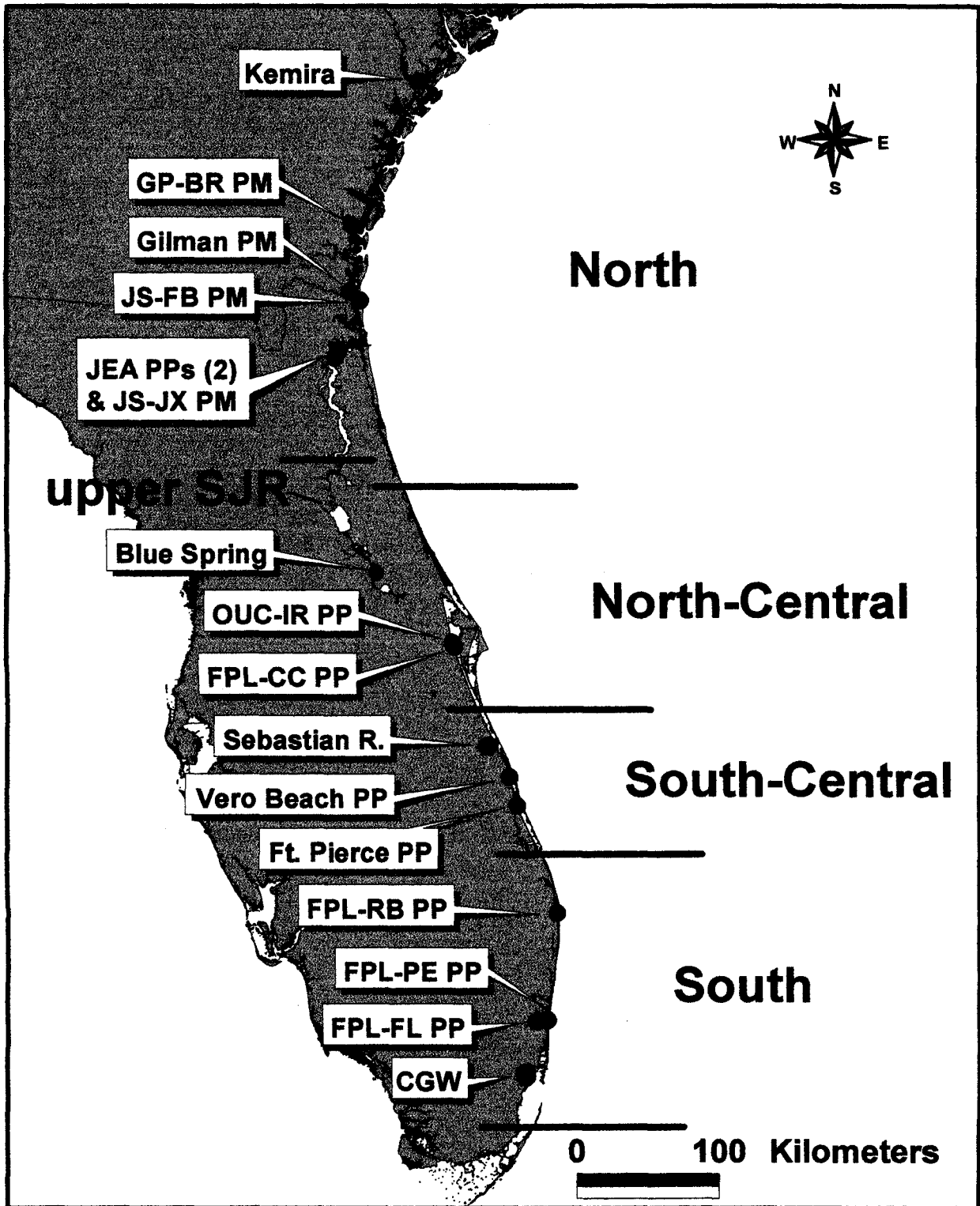


Figure 2. The number of warm-water refugia used by 68 tagged manatees in a winter versus tracking duration between 1 November and 31 March along the Atlantic coast of Florida and Georgia. Data from a total of 152 manatee-winters are plotted, so some individuals are represented by multiple points. The dashed line depicts the criterion (100 days tracked) used for censoring data prior to analyses of the number of refugia used per winter.

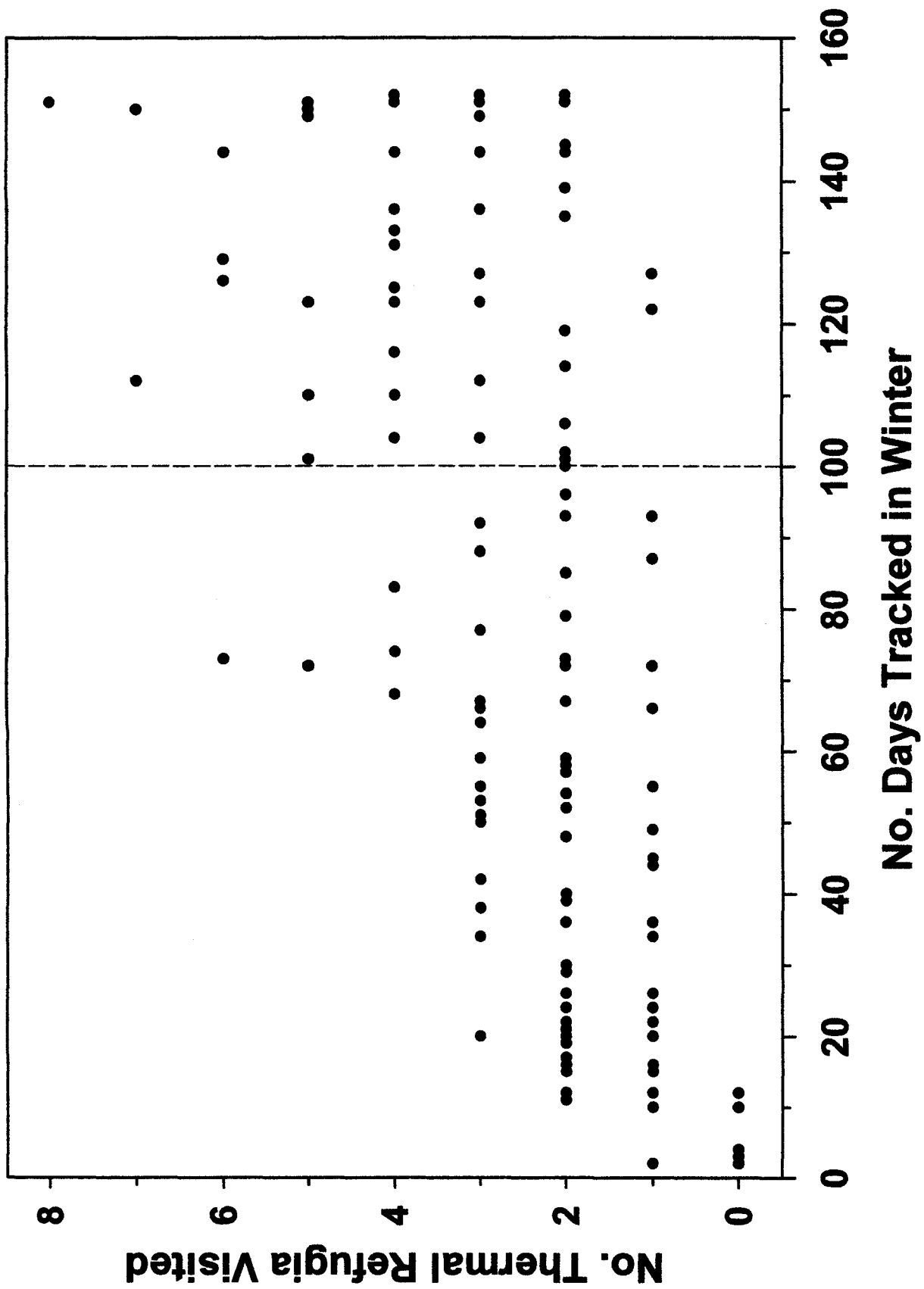


Figure 3. The mean number of warm-water refugia used by tagged manatees in a winter as a function of tracking duration between 1 November and 31 March along the Atlantic coast of Florida and Georgia. Standard error bars and sample sizes (i.e., no. of manatees) are shown. Individuals were represented only once (as a mean) within a tracking duration category, but may be included in multiple categories. A minimum of 100 days tracked was chosen as the criterion for inclusion of data in analyses on the number of refugia used per winter.

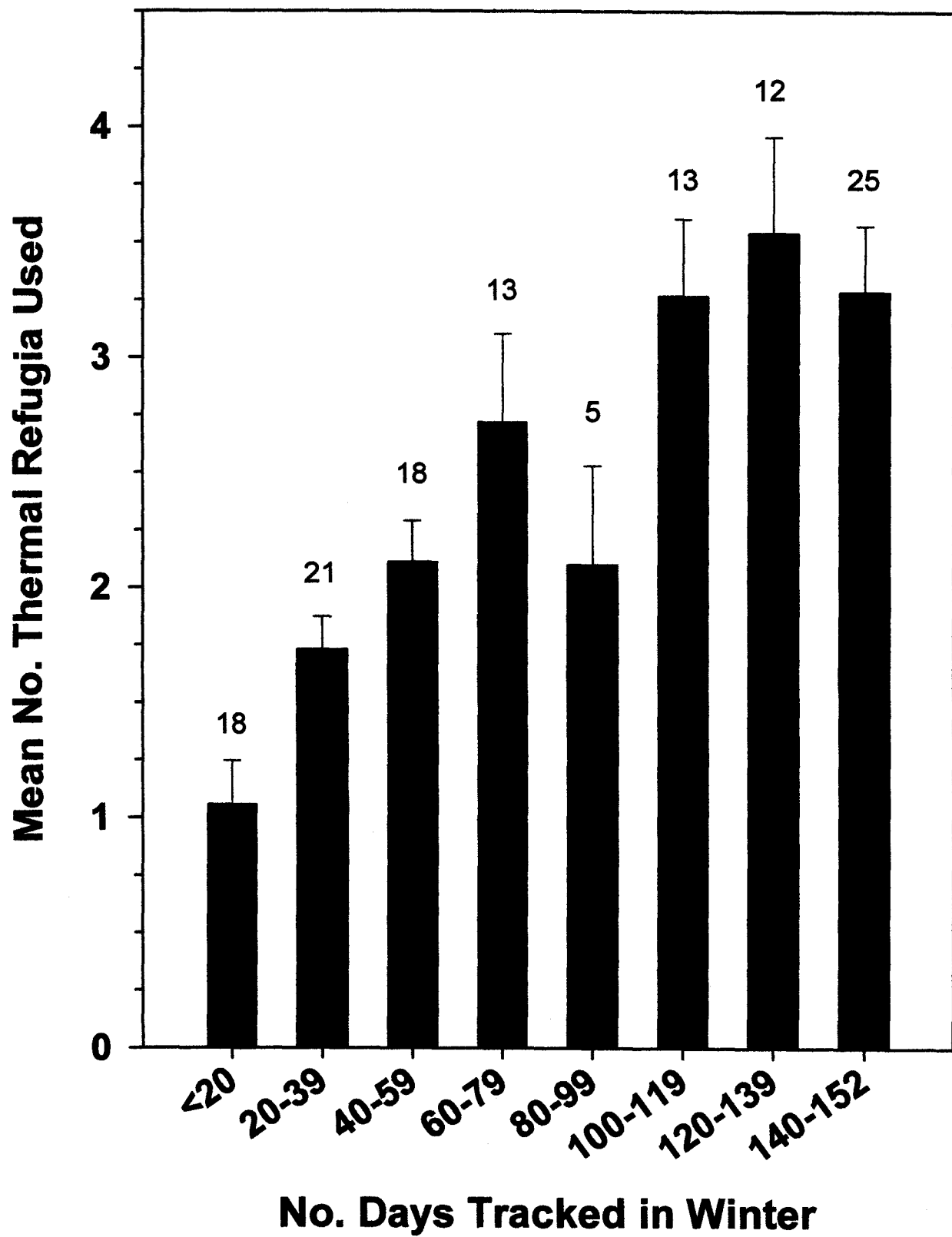


Figure 4. The number of warm-water refugia used by 68 tagged manatees over their entire tracking periods versus cumulative tracking duration between 1 November and 31 March along the Atlantic coast of Florida and Georgia. The dashed line depicts the criterion (150 days tracked) used for censoring data prior to analyses of the number of refugia used over an individual's tracking history.

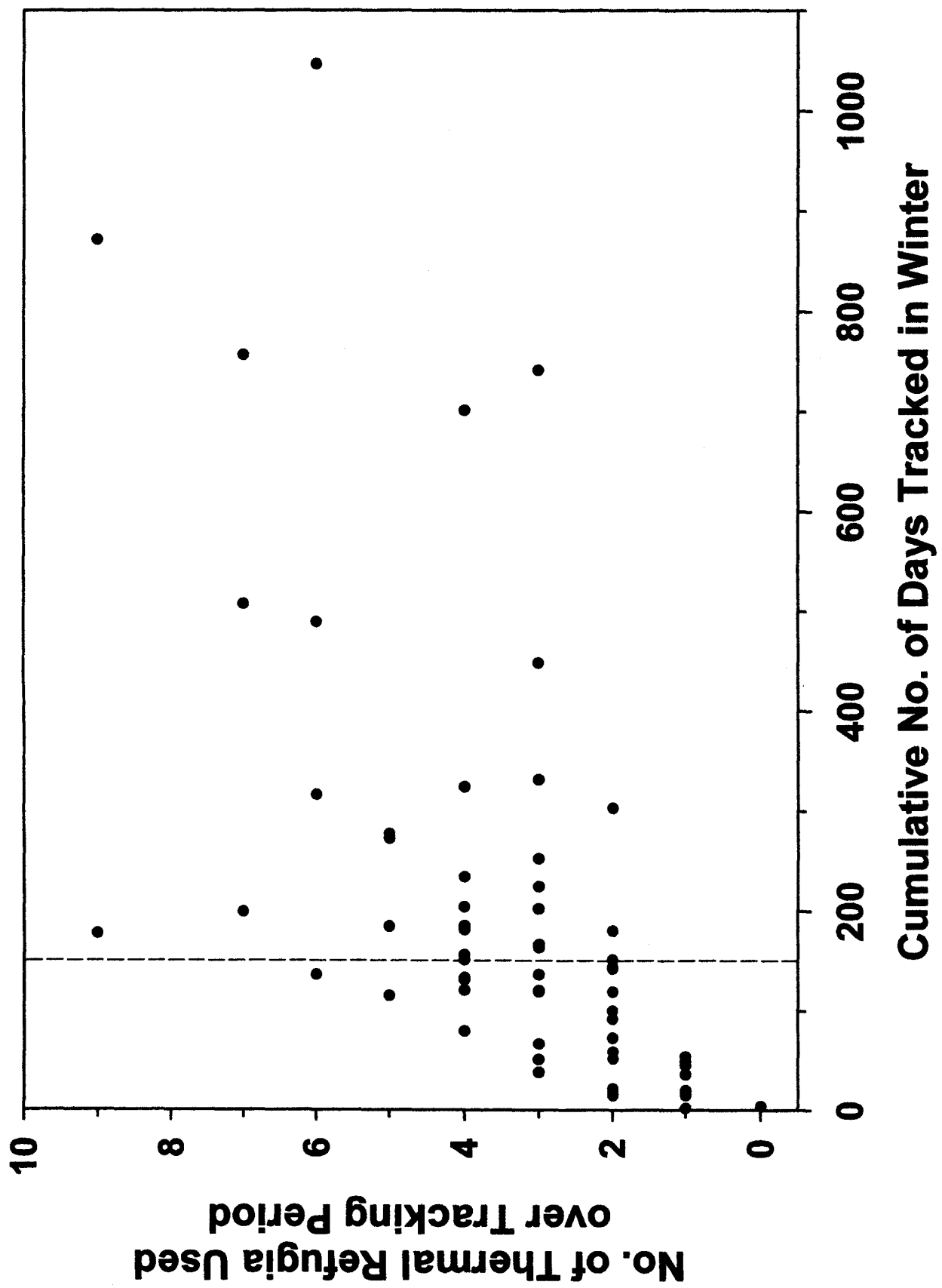


Figure 5. The mean number of warm-water refugia used by 68 tagged manatees over their entire tracking periods as a function of cumulative tracking duration between 1 November and 31 March along the Atlantic coast of Florida and Georgia. Standard error bars and sample sizes (i.e., no. of manatees) are shown. Individuals were represented only once within a tracking duration category. A minimum of 150 days tracked was chosen as the criterion for inclusion of data in analyses on the number of refugia used over an individual's tracking history.

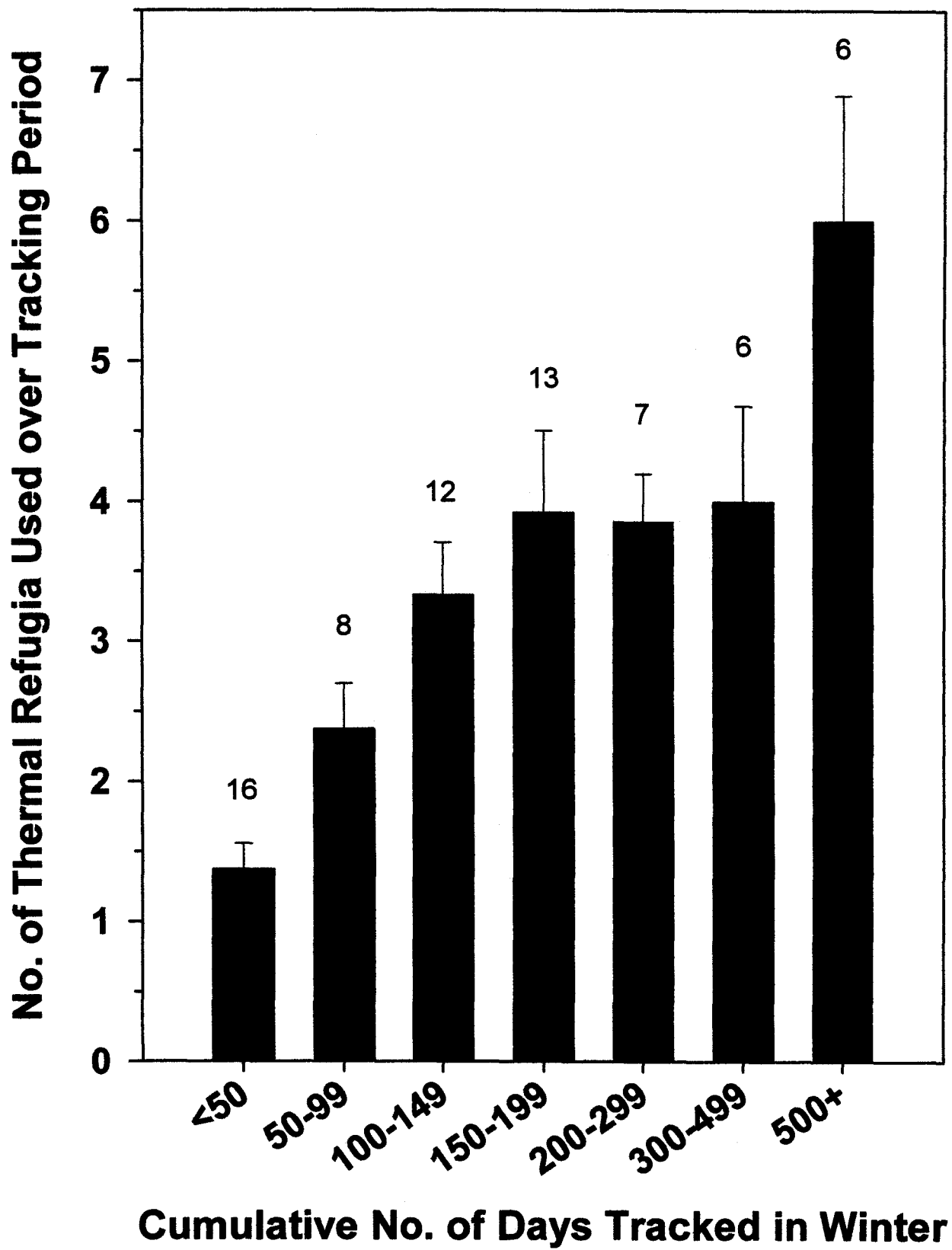


Figure 6. Frequency distribution of the mean number of warm-water refugia used per winter (1 November - 31 March) by 37 tagged manatees along the Atlantic coast of Florida and Georgia.

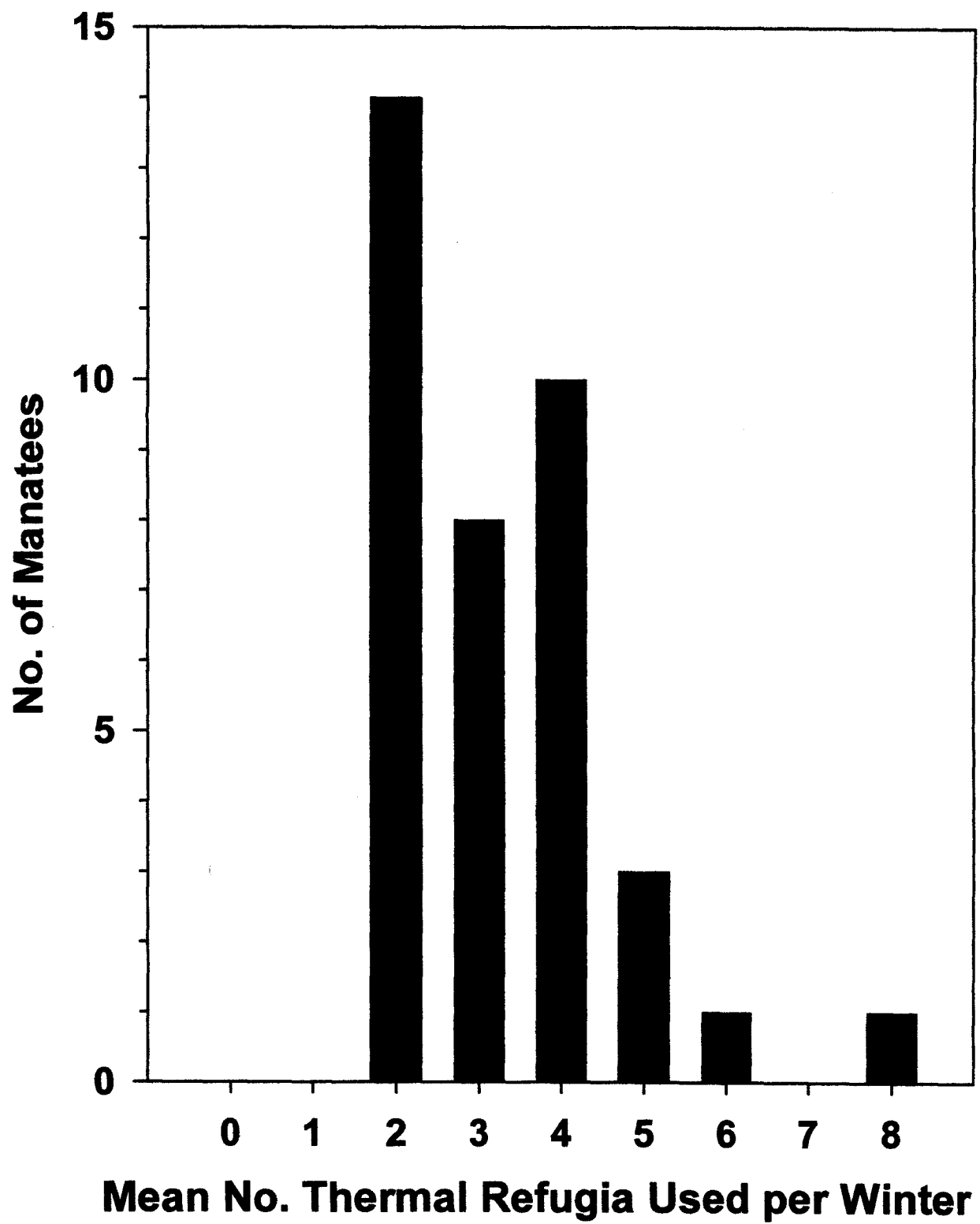


Figure 7. Frequency distribution of the total number of warm-water refugia used by 32 tagged manatees along the Atlantic coast of Florida and Georgia during the winter (1 November - 31 March) over their entire tracking periods.

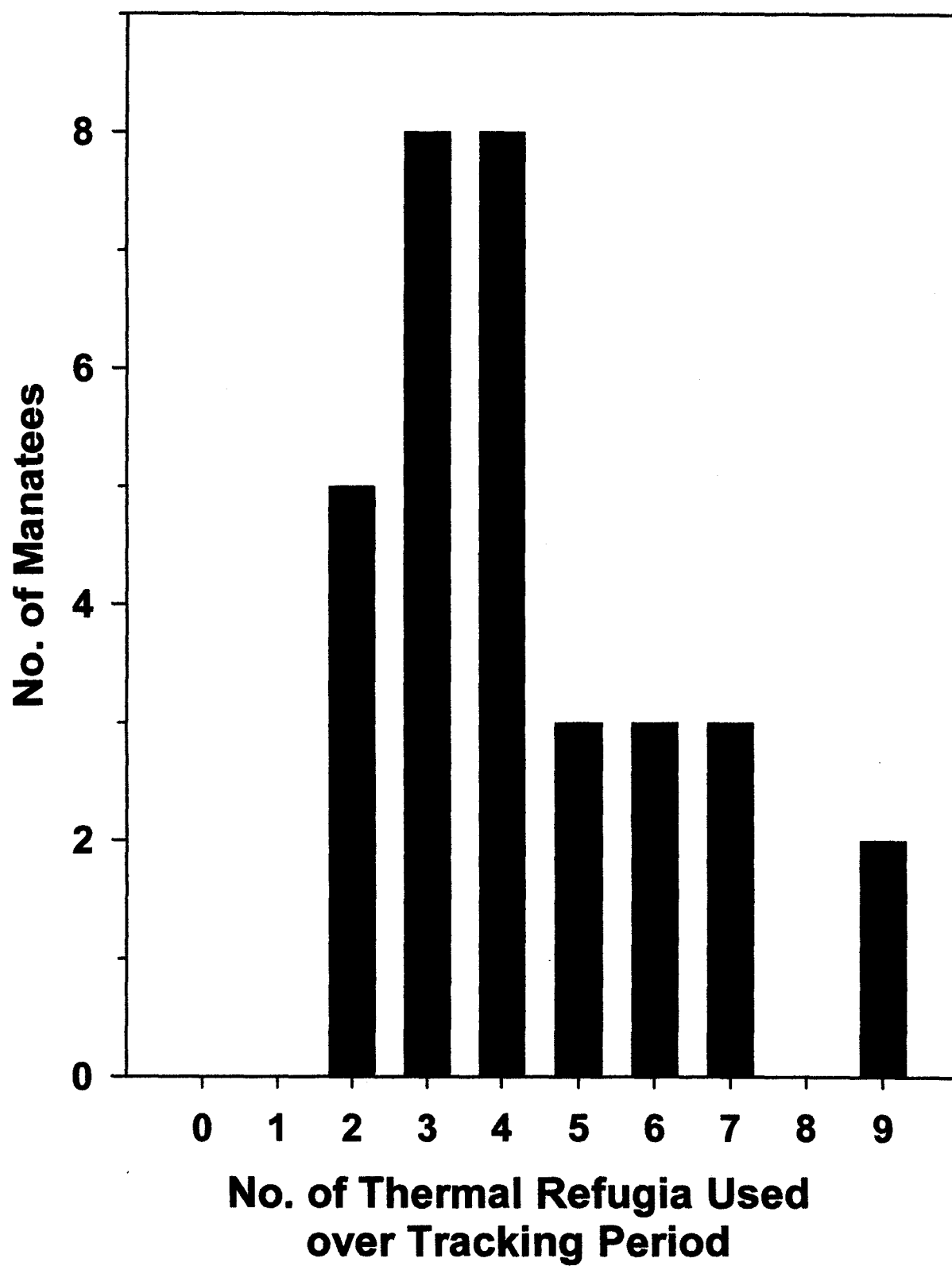


Figure 8. Frequency distribution of the mean number of regions (see Fig. 1) per winter (1 November - 31 March) in which warm-water refugia were used by 37 tagged manatees along the Atlantic coast of Florida and Georgia.

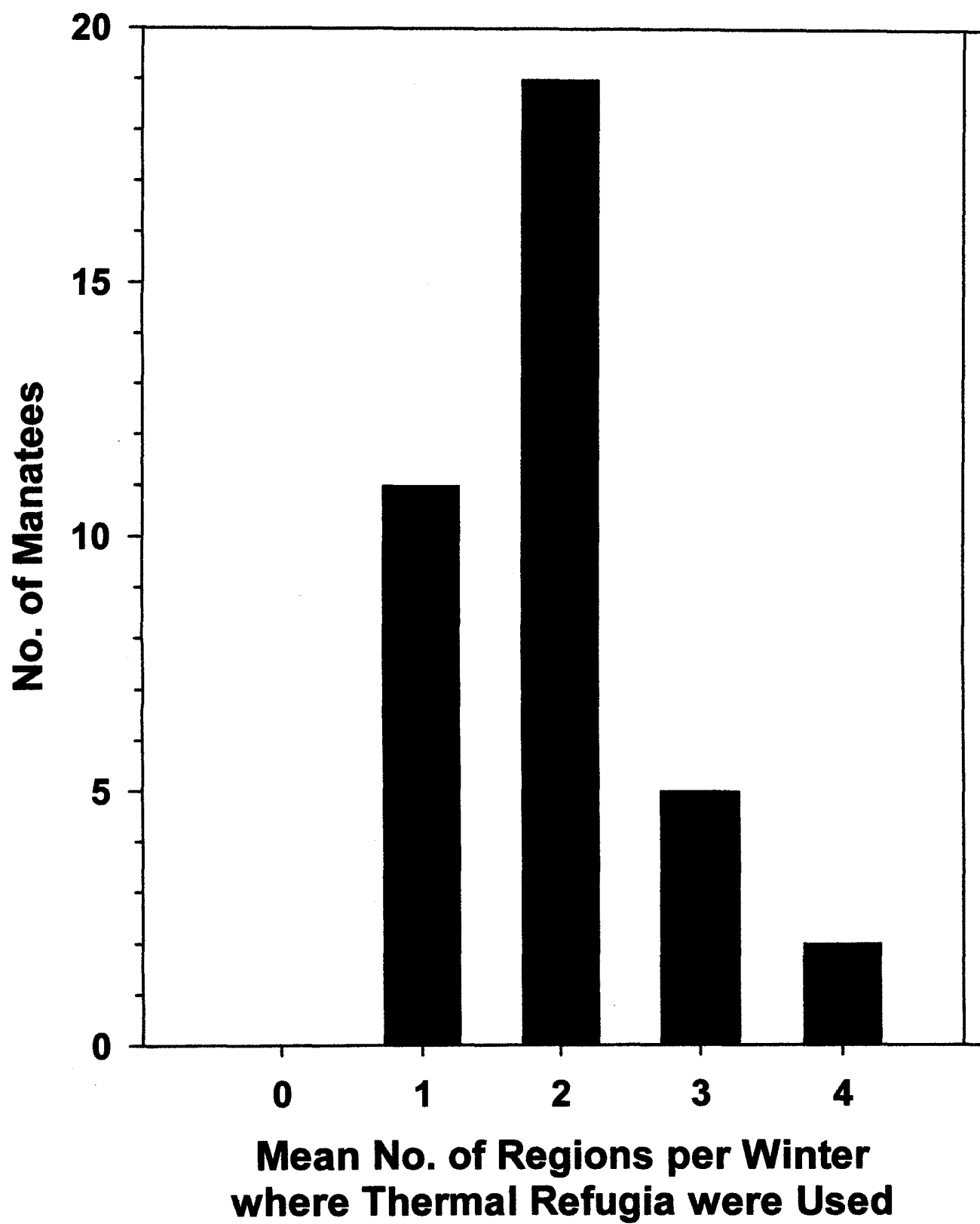


Figure 9. Frequency distribution of the total number of regions (see Fig. 1) in which 32 tagged manatees used warm-water refugia at some time during their entire winter tracking periods (1 November - 31 March) along the Atlantic coast of Florida and Georgia.

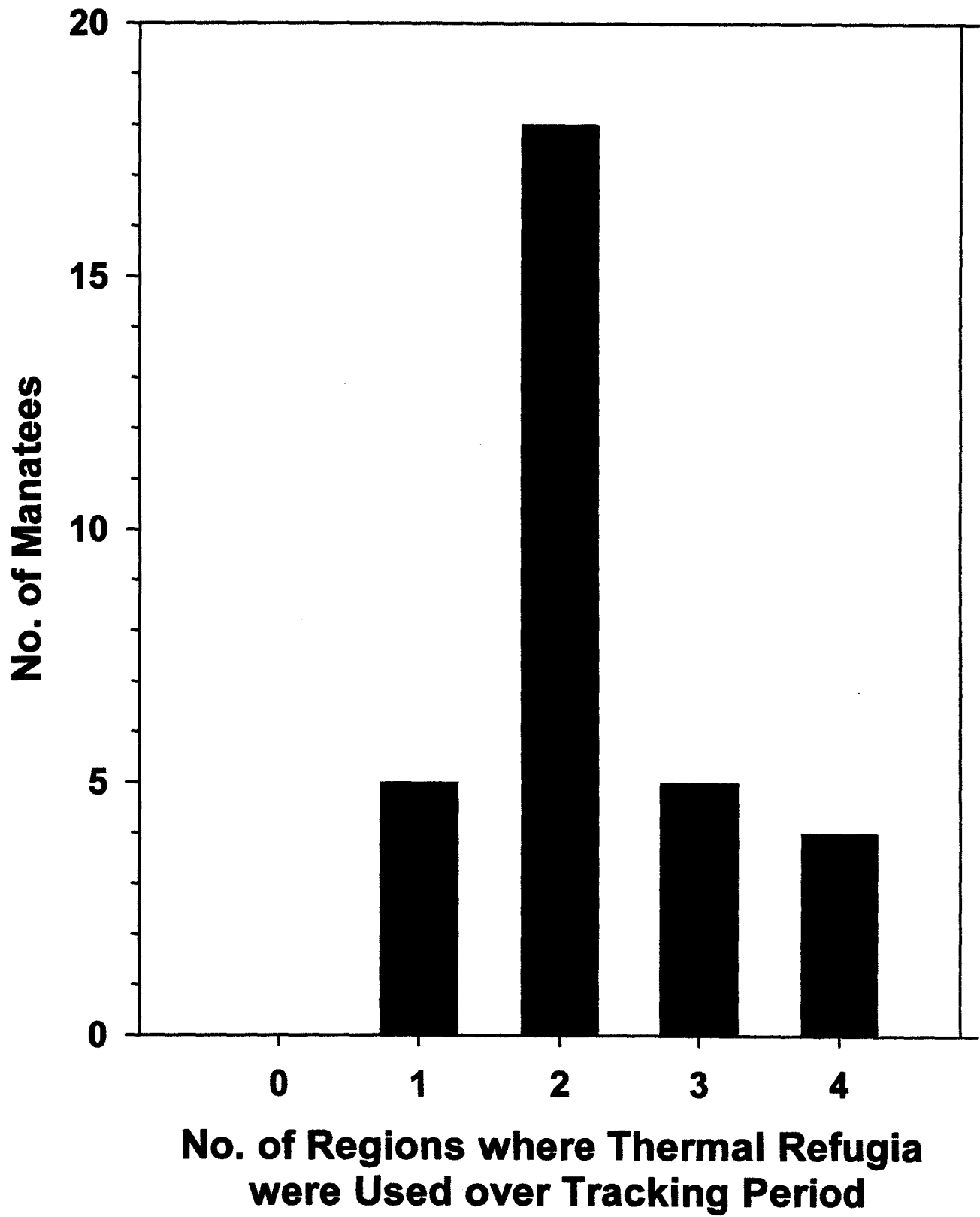
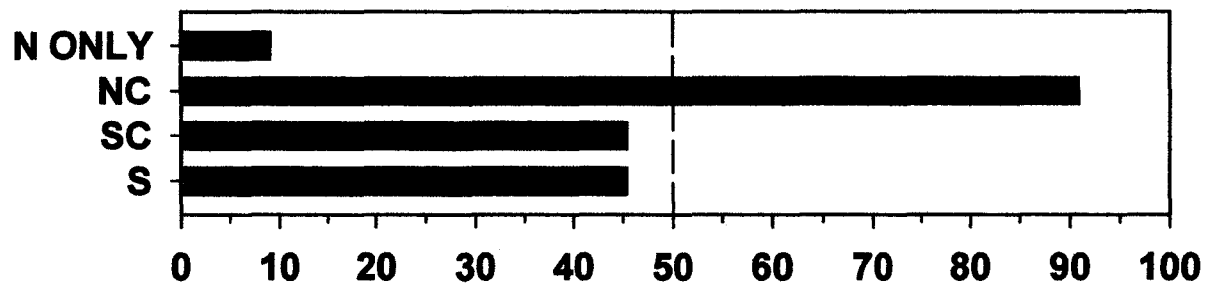
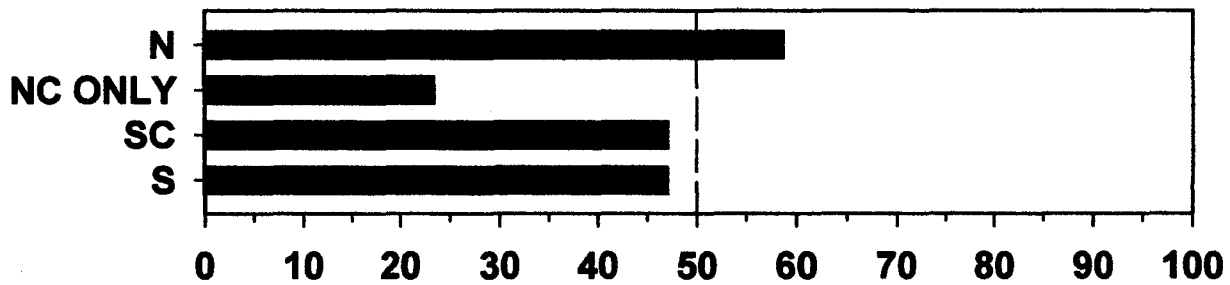


Figure 10. Percentages of tagged manatees using warm-water refugia in a given region that also used refugia in each of the other regions. Total sample size is 32 manatees, but individuals using more than 1 region are included in more than 1 plot.

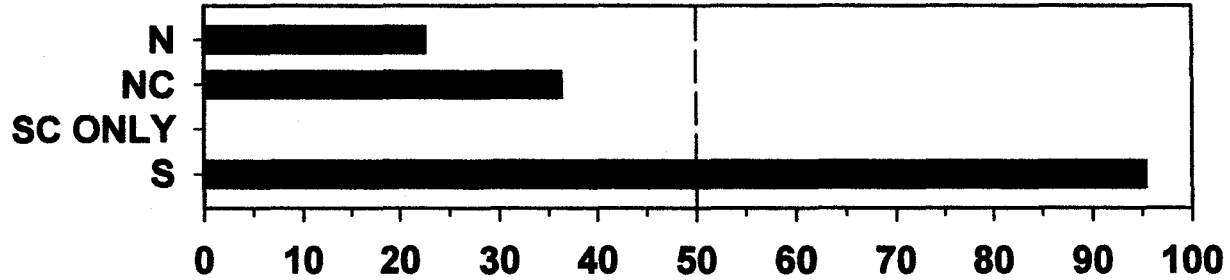
Manatees in NORTH Region (n = 11)



Manatees in NORTH-CENTRAL Region (n = 17)



Manatees in SOUTH-CENTRAL Region (n = 22)



Manatees in SOUTH Region (n = 22)

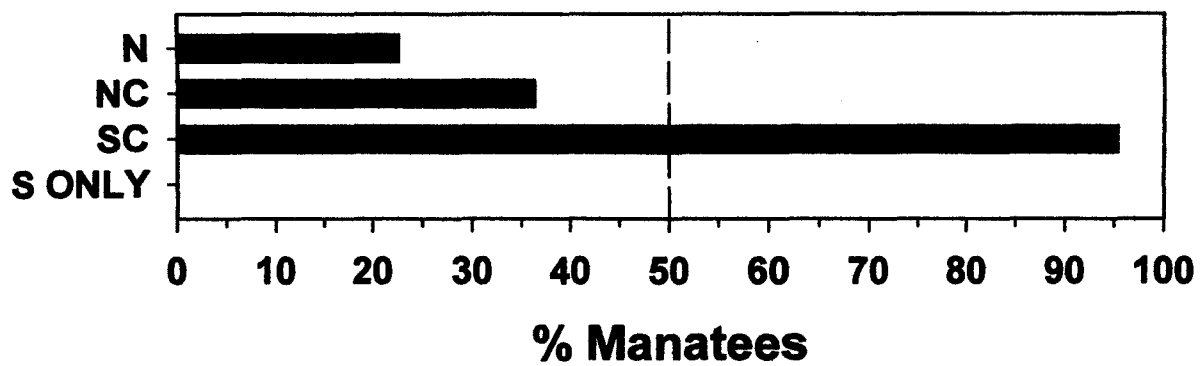


Figure 11. Number of tagged manatees (total N = 38) using each of the warm-water refuge areas along the Atlantic coast of Florida and Georgia in winter (1 November - 31 March), broken down by use as a primary or a secondary refuge. A primary refuge was visited by an individual on at least 33% of its total days at warm-water sites within any given winter. Of the manatees that visited each site, the percentage that used the site as a primary refuge is shown at the ends of the bars. Distances between sites on the y-axis are not to scale (see Fig. 1). Regional designations are denoted by the dashed lines. Abbreviations are as follows: BC = 2 Brevard County power plants; BRUN = Georgia-Pacific pulp mill in Brunswick, GA; CGW = Coral Gables Waterway; GIL-FB = Gilman Paper Co. pulp mill in St. Marys, GA and Jefferson-Smurfit Corp. pulp mill in Fernandina Beach, FL; FtP = Henry D. King Municipal power plant in Ft. Pierce, FL; KEM = Kemira gypsum plant; N = north region; NC = north-central region; PE-FL = Florida Power and Light power plants at Port Everglades and Fort Lauderdale; RB = Florida Power and Light Riviera Beach power plant; S = south region; SC = south-central region; SEB = north fork of Sebastian River; SJR = 2 Jacksonville Electric Authority power plants and the Jefferson-Smurfit Corp. pulp mill in Jacksonville, FL; and VB = Vero Beach power plant.

Warm-water Refuge

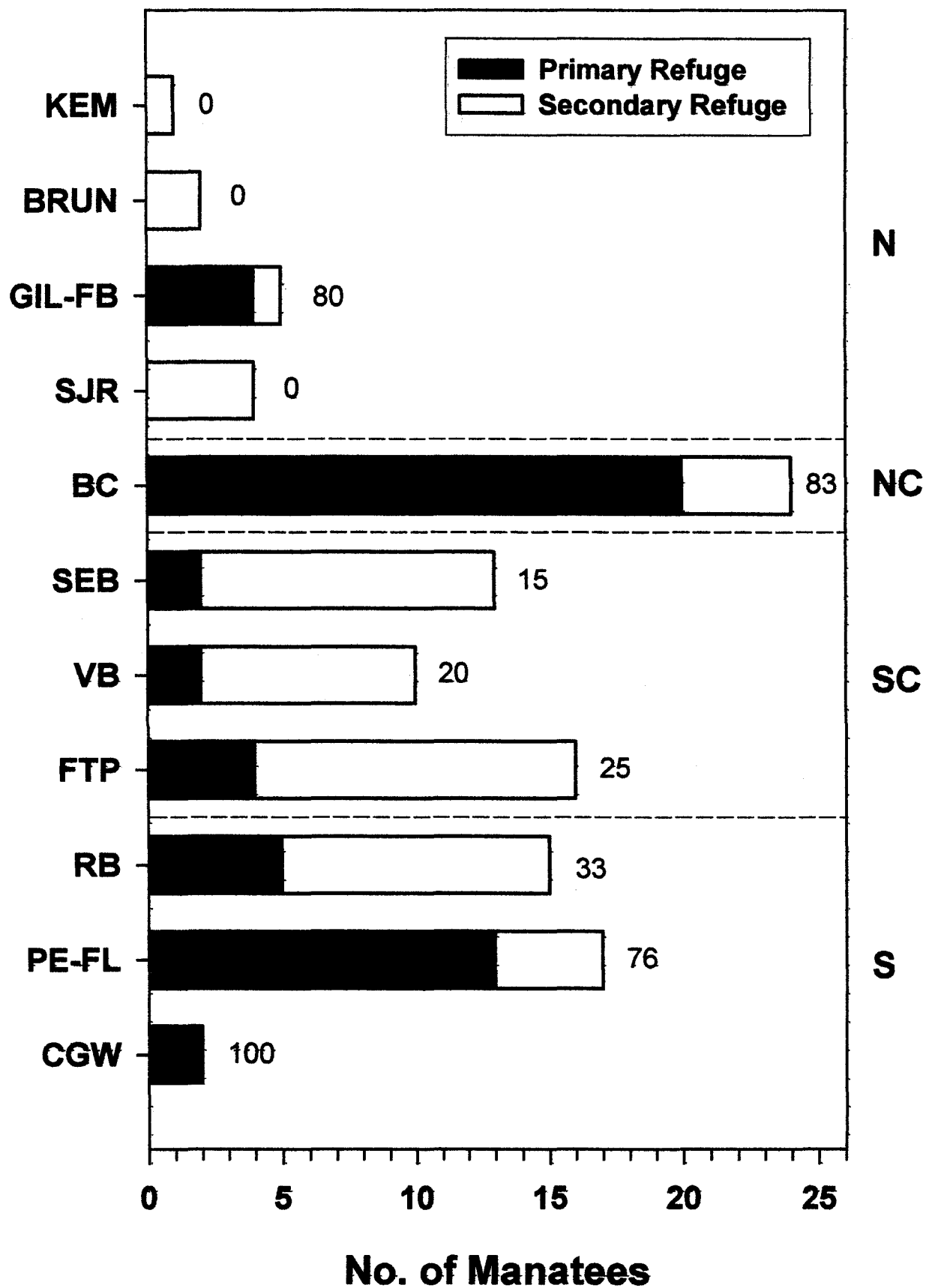
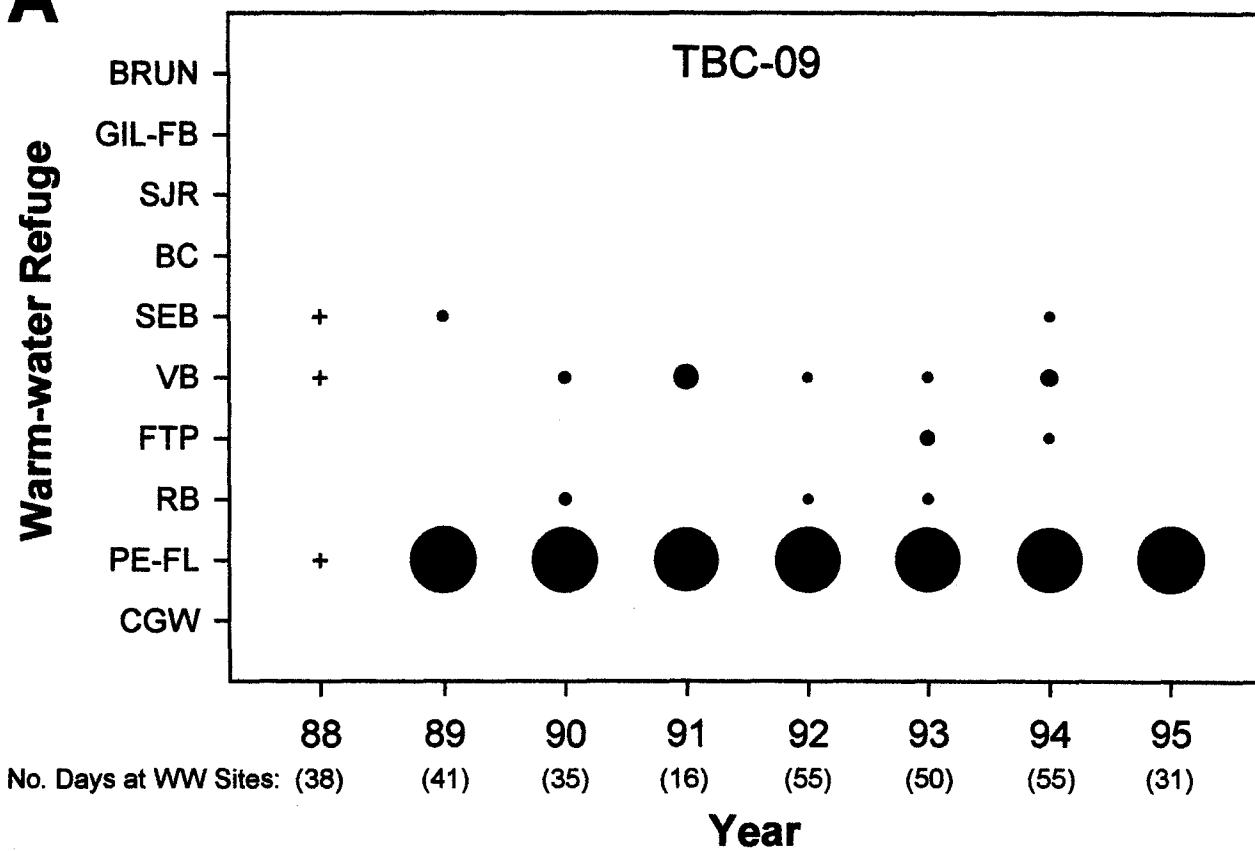
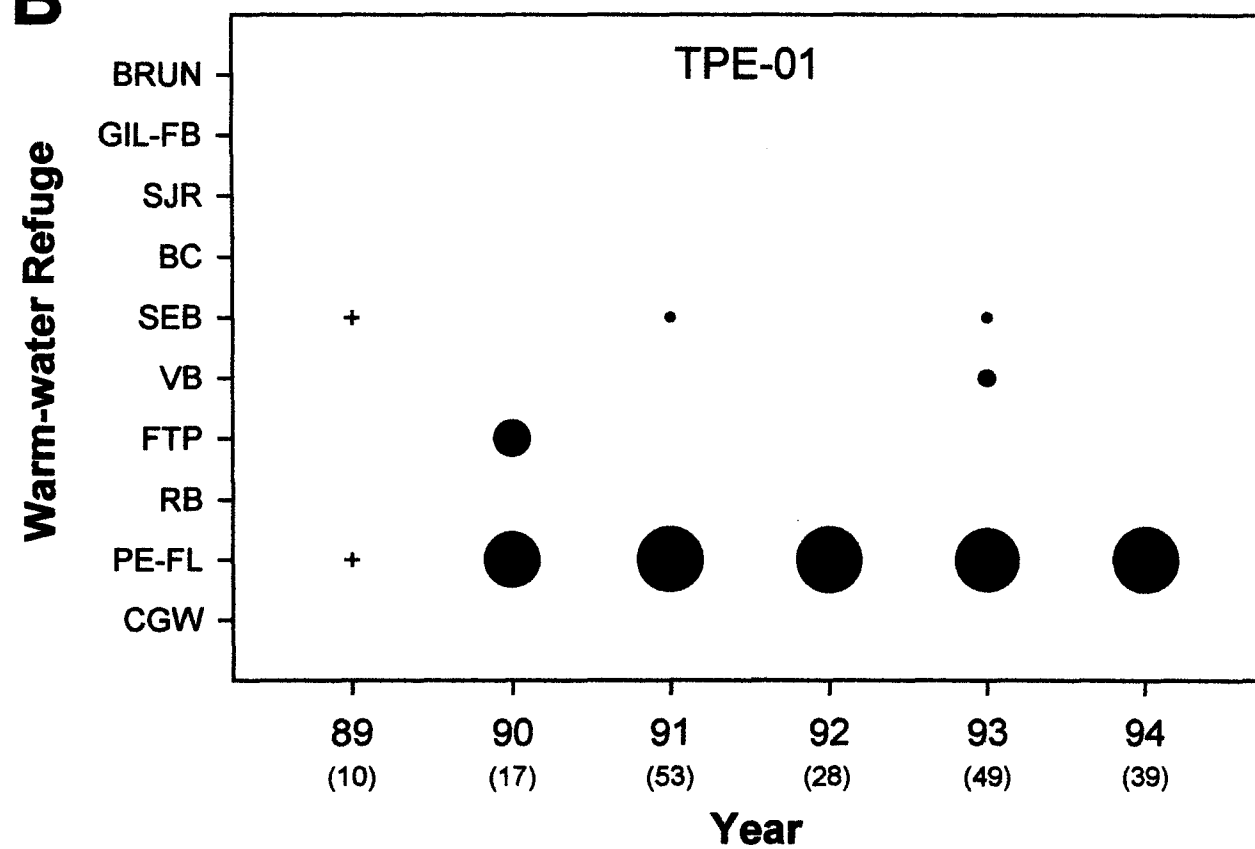
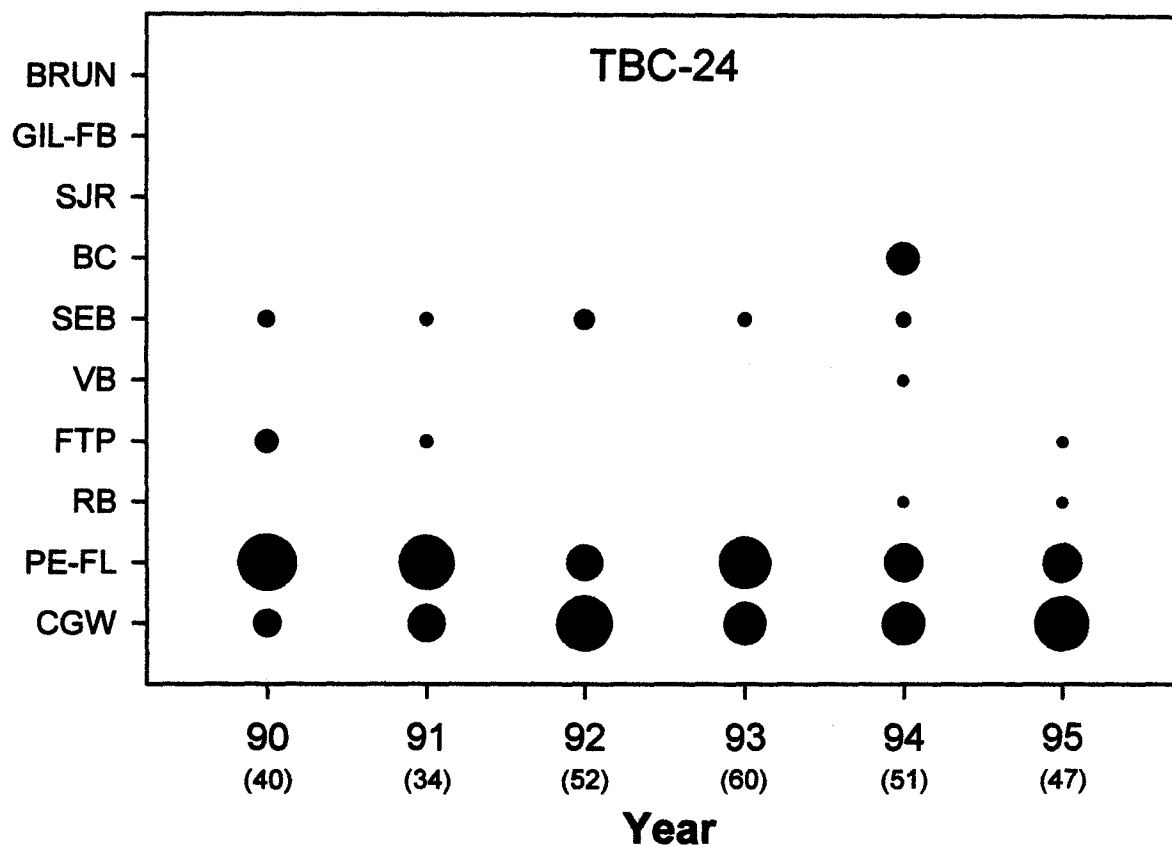


Figure 12. Use of warm-water refuge areas across winters (1 November - 31 March) by 17 tagged manatees along the Atlantic coast of Florida and Georgia. The relative area of each circle represents the percentage of days at that refuge out of the total number of days located at warm-water sites during that winter (n, given below the year); a large, single circle equals 100% (e.g., H) and the smallest circles are <5%. A cross denotes presence at a refuge in years not meeting criteria (see Methods). Distances between sites on the y-axis are not to scale (see Fig. 1). Years refer to January of that winter (e.g., 90 = 1Nov89 - 31Mar90). Abbreviations are as in Figure 11.

A**B**

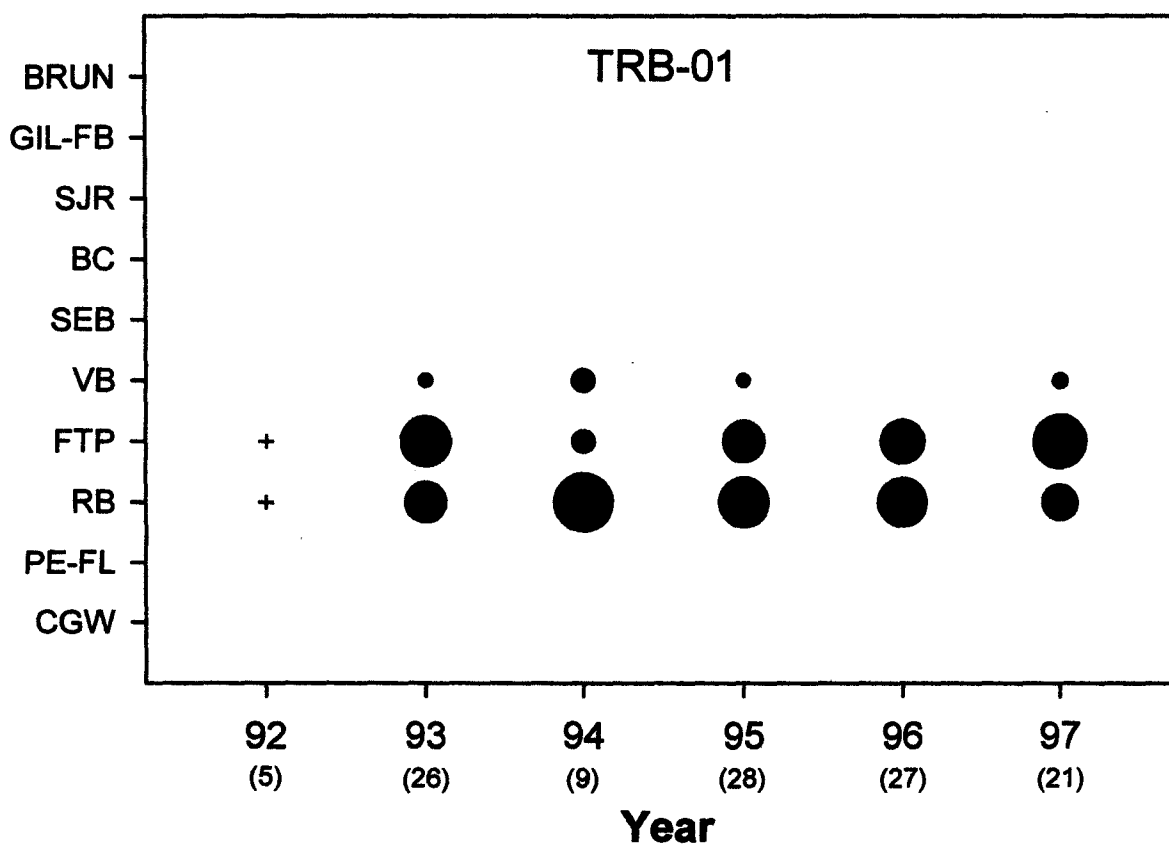
C

Warm-water Refuge



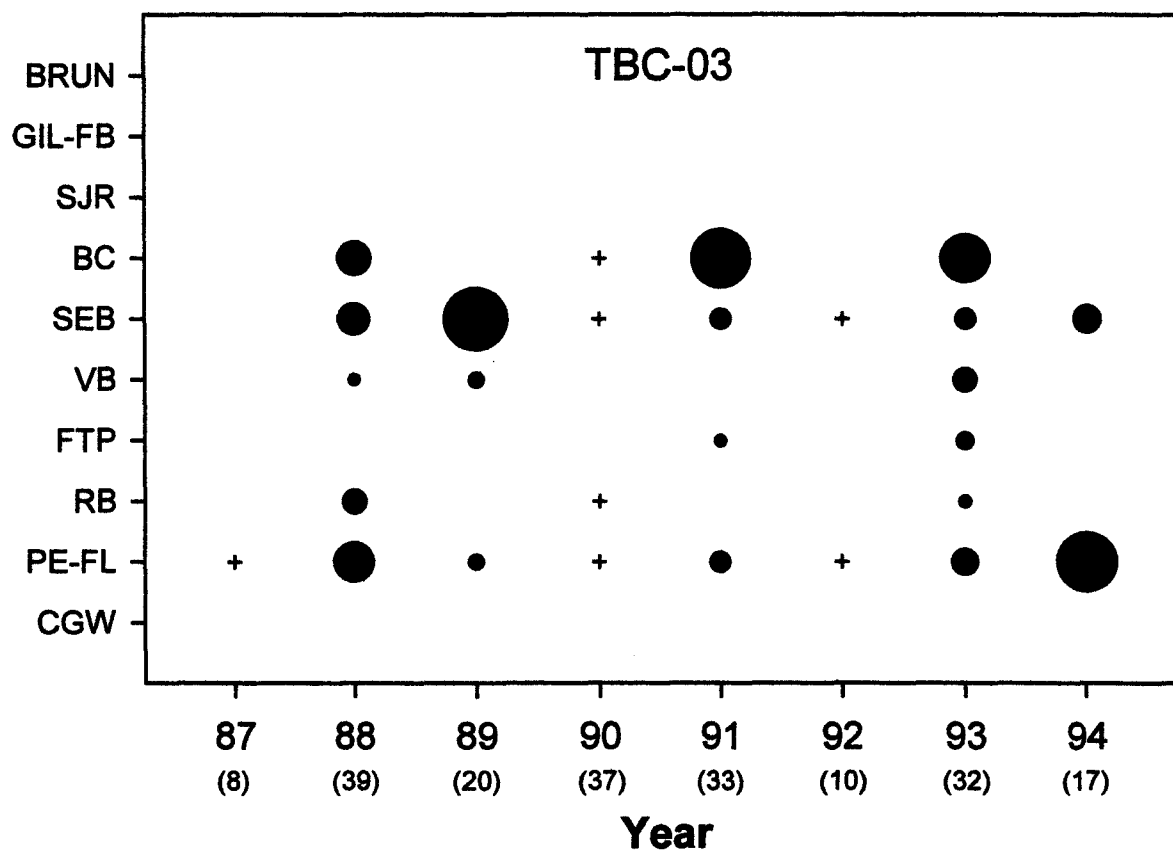
D

Warm-water Refuge



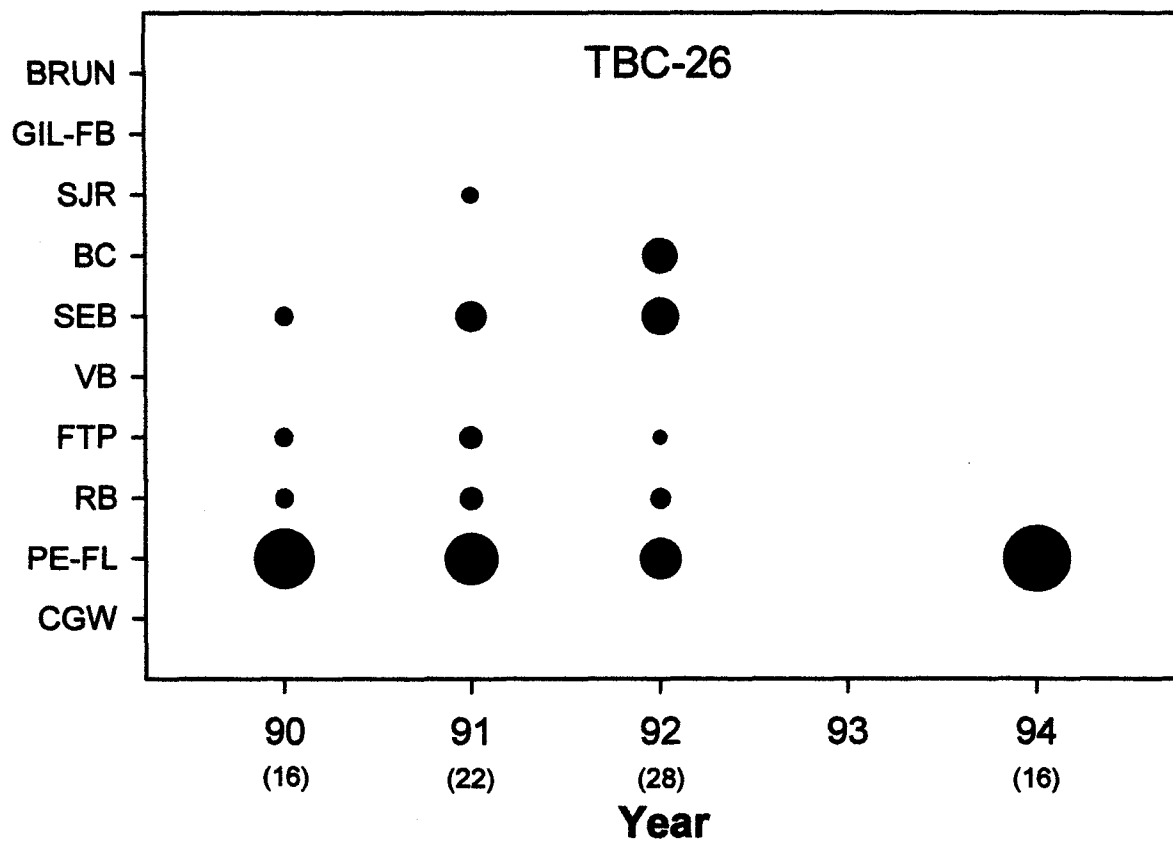
III

Warm-water Refuge

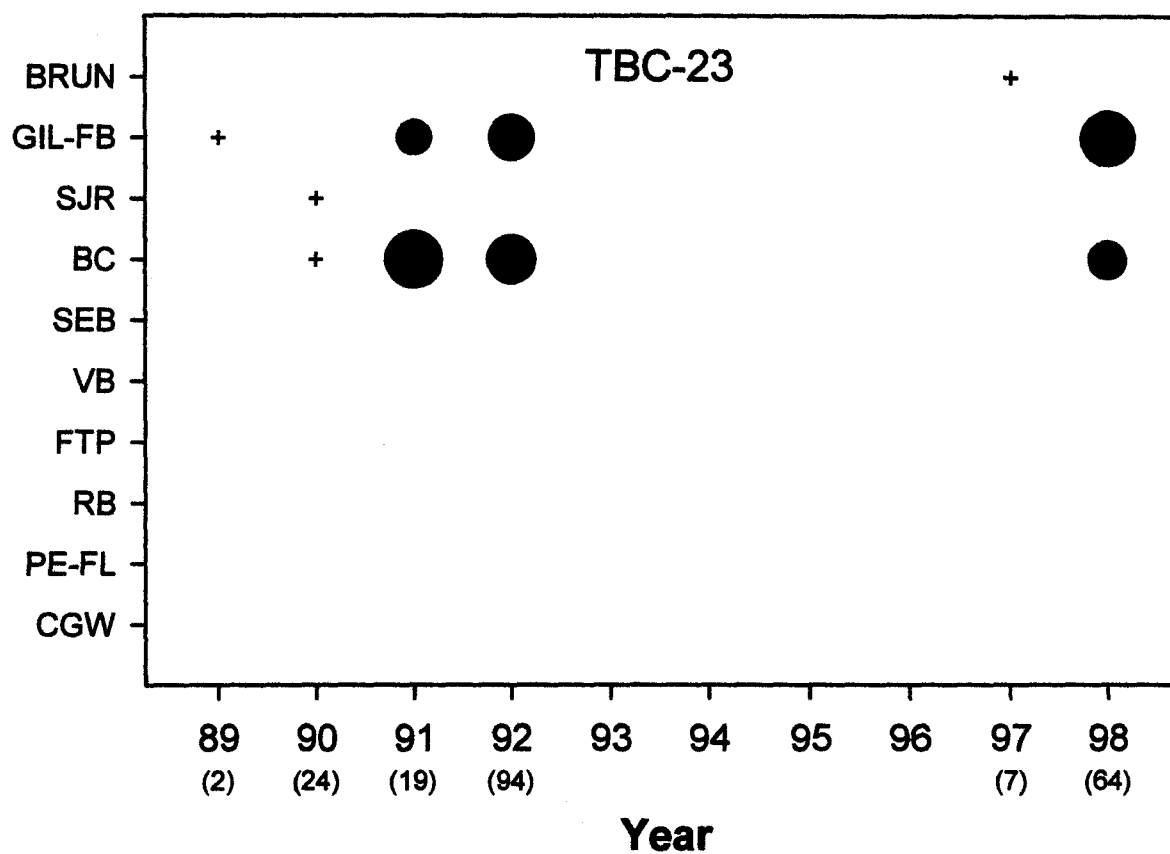


IV

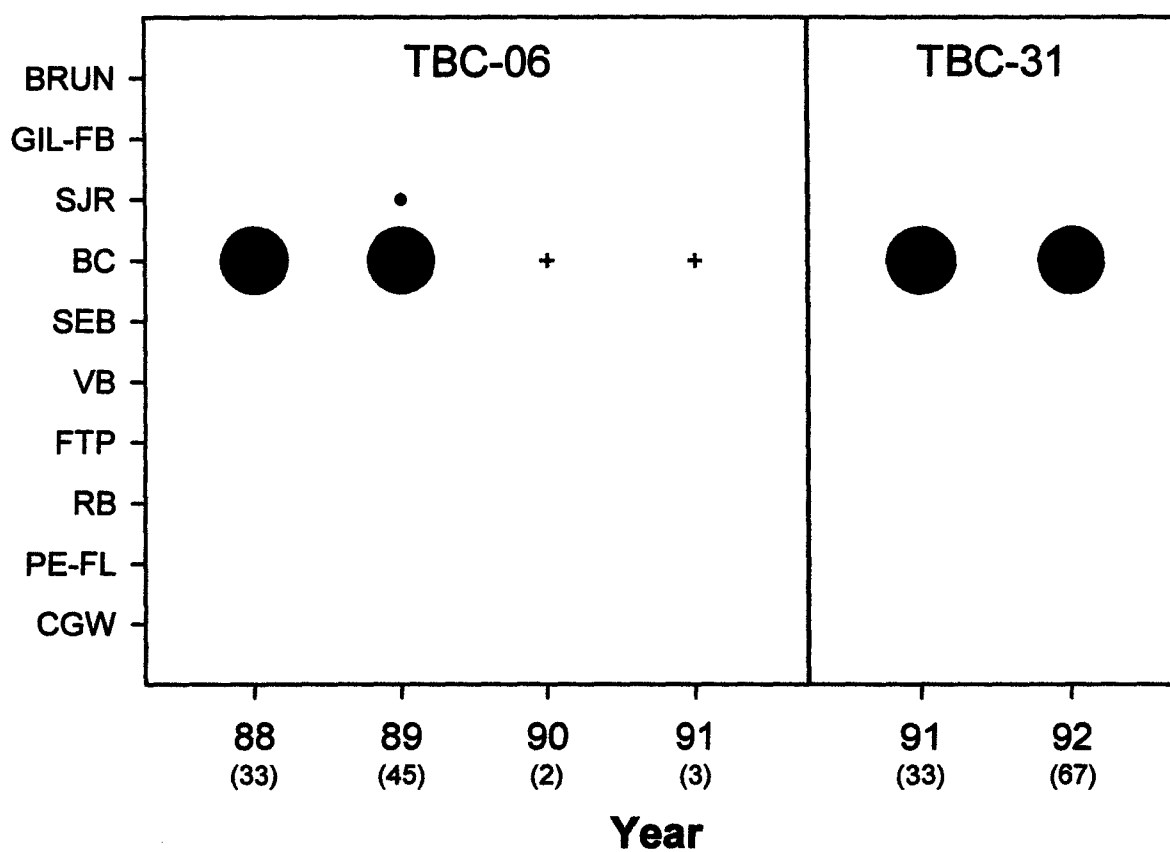
Warm-water Refuge



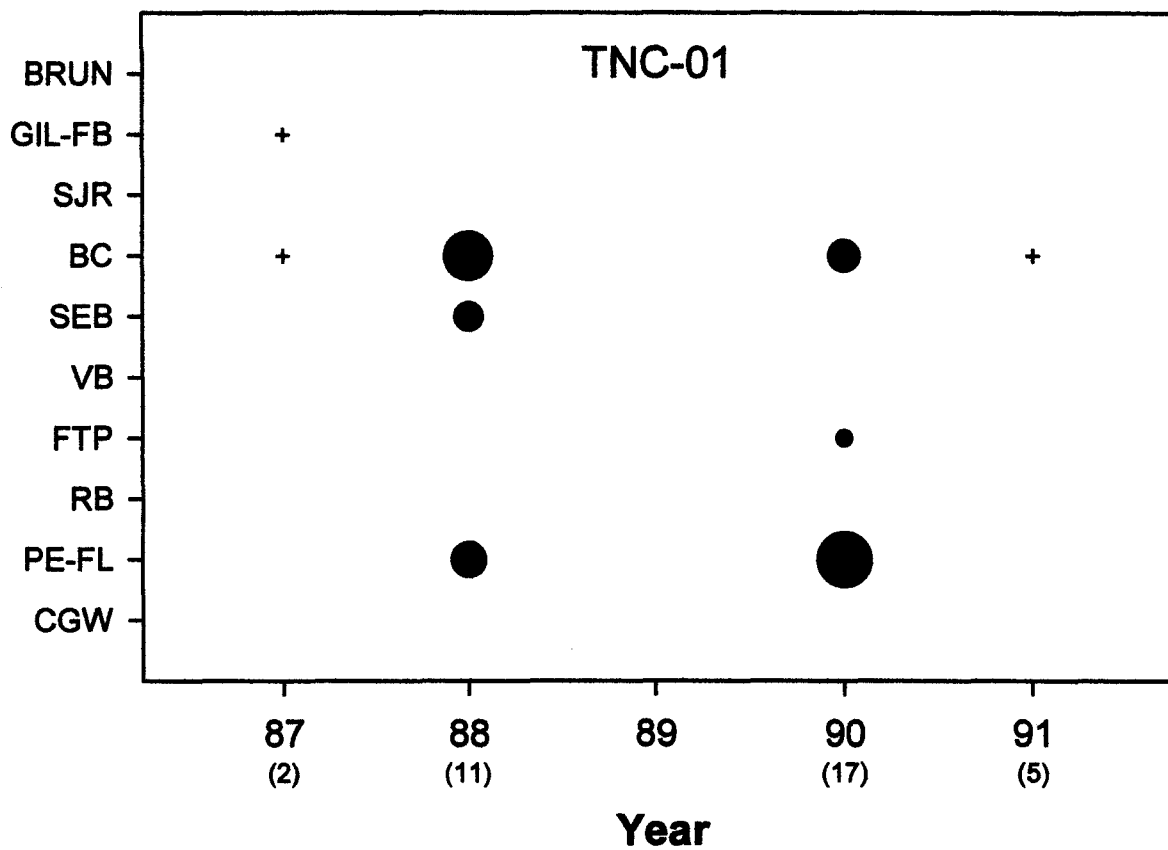
Warm-water Refuge



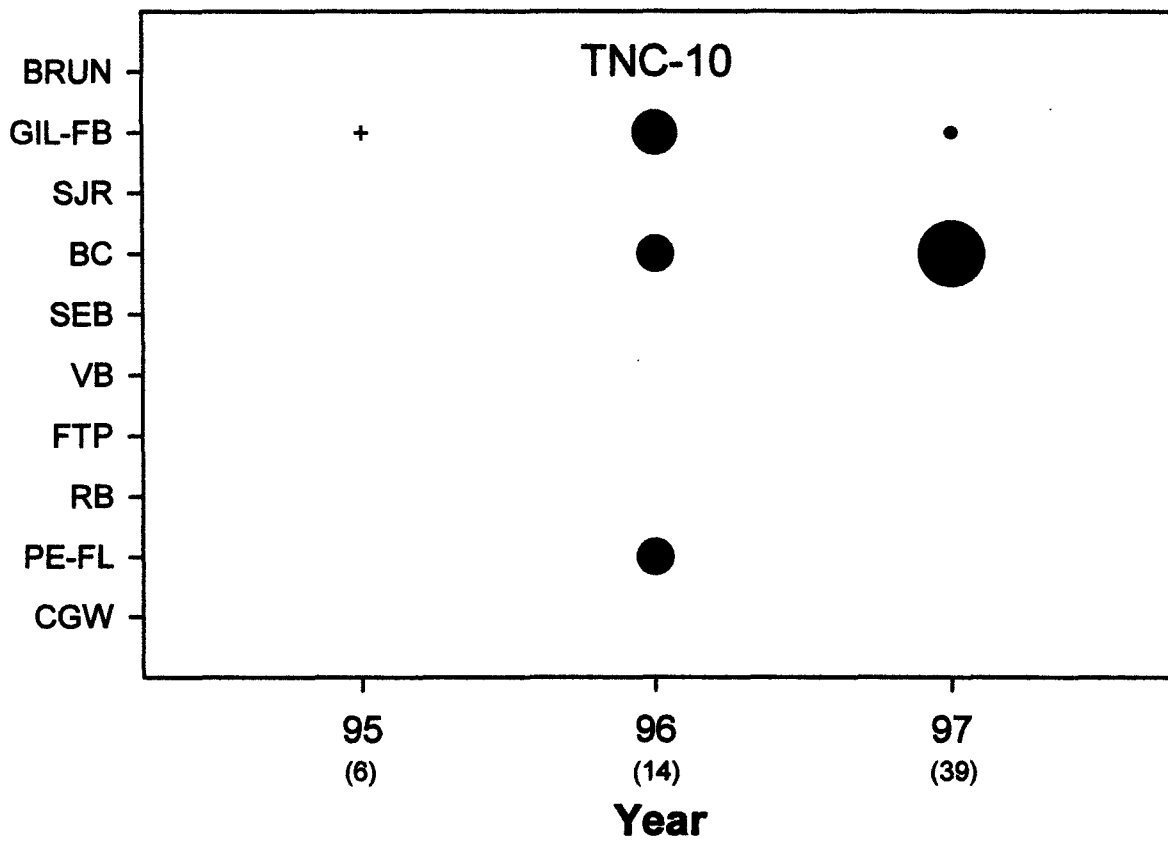
Warm-water Refuge



Warm-water Refuge

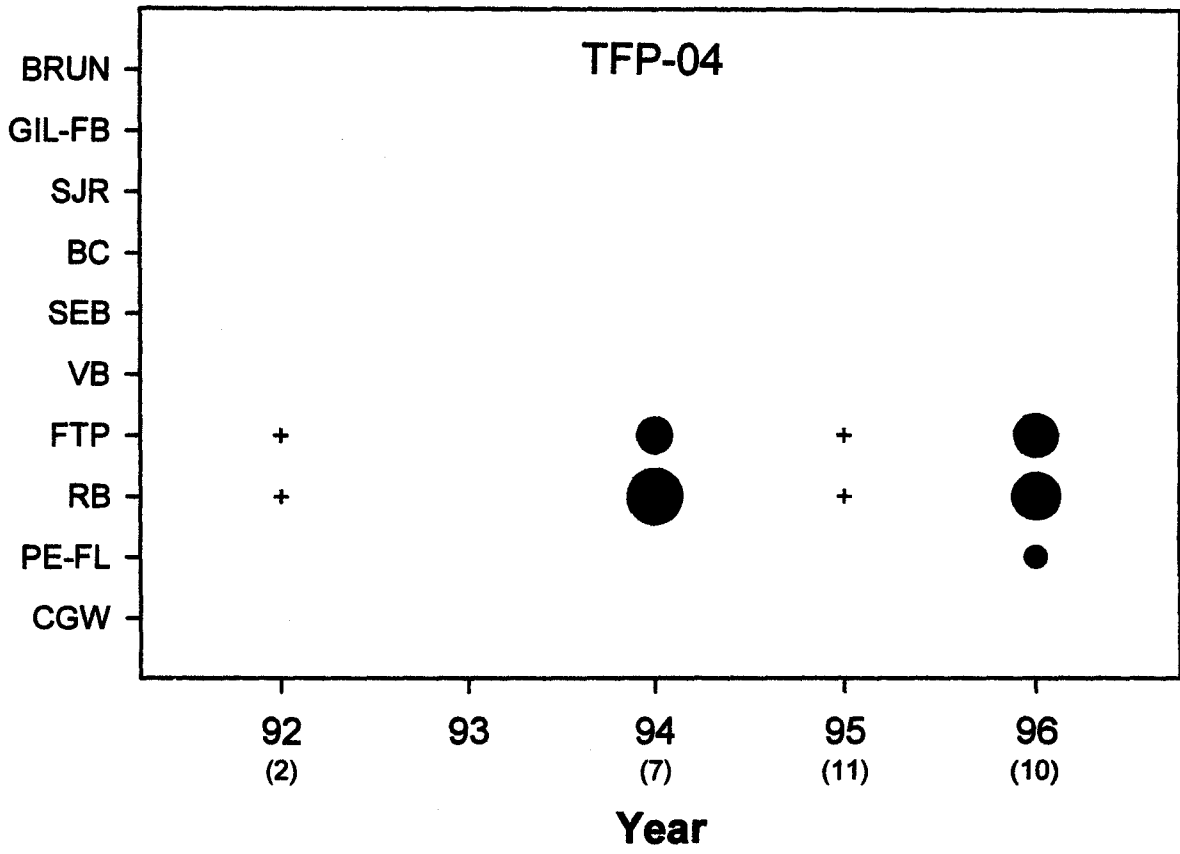


Warm-water Refuge



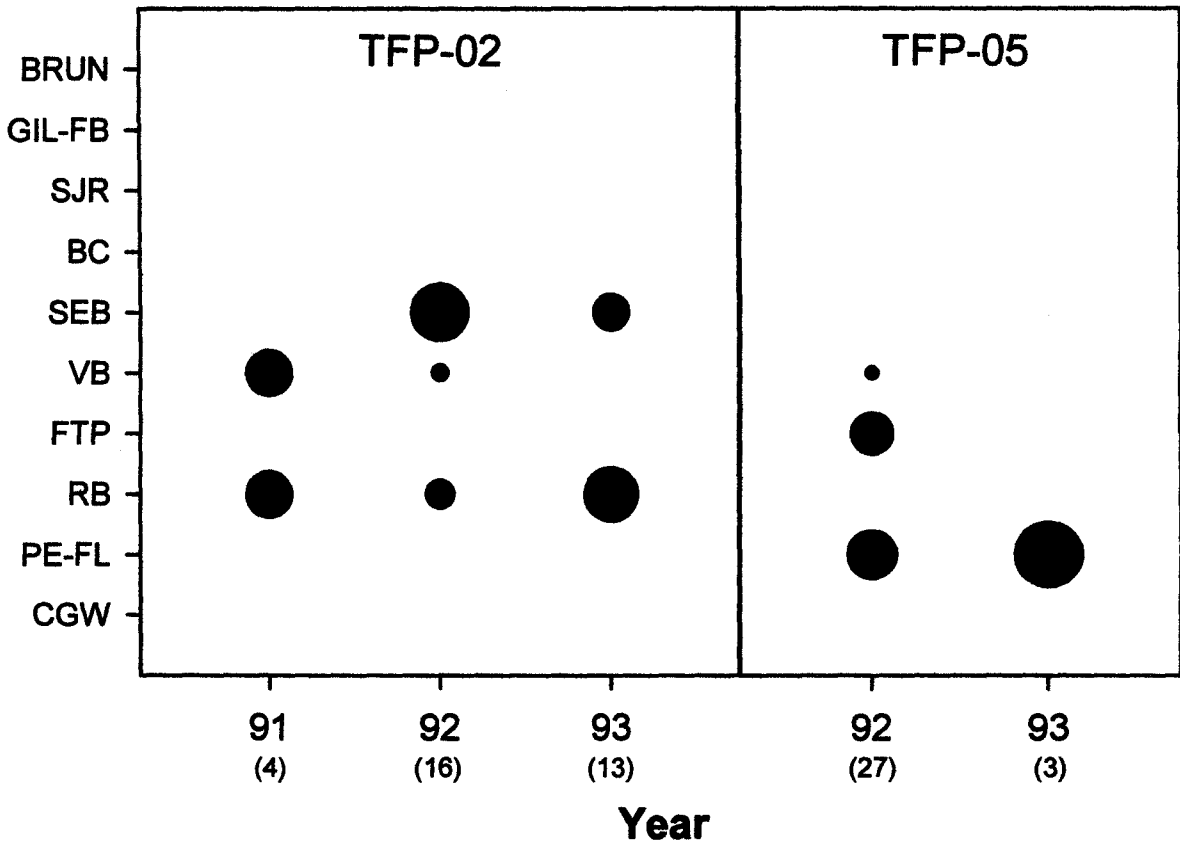
K

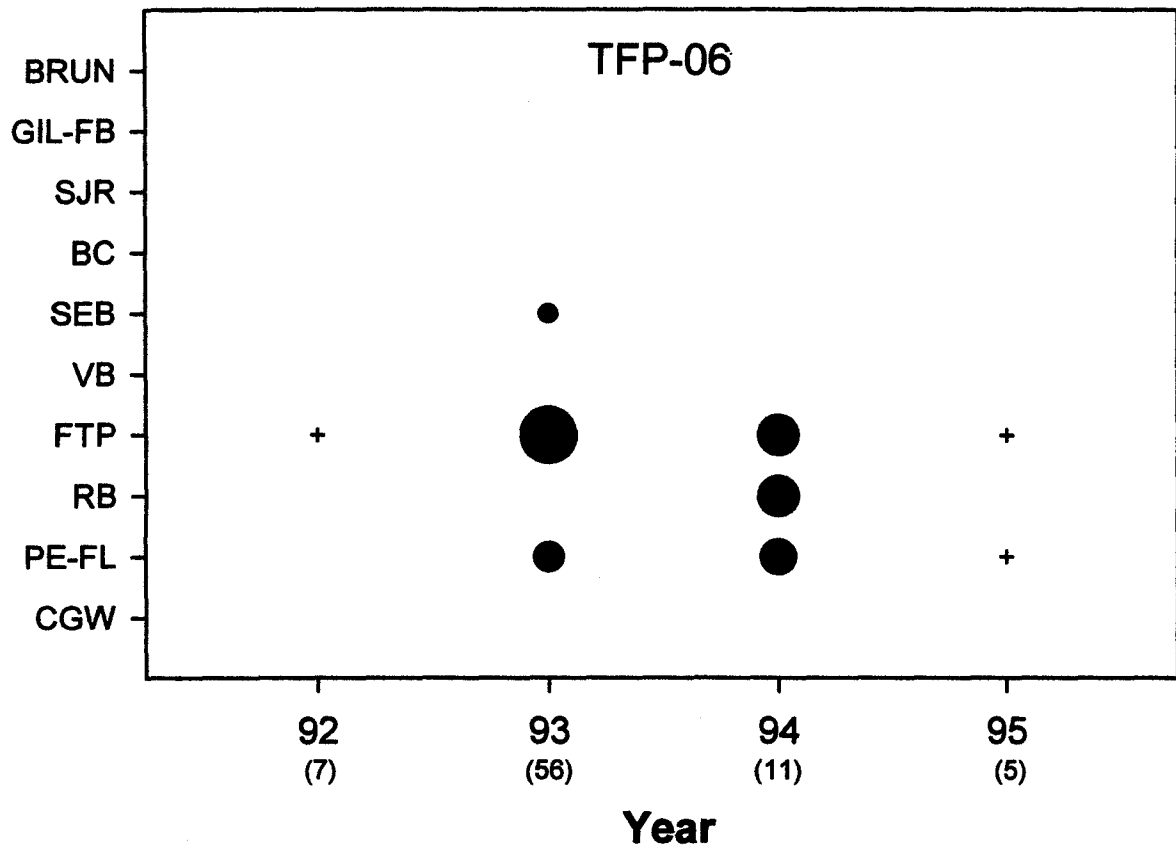
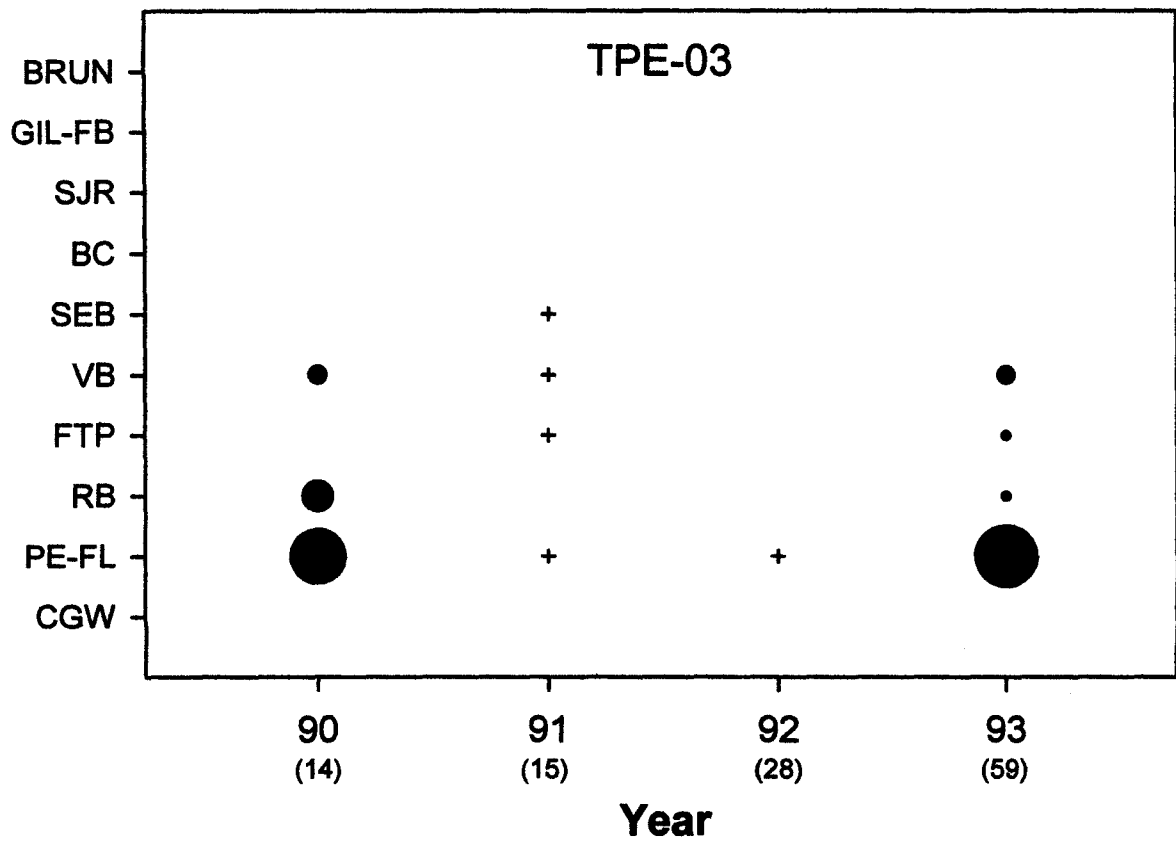
Warm-water Refuge



L

Warm-water Refuge



M**Warm-water Refuge****N****Warm-water Refuge**

O

Warm-water Refuge

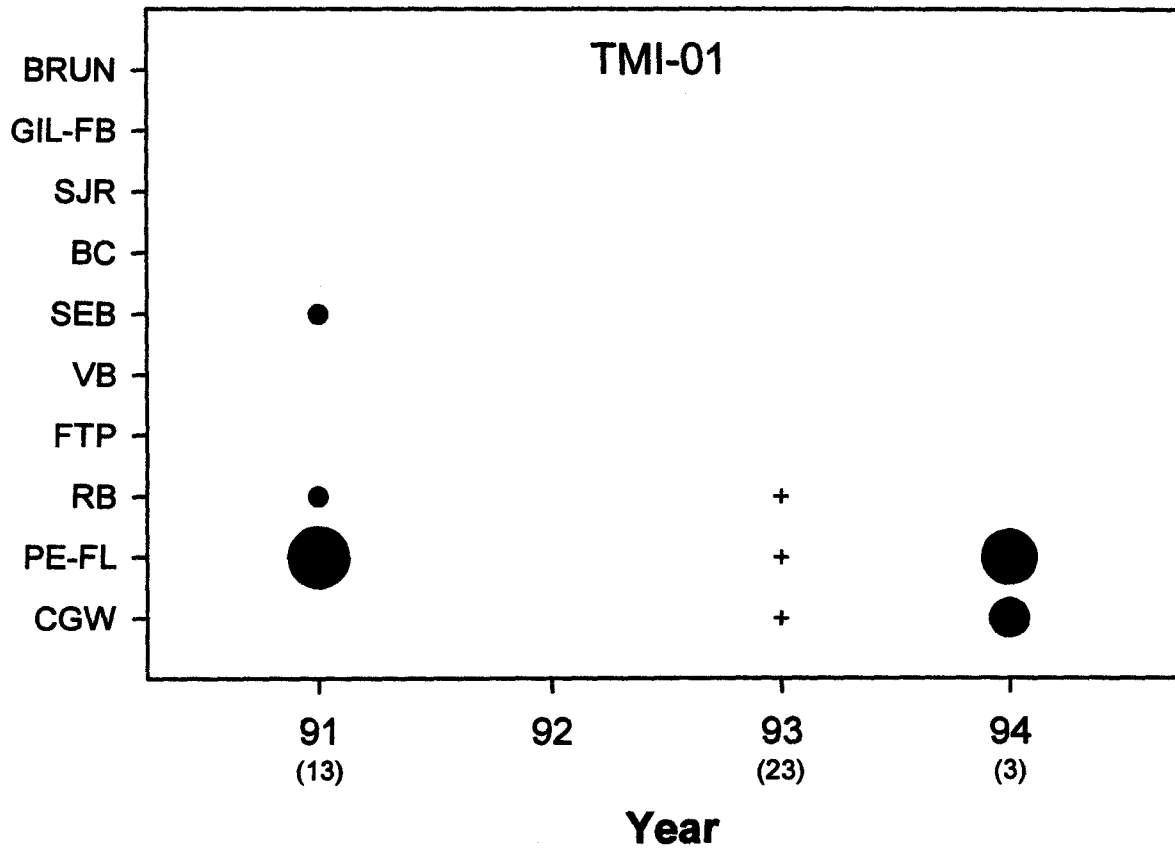


Figure 13. Seasonal variation in the frequency of manatee use (i.e., percentage of pooled manatee-days) of industrial and “natural” warm-water refugia along the Atlantic coast of Florida and Georgia. Total sample size is 58 manatees with satellite-monitored tags; monthly sample size varies from 33 - 48 individuals and 1417 - 2366 manatee-days with locations.

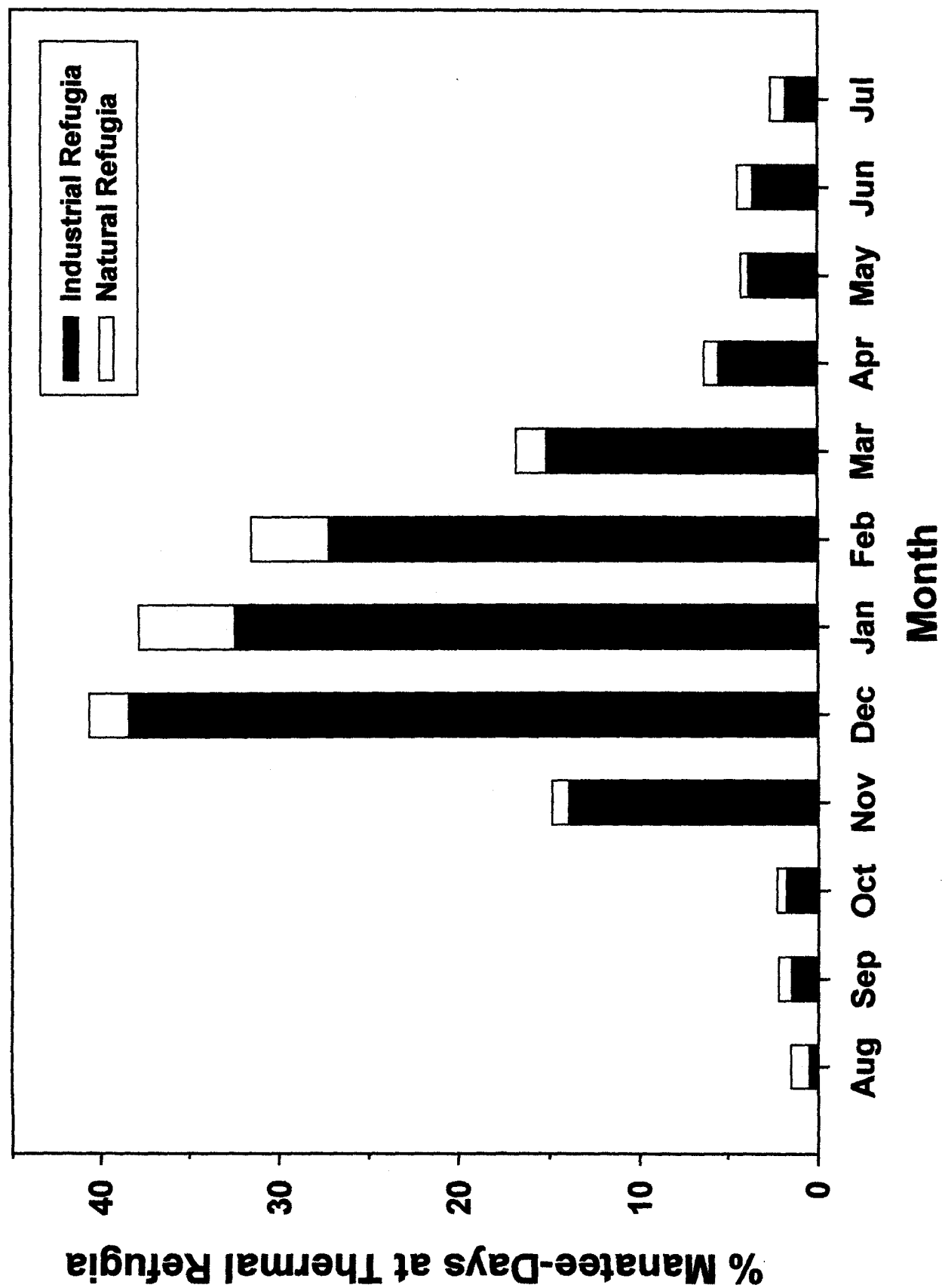


Figure 14. Regional variation in the frequency of manatee use (i.e., percentage of pooled manatee-days) of industrial and “natural” warm-water refugia during winter (Dec - Feb) along the Atlantic coast of Florida and Georgia. Numbers along bars refer to the number of manatees tracked by satellite in each region during winter (total N = 48 individuals). The numbers of manatee-days were 392, 1569, 1066, and 2299 for the N, NC, SC, and S regions, respectively. See Figure 1 for definition of regions.

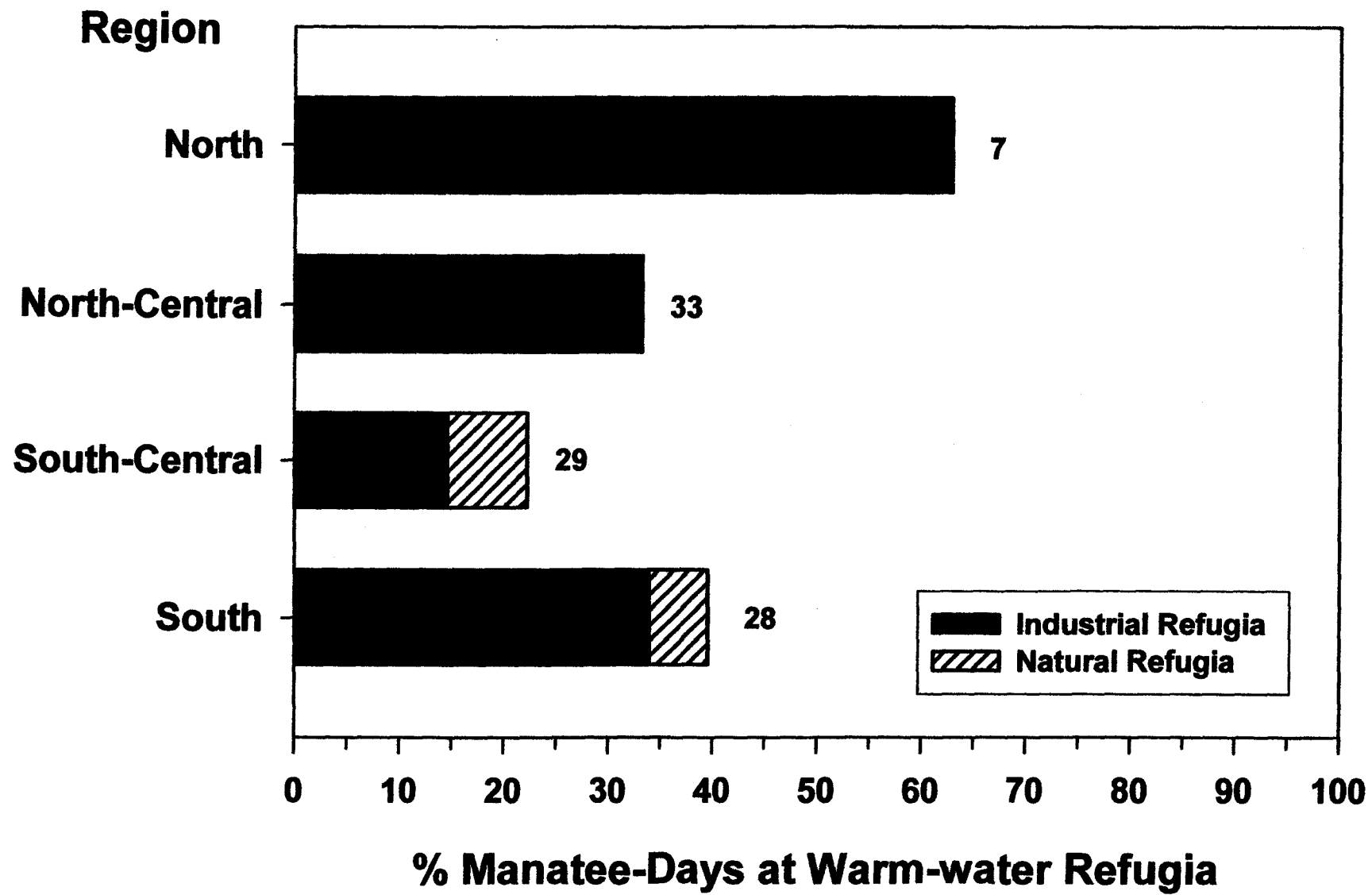


Figure 15. Seasonal variation in the frequency of manatee use (i.e., percentage of pooled manatee-days) of warm-water refugia by region of the Atlantic coast of Florida and Georgia (see Fig. 1). Total sample size is 53 manatees with satellite-monitored tags; N refers to the number of manatees tracked in each region between October and April.

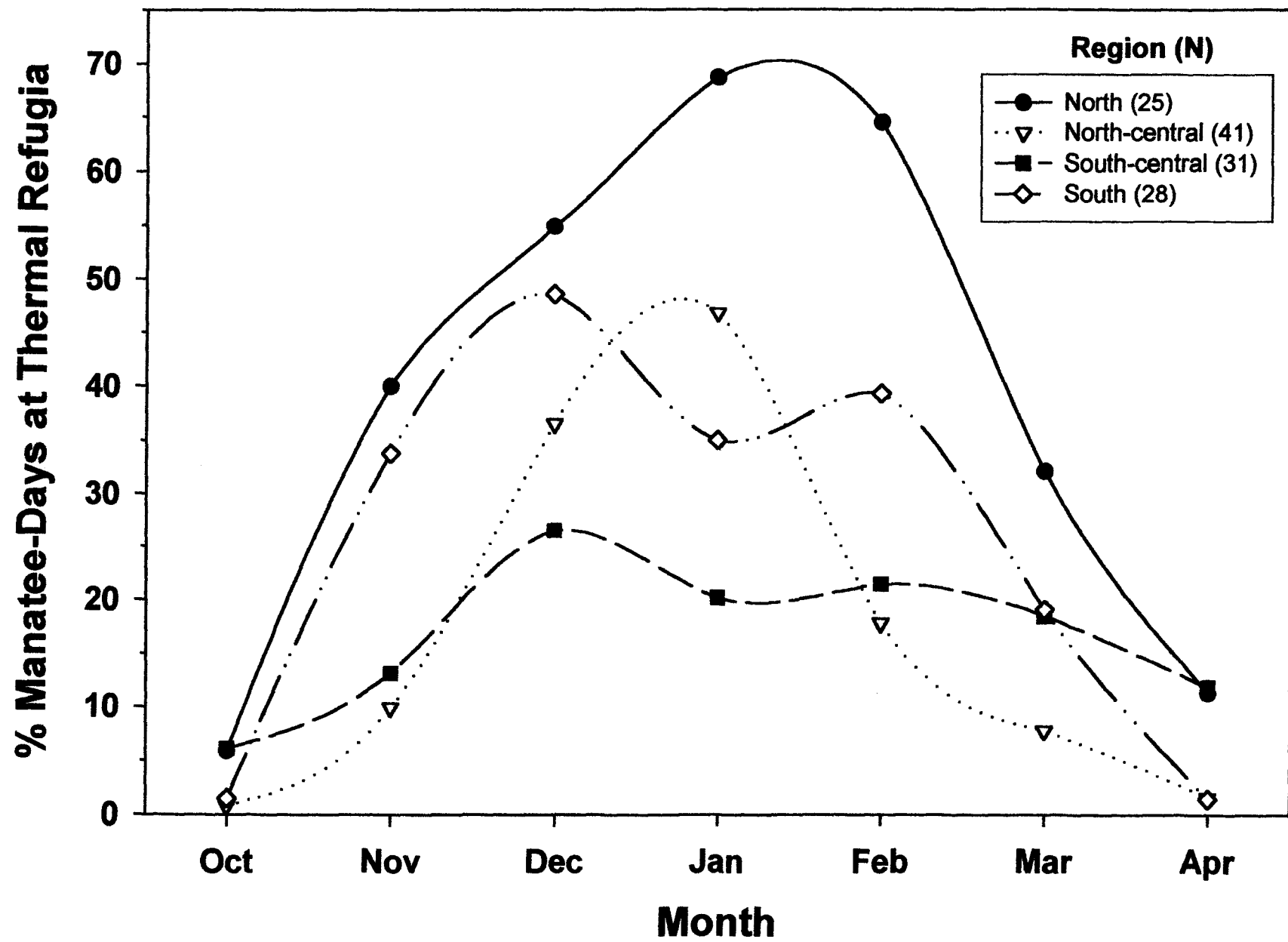


Figure 16. Tagged manatee use of industrial warm-water refugia in the north-central region during the months of November through March in relation to mean daily water temperature in northern Brevard County, FL. Total sample size is 34 manatees with satellite-monitored tags, amounting to 3263 manatee-days from 1988 - 1998. Temperature categories are interpreted as follows: 15 °C = 15.0 - 15.9 °C.

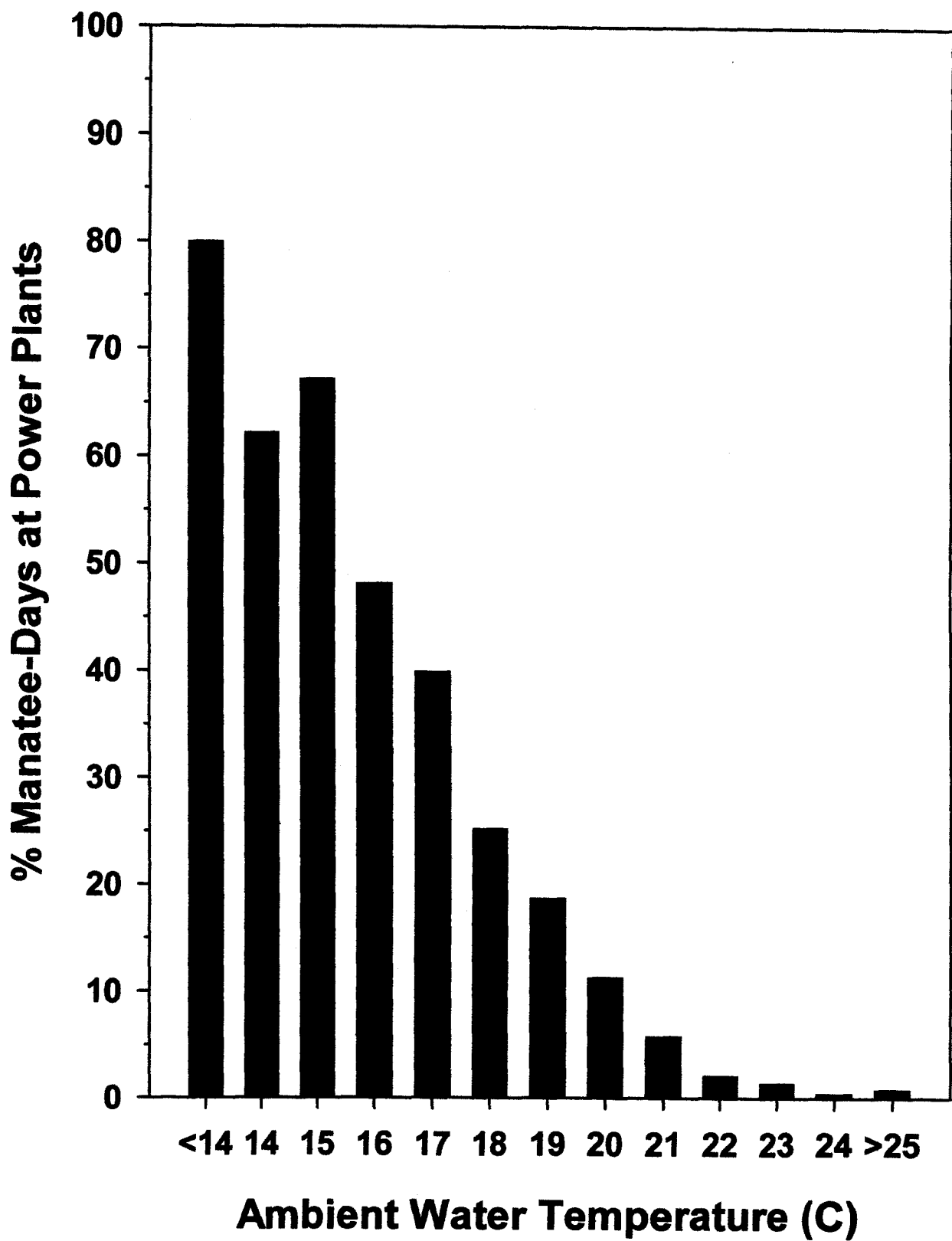
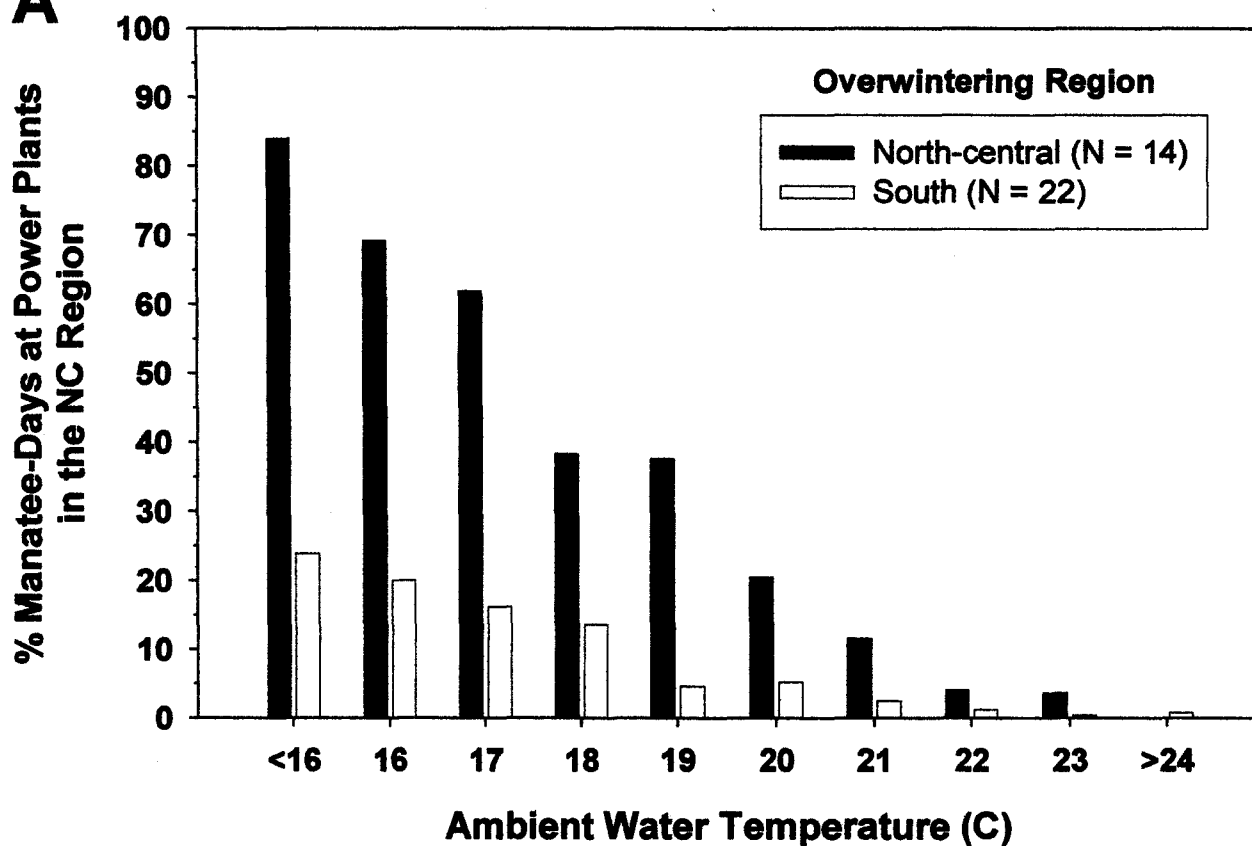
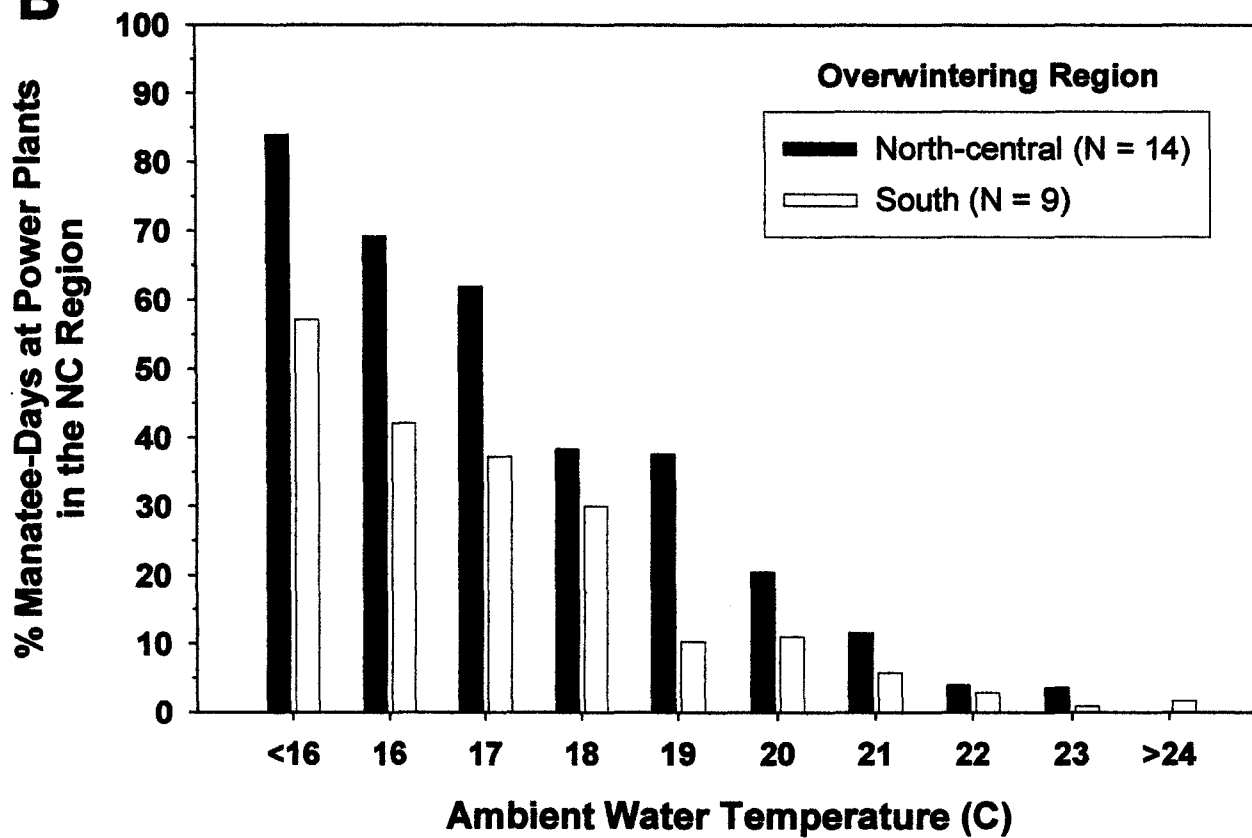


Figure 17. Tagged manatee use of industrial warm-water refugia in the north-central region during the months of November through March (1988 - 1998) in relation to mean daily water temperature in northern Brevard County, FL and broken down by an individual's overwintering region. (A) For 34 manatees located via satellite telemetry in the NC region during the winter, including 22 that migrated to the S or SC regions. (B) For 21 manatees located via satellite telemetry in the NC region during the winter, as in (A) but only including individuals that used the Brevard County power plants at some time during their winter tracking periods. Note that 2 individuals are included in both overwintering region categories because they changed migratory patterns across years. Temperature categories are interpreted as follows: 15 °C = 15.0 - 15.9 °C.

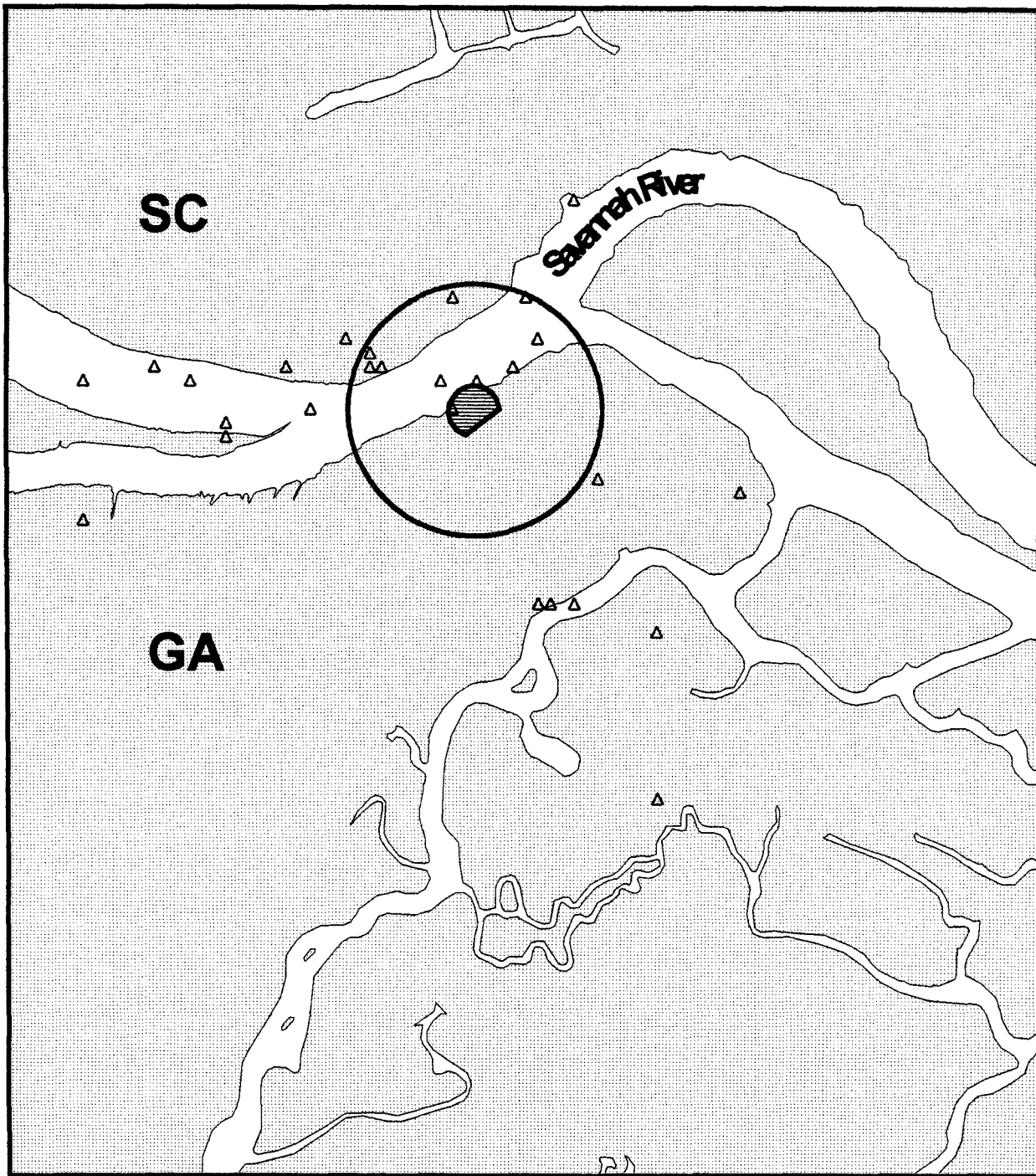
A**B**

APPENDICES

Appendix A. Maps of each of the 16 warm-water sites used by radio-tagged manatees in this study, showing the polygons used to determine manatee presence based on VHF telemetry data (smaller, hatched polygons) and on PTT telemetry data (larger, open circles or polygons). Telemetry locations of tagged manatees during the months of November through March are also shown. All maps are plotted to the same scale (except Fig. A-11) in the NAD-83 datum and UTM zone 17N projection. See Figure 1 for geographic reference.

Figure A-1. Site of the Kemira gypsum plant's warm-water discharge pipe along the Savannah River, Savannah, GA, showing Argos locations (LC2 and LC3, Δ) of 1 tagged manatee in winter 1997-98. The discharge site was first located on an aerial photographic image obtained from the Microsoft TerraServer web site; coordinates (Y = 3549835, X = 497435) were then determined from a USGS quadrangle map. Although the site plots over 100 m inland on the NOAA southeastern states shoreline coverage (scale $\approx$ 1:70,000 - 1:80,000) depicted here, it matches well to a finer-resolution Georgia hydrography coverage (scale = 1:31,000).

Kemira Gypsum Plant

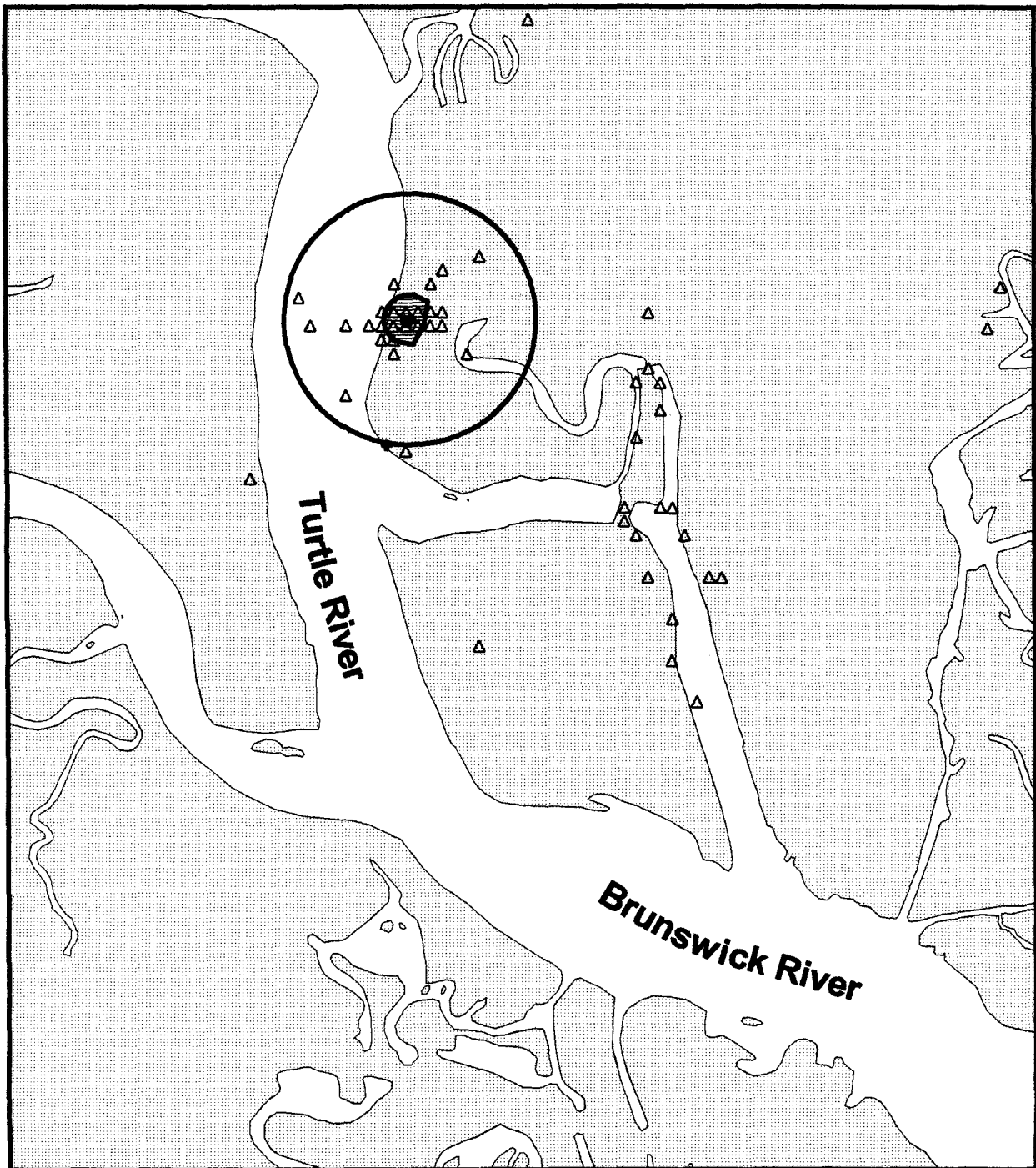


1 0 1 2 Kilometers



Figure A-2. Site of the Georgia-Pacific Company pulp mill's warm-water discharge canal along the Turtle River, Brunswick, GA, showing visual observations (+) and Argos locations (LC3, Δ) of tagged manatees. In recent years this plant has diffused its effluent during the warm season and shifted to direct discharge into a narrow canal starting around the first of January (Barbara Zoodsma, pers. comm.). The discharge site was located on an aerial photographic image obtained from the Microsoft TerraServer web site; coordinates (Y = 3448046, X = 450287) were then determined from a Georgia hydrography coverage (scale = 1:31,000).

Georgia-Pacific Pulp Mill



1 0 1 2 Kilometers



Figure A-3. Site of the Gilman Paper Company's warm-water discharges along the North River, St. Mary's, GA, showing visual observations (⛶) and Argos locations (LC3, Δ) of tagged manatees. The discharge was shifted from the original northerly site (Y = 3401829, X = 448410) to a more southerly site (Y = 3400894, X = 448376) in December 1990, after the completion of the so-called "manatee corral" where manatees were able to access a partially enclosed basin of warm water. Due to sedimentation and other problems, the outfall was shifted again to a site immediately adjacent to the southerly site. Coordinates were determined from examination of digital orthophoto quarter quads (DOQQs) at 3-m resolution.

Figure A-4. Site of the Jefferson-Smurfit pulp mill's warm-water discharge along the Amelia River, Fernandina Beach, FL, showing visual observations (✚) and Argos locations (LC3, Δ) of tagged manatees. Coordinates (Y = 3394762, X = 456128) were determined from examination of DOQQs at 3-m resolution. The effluent was diffused in November 1997 for water quality reasons, effectively eliminating this site as a manatee warm-water refuge.

Jefferson-Smurfit Pulp Mill

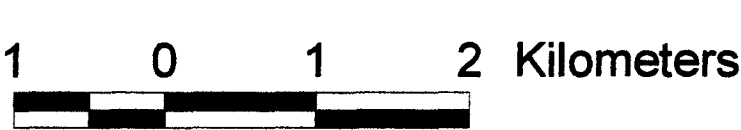
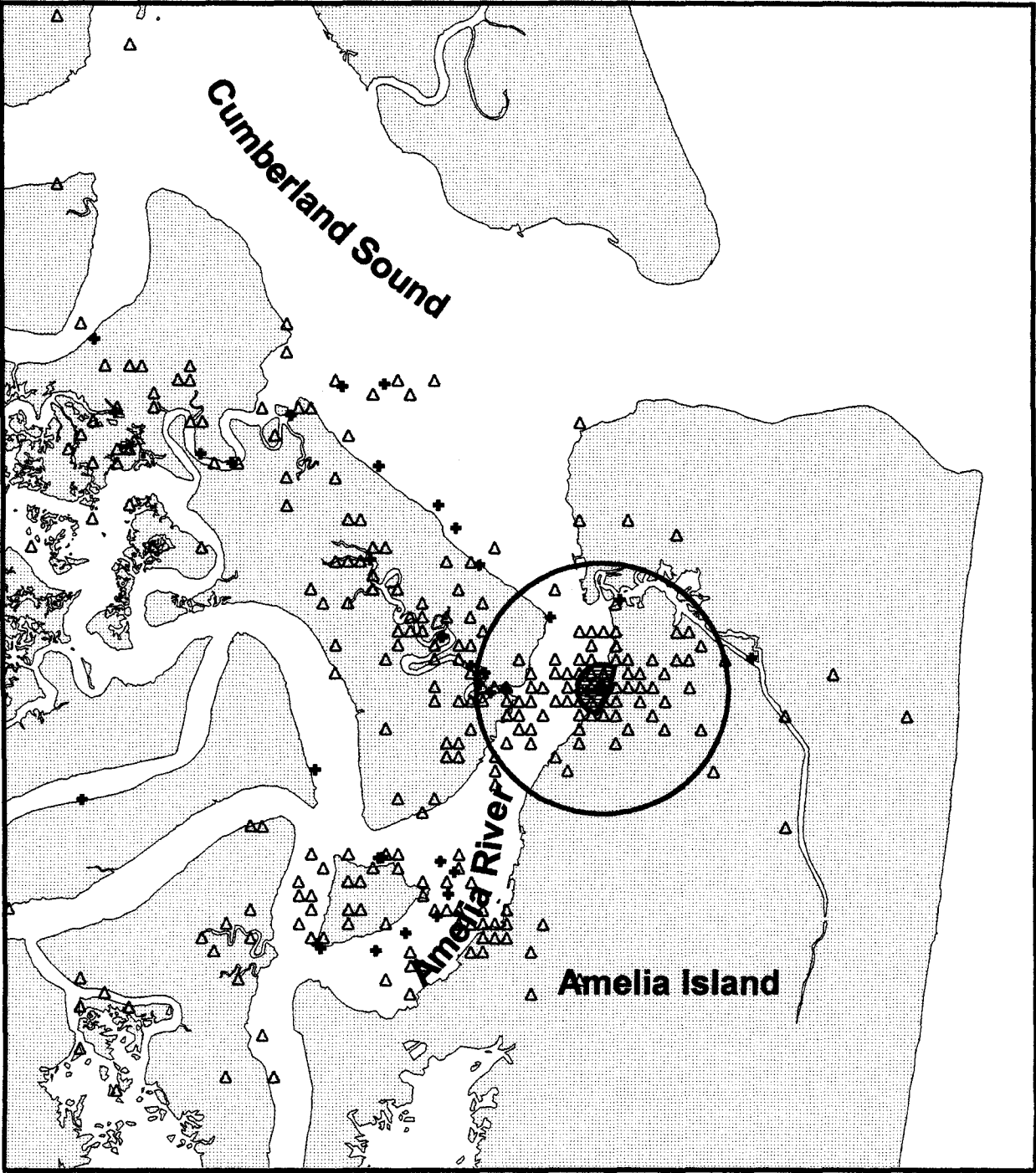
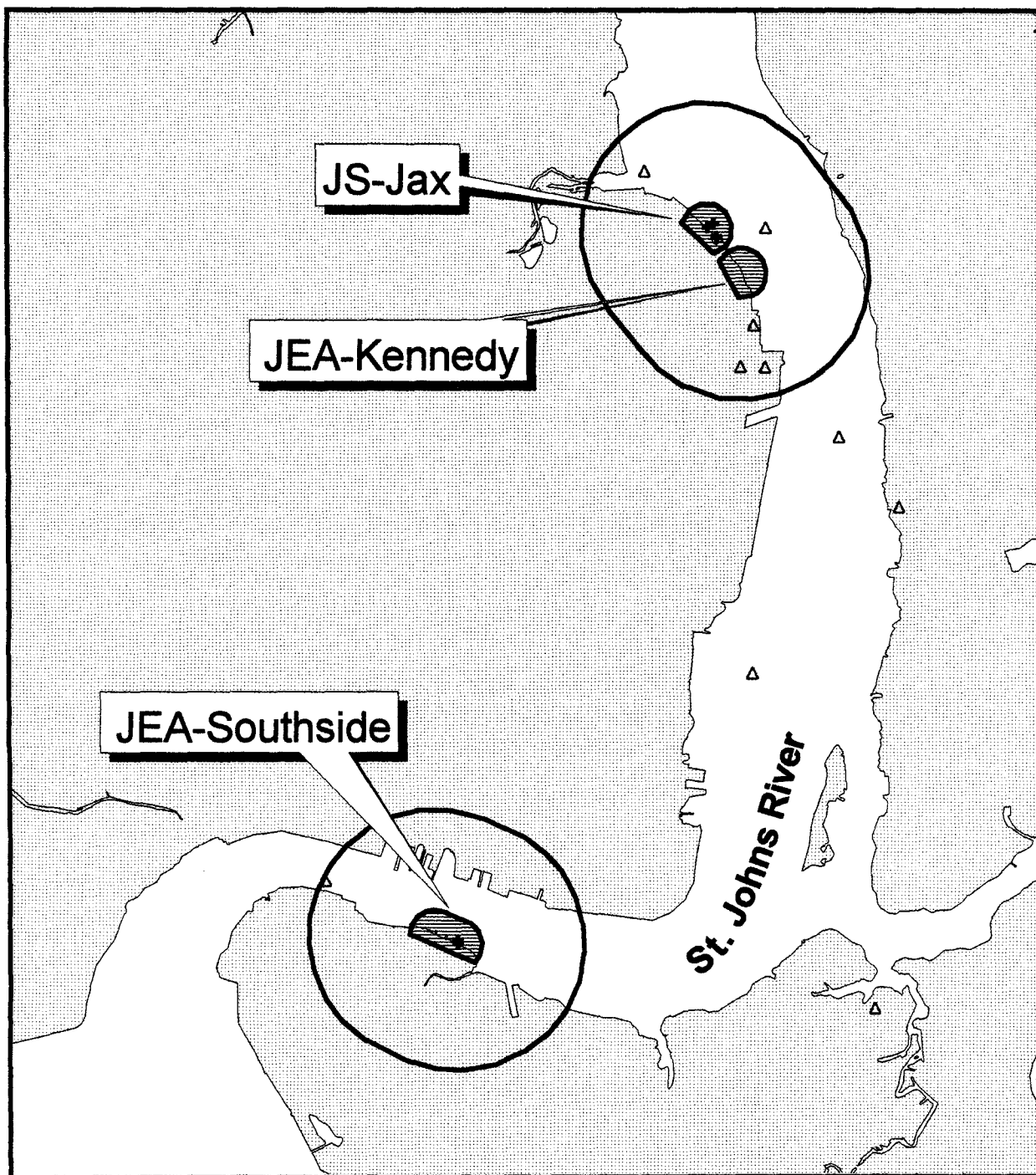


Figure A-5. Locations of 3 industrial warm-water effluents along the lower St. Johns River, Jacksonville, FL, showing visual observations (✚) and Argos locations (LC2 and LC3, Δ) of tagged manatees. The Jefferson-Smurfit plant (formerly Alton Packing Corp.) (JS-JX) discharged warm water from a pipe (Y = 3359712, X = 439869) that attracted manatees early in the study until at least the 1989-90 winter; sometime later the effluent was diffused, eliminating this site as a manatee warm-water refuge (J. Valade, pers. comm.). Sharing a common property boundary with JS-JX is the Jacksonville Electric Authority's Kennedy Generating Station (Y = 3359361, X = 440137), which produced a minor, intermittent source of warm water during this study. Jacksonville Electric Authority's Southside Generating Station has a discharge canal (pipe coordinates at west end: Y = 3354097, X = 437711) that manatees could enter at high tide; otherwise they aggregated near the mouth of the canal at the east end (Y = 3354022, X = 437879). Site coordinates were determined from examination of DOQQs at 3-m resolution with the aid of facility site maps.

Lower St. Johns River Industrial Effluents

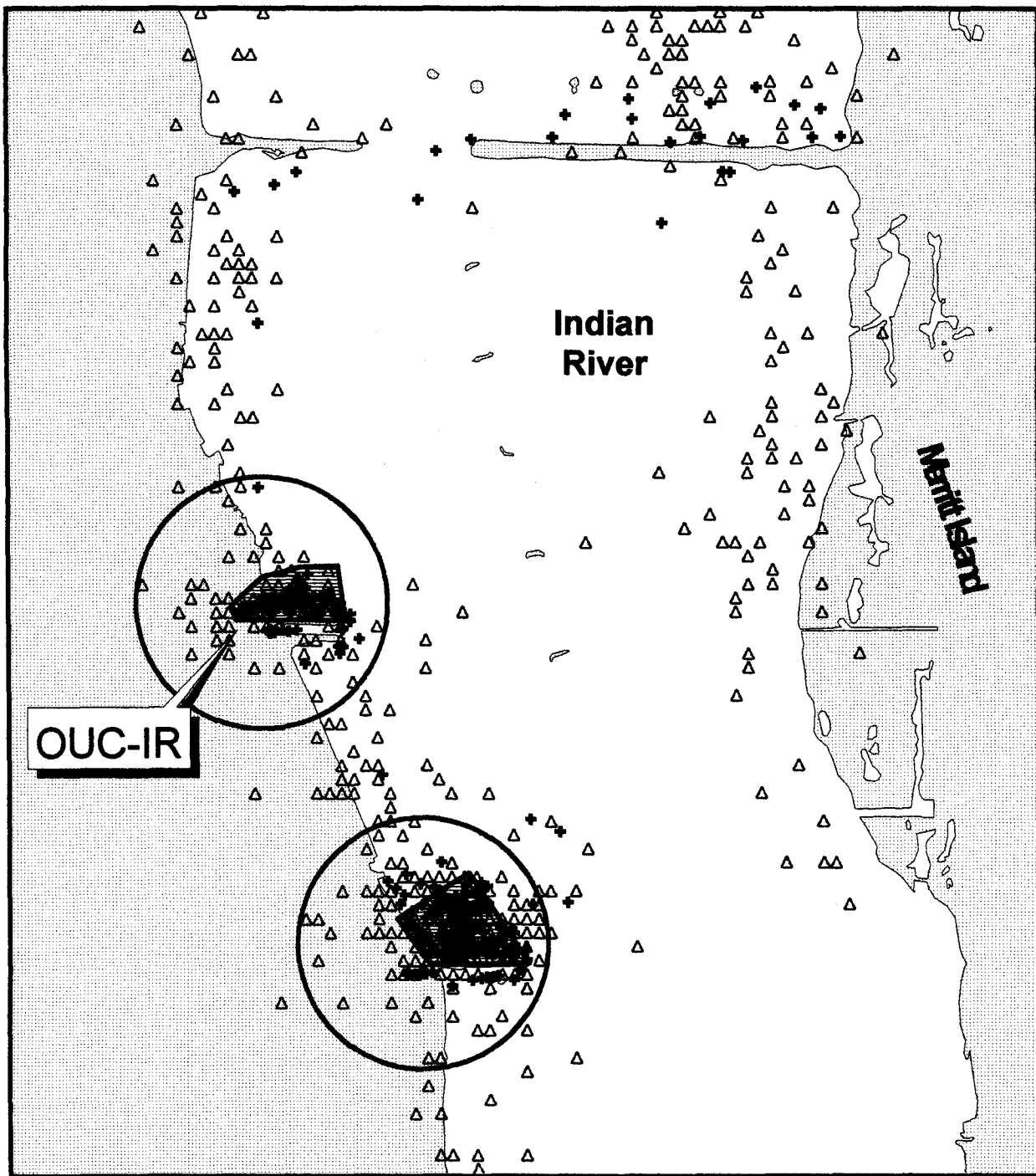


1 0 1 2 Kilometers

A horizontal scale bar with alternating black and white segments, representing distances of 1, 0, 1, and 2 kilometers.

Figure A-6. Locations of 2 power plant warm-water effluents along the northern Indian River, Titusville, FL, showing visual observations (+) and Argos locations (LC3, Δ) of tagged manatees. The Orlando Utilities Commission's Indian River power plant (OUC-IR) discharged warm water into a canal (Y = 3151950, X = 521722) and the Florida Power and Light's Canaveral power plant (FPL-CC) discharged at 2 sites (approximate coordinates for Unit 2 where most manatees aggregated: Y = 3149326, X = 523150). The large volumes of heated water and the breakwaters bounding the sites to the south resulted in extensive thermal plumes that extended well into the Indian River. Note that most Argos locations in the thermal plumes are obscured by VHF locations. Effluent coordinates were determined from a digital NOAA coverage of the shoreline (scale = 1:40,000) (Florida Department of Environmental Protection 1998).

Brevard County Power Plants

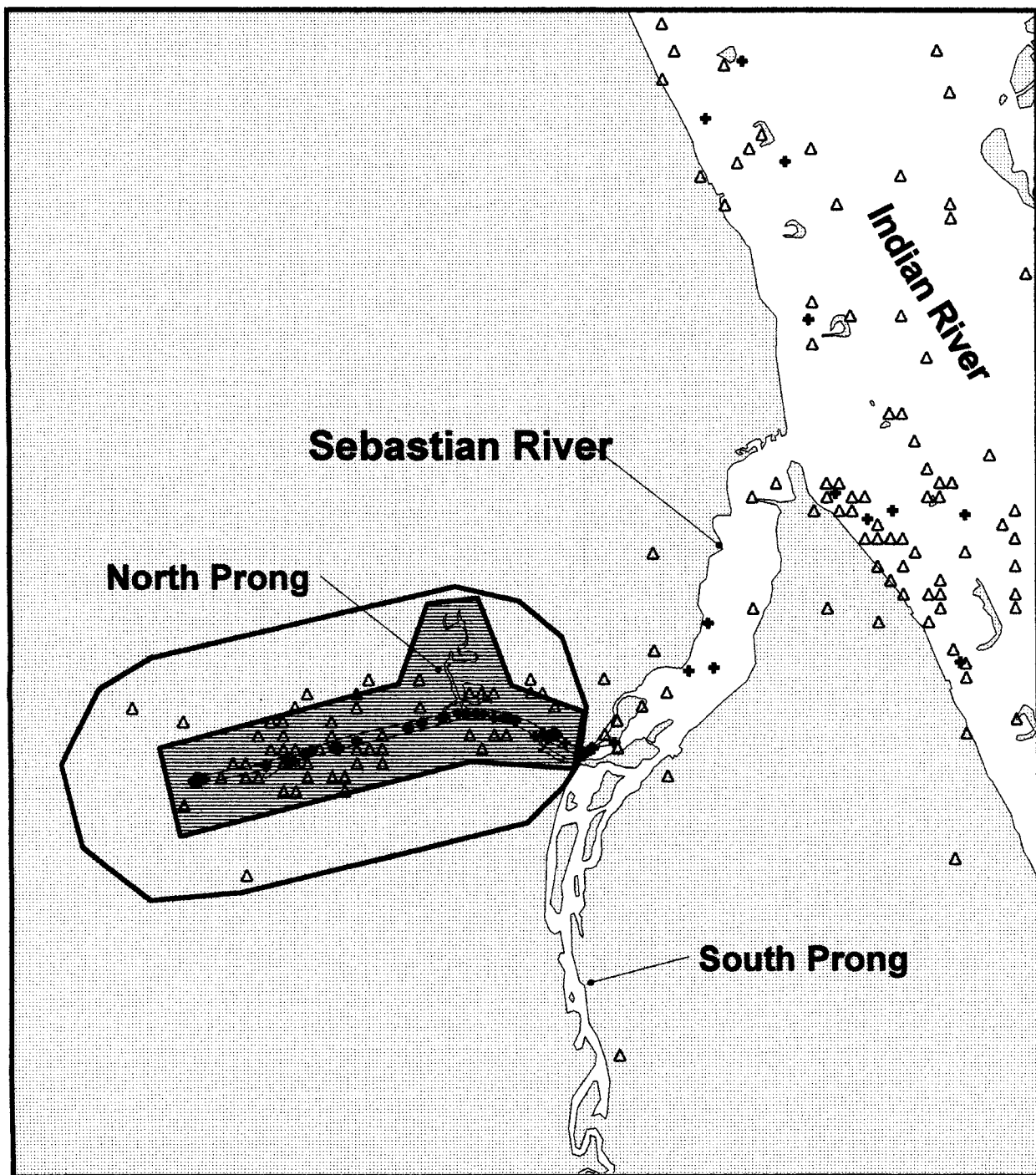


1 0 1 2 Kilometers



Figure A-7. A “natural” warm-water refuge in the north fork of the Sebastian River, Sebastian, FL, showing visual observations (✚) and Argos locations (LC3, Δ) of tagged manatees. The portion of the waterway most frequented by manatees during cool weather is a dredged canal.

North Fork of Sebastian River



1 0 1 2 Kilometers

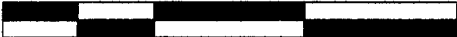
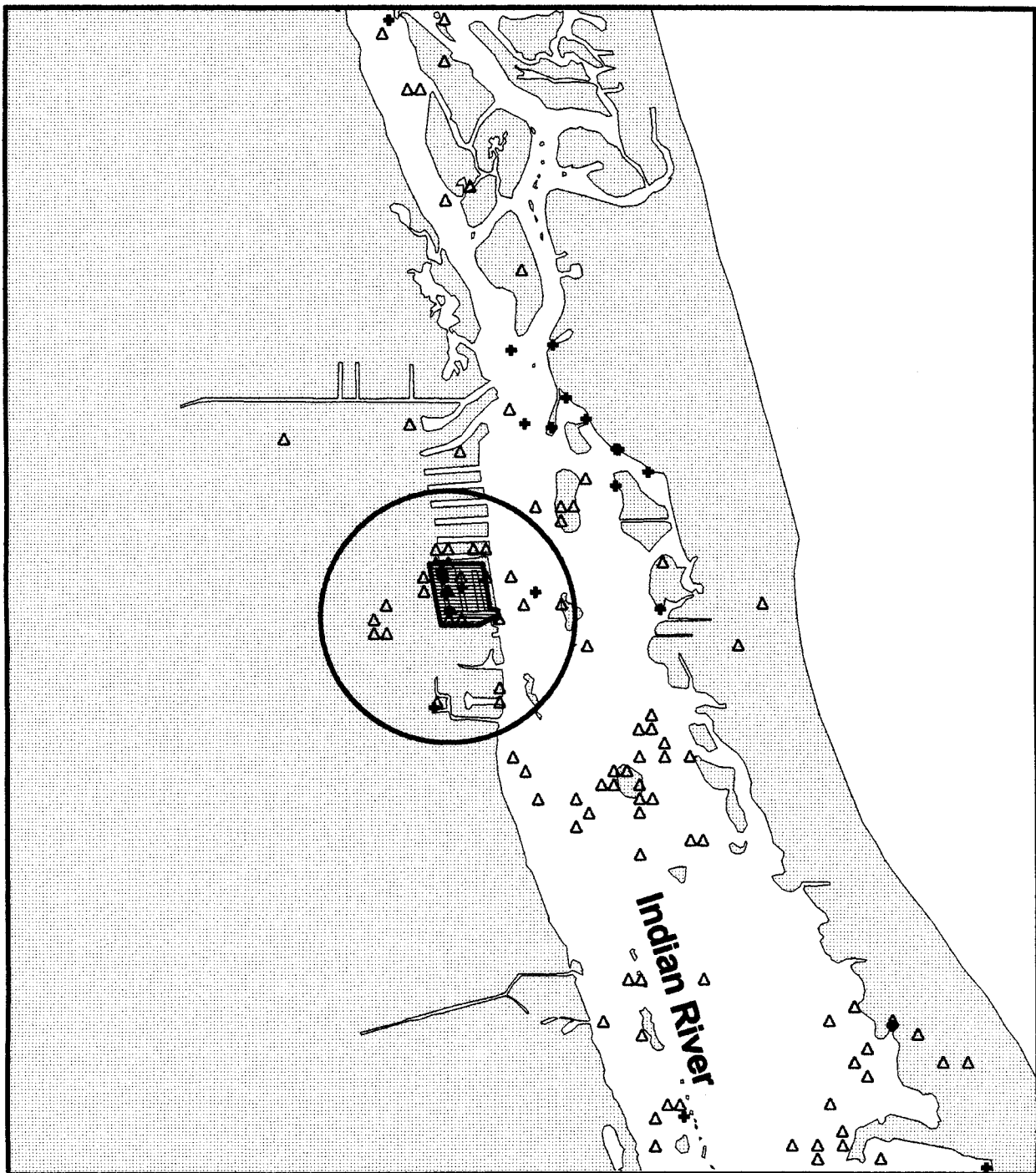
A horizontal scale bar with alternating black and white segments, representing distances of 1, 0, 1, and 2 kilometers.

Figure A-8. Site of the Vero Beach power plant discharge along the Indian River, Vero Beach, FL, showing visual observations (✚) and Argos locations (LC3, Δ) of tagged manatees. Coordinates of the discharge site (Y = 3056824, X = 561273) were determined from a digital NOAA coverage of the shoreline (scale = 1:40,000) (Florida Department of Environmental Protection 1998).

Vero Beach Power Plant

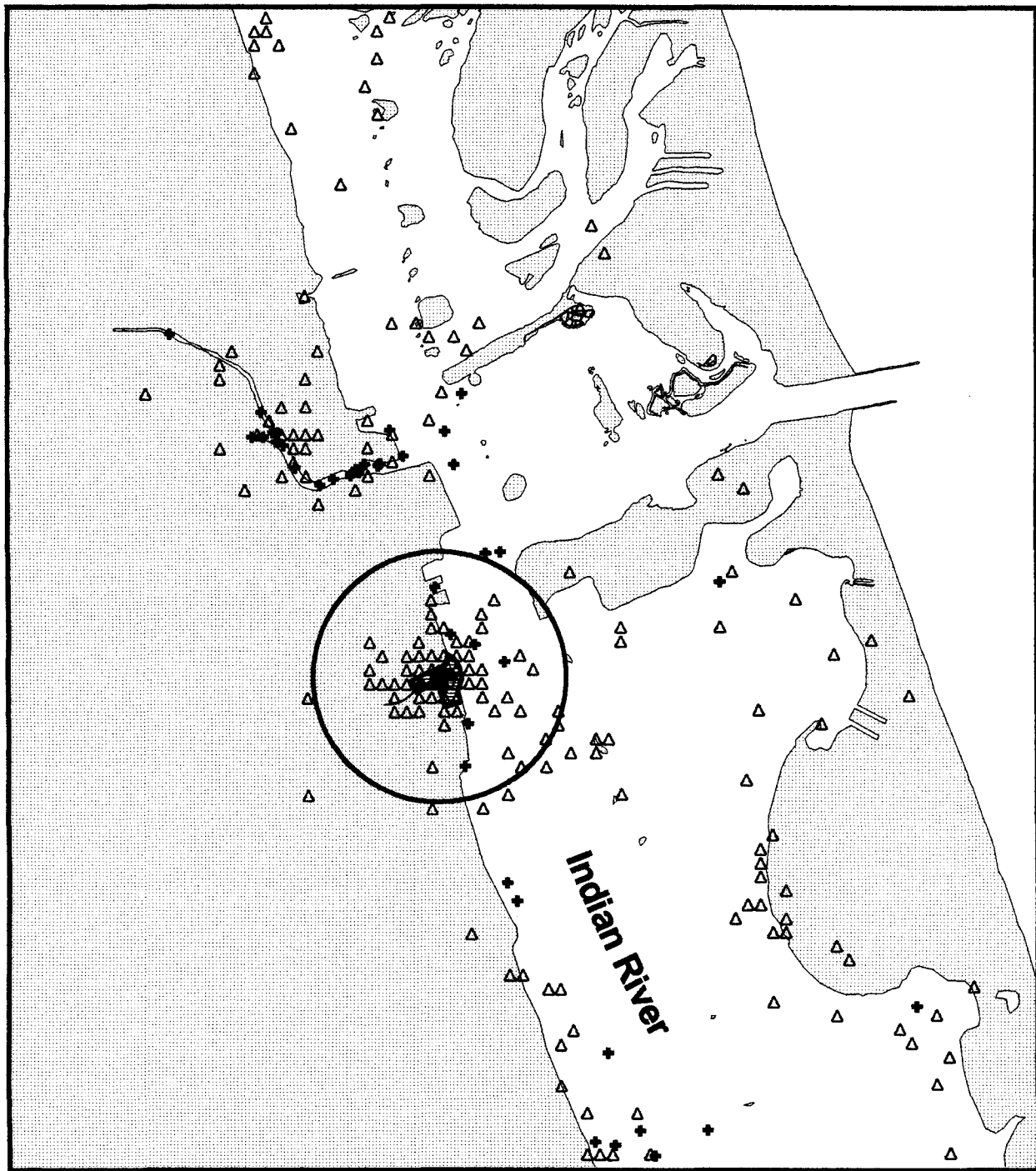


1 0 1 2 Kilometers



Figure A-9. Site of the Henry D. King municipal power plant discharge along the Indian River, Ft. Pierce, FL, showing visual observations (✚) and Argos locations (LC3, Δ) of tagged manatees. Coordinates of the discharge site (Y = 3036616, X = 566846) were determined from a digital NOAA coverage of the shoreline (scale = 1:40,000) (Florida Department of Environmental Protection 1998).

Fort Pierce Power Plant

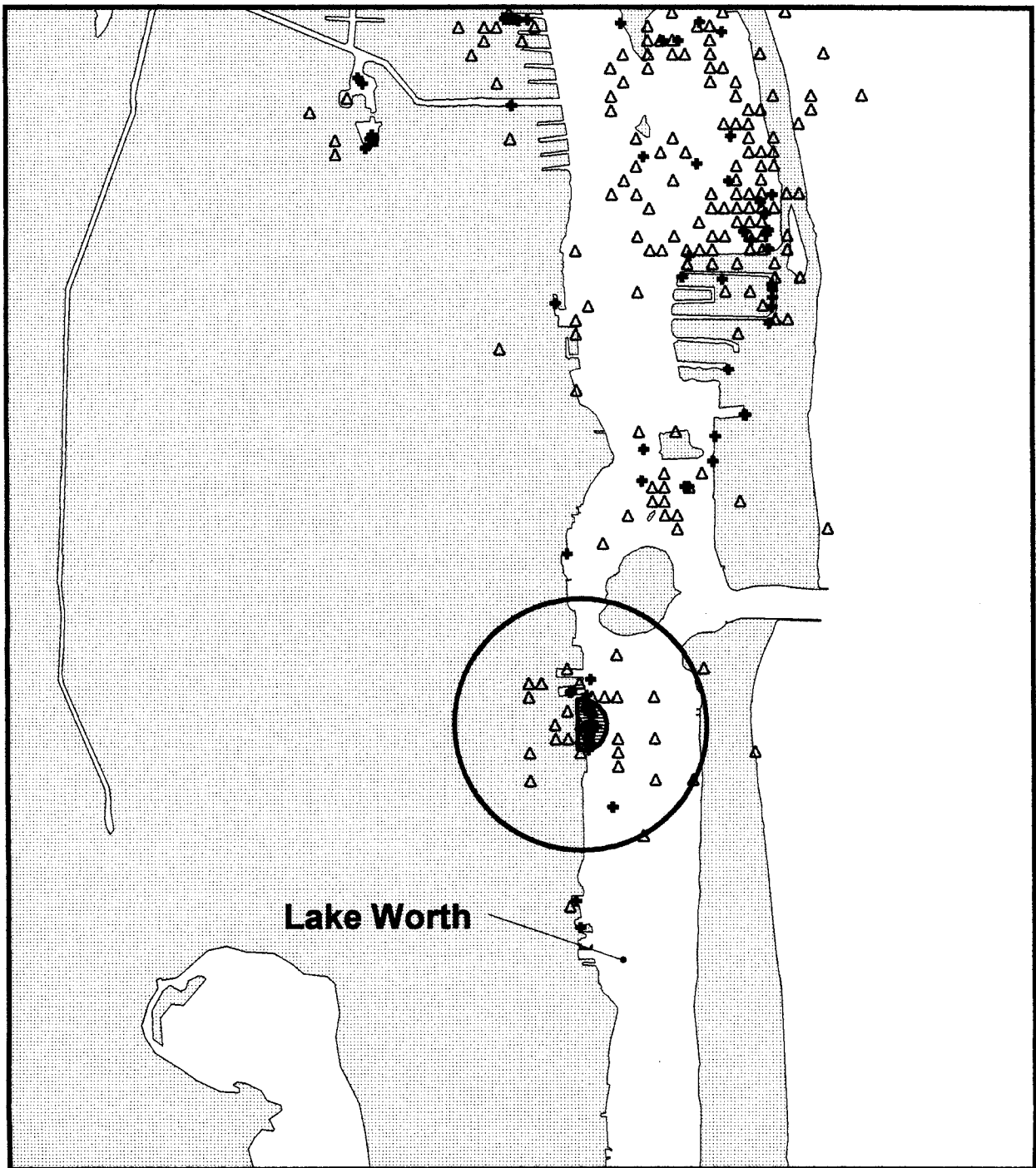


1 0 1 2 Kilometers

A horizontal scale bar with alternating black and white segments, used to indicate distance in kilometers.

Figure A-10. Site of the Florida Power and Light Riviera Beach power plant along Lake Worth, Riviera Beach, FL, showing visual observations (+) and Argos locations (LC3, Δ) of tagged manatees. Coordinates of the discharge site (Y = 2960644, X = 594374) were determined from a digital NOAA coverage of the shoreline (scale = 1:40,000) (Florida Department of Environmental Protection 1998).

FPL Riviera Beach Power Plant



1 0 1 2 Kilometers



Figure A-11. Sites of two Florida Power and Light power plants in Port Everglades, FL (FPL-PE) and Fort Lauderdale, FL (FPL-FL), showing visual observations (+) and Argos locations (LC3, Δ) of tagged manatees. Coordinates of the FPL-PE discharge site (Y = 2885319, X = 587427) were determined from a digital NOAA coverage of the shoreline (scale = 1:40,000) (Florida Department of Environmental Protection 1998). Coordinates of the FPL-FL discharge site (Y = 2883602, X = 580110) were determined from examination of DOQQs at 3-m resolution with the aid of ground photographs and field notes.

FPL Port Everglades & Ft. Lauderdale Power Plants

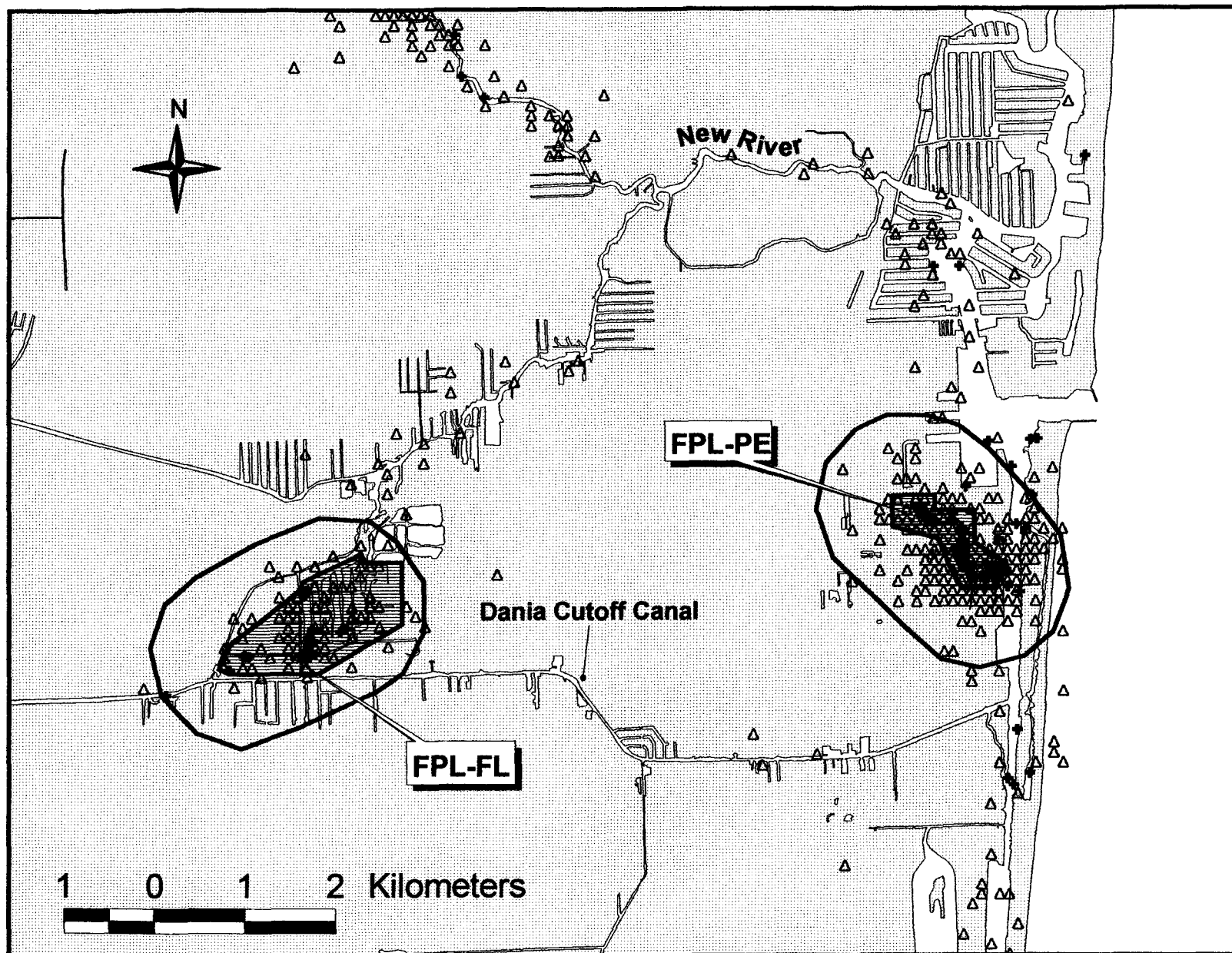
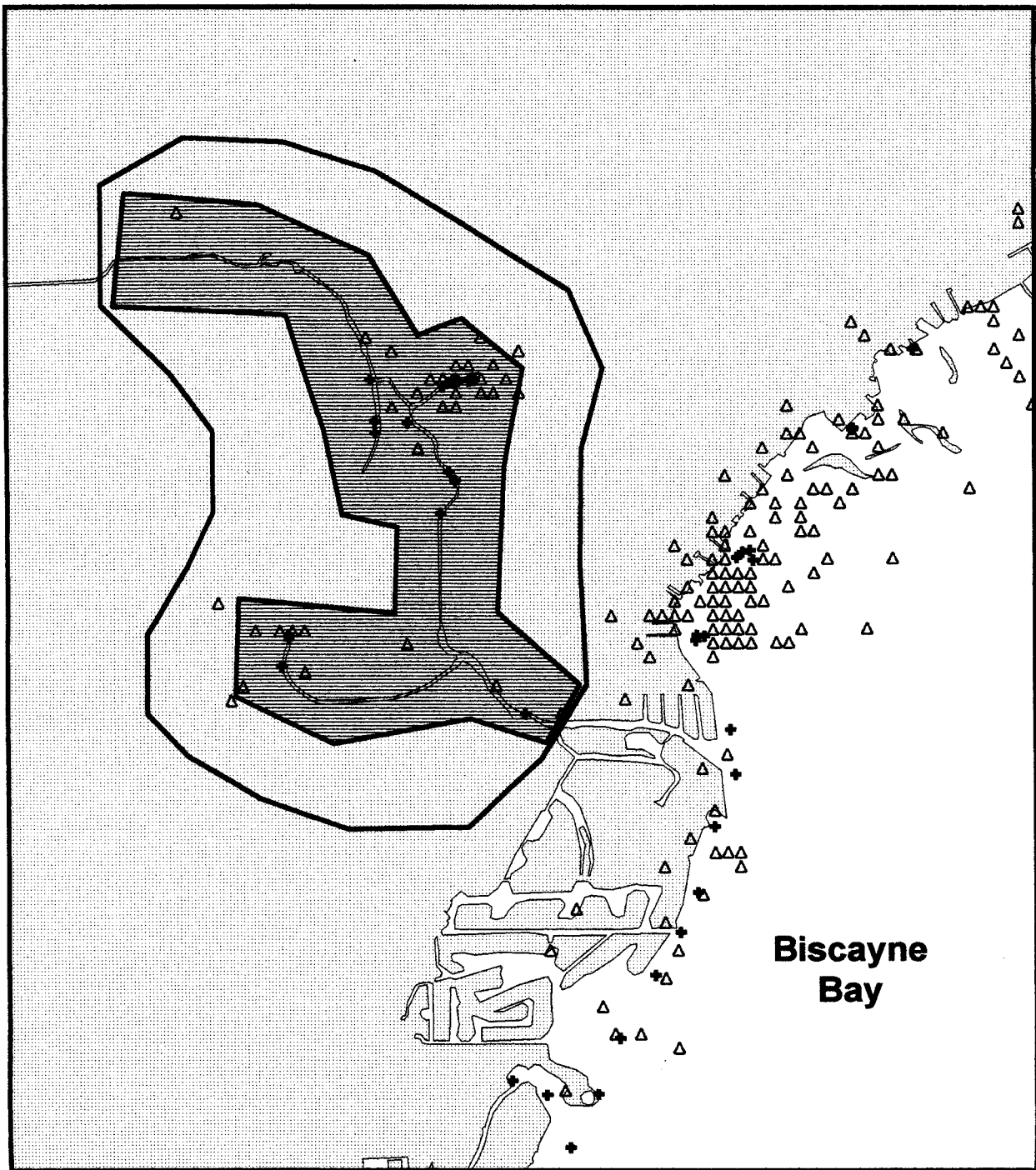


Figure A-12. A “natural” warm-water refuge in the Coral Gables Waterway at the edge of Biscayne Bay, Coral Gables, FL, showing visual observations (⊕) and Argos locations (LC3, Δ) of tagged manatees. This dredged waterway is apparently fed by seeps or other sources of constant-temperature ground water.

Coral Gables Waterway



1 0 1 2 Kilometers



Appendix B. Tables showing the number of days tracked (i.e., carrying a functioning radio-tag), the number of days located (by Argos or in the field), the number of warm-water refugia used, the number of regions in which warm-water sites were visited, the number of days located at each warm-water refuge, and the number of days present at all warm-water refugia by region. These variables are tabulated for each individual by year (Tables B-1 and B-2) and cumulatively over each individual's entire tracking history (Tables B-3 and B-4).

Table B-1. Data for each radio-tagged manatee (N = 71) and year (November to March, n = 175 manatee-winters) on tracking effort, number of warm-water refugia visited, number of regions (see Fig. 1) where refugia were visited, and the number of days at refugia in each region.

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-01	Dixie	1986-87	67	22	3	2	0	1	0	5
TBC-01	Dixie	1987-88	66	60	3	2	0	2	0	12
TBC-03	Moon	1986-87	55	33	1	1	0	0	0	8
TBC-03	Moon	1987-88	144	110	6	3	0	11	10	19
TBC-03	Moon	1988-89	64	64	3	2	0	0	19	1
TBC-03	Moon	1989-90	72	61	5	3	0	15	2	21
TBC-03	Moon	1990-91	123	118	5	3	0	29	4	3
TBC-03	Moon	1991-92	72	56	2	2	0	0	1	9
TBC-03	Moon	1992-93	112	108	7	3	0	17	9	6
TBC-03	Moon	1993-94	114	102	2	2	0	0	3	14
TBC-04	Eclipse	1986-87	144	91	2	1	0	0	0	13
TBC-05	Gyro	1986-87	139	116	2	1	0	57	0	0
TBC-05	Gyro	1987-88	3	5	0	0	0	0	0	0

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-05	Gyro	1988-89	0	2	1	1	0	1	0	0
TBC-06	Moe	1987-88	152	74	2	1	0	33	0	0
TBC-06	Moe	1988-89	151	131	3	2	1	50	0	0
TBC-06	Moe	1989-90	16	16	2	1	0	2	0	0
TBC-06	Moe	1990-91	12	8	2	1	0	3	0	0
TBC-09	C-cow	1987-88	83	66	4	2	0	0	3	35
TBC-09	C-cow	1988-89	144	95	3	2	0	0	1	40
TBC-09	C-cow	1989-90	125	102	4	2	0	0	1	34
TBC-09	C-cow	1990-91	92	33	3	2	0	0	2	14
TBC-09	C-cow	1991-92	151	145	4	2	0	0	1	55
TBC-09	C-cow	1992-93	150	112	5	2	0	0	3	48
TBC-09	C-cow	1993-94	151	140	5	2	0	0	5	50
TBC-09	C-cow	1994-95	151	134	2	1	0	0	0	31
TBC-10	Fran	1987-88	67	32	2	1	0	8	0	0
TBC-10	Fran	1989-90	0	1	1	1	0	0	0	1

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-11	Gloria	1987-88	59	26	2	1	0	9	0	0
TBC-12	Heike	1987-88	16	6	1	1	0	5	0	0
TBC-12	Heike	1988-89	0	2	1	1	0	2	0	0
TBC-13	Irene	1987-88	136	77	3	2	0	22	0	2
TBC-13	Irene	1988-89	0	1	1	1	0	1	0	0
TBC-14	Jerome	1987-88	131	77	4	2	0	14	0	15
TBC-15	Karen	1987-88	135	73	2	1	0	37	0	0
TBC-15	Karen	1988-89	30	31	2	1	0	10	0	0
TBC-15	Karen	1989-90	15	13	2	1	0	12	0	0
TBC-16	Larry	1987-88	4	3	0	0	0	0	0	0
TBC-17	Madonna	1987-88	38	30	3	2	0	14	0	2
TBC-17	Madonna	1989-90	0	1	1	1	0	0	0	1
TBC-18	Leroy	1987-88	2	2	0	0	0	0	0	0
TBC-18	Leroy	1988-89	0	2	1	1	0	2	0	0
TBC-18	Leroy	1989-90	0	1	0	0	0	0	0	0

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-20	Ruth	1988-89	116	66	4	2	0	0	3	13
TBC-20	Ruth	1989-90	68	65	4	2	0	0	1	24
TBC-21	Willie	1988-89	0	1	0	0	0	0	0	0
TBC-21	Willie	1989-90	22	17	1	1	0	0	2	0
TBC-21	Willie	1990-91	0	1	1	1	0	0	0	1
TBC-23	Hillary	1988-89	2	3	1	1	2	0	0	0
TBC-23	Hillary	1989-90	55	55	3	2	5	23	0	0
TBC-23	Hillary	1990-91	133	45	4	2	5	14	0	0
TBC-23	Hillary	1991-92	152	149	4	2	46	56	0	0
TBC-23	Hillary	1996-97	24	24	1	1	7	0	0	0
TBC-23	Hillary	1997-98	123	121	3	2	43	25	0	0
TBC-24	Betty	1989-90	123	115	4	2	0	0	6	34
TBC-24	Betty	1990-91	144	91	4	2	0	0	2	32
TBC-24	Betty	1991-92	152	146	3	2	0	0	4	48
TBC-24	Betty	1992-93	151	139	4	2	0	0	2	59

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-24	Betty	1993-94	150	128	7	3	0	11	3	37
TBC-24	Betty	1994-95	151	138	4	2	0	0	1	46
TBC-25	D-cow	1989-90	151	99	3	2	0	0	2	33
TBC-25	D-cow	1990-91	12	4	0	0	0	0	0	0
TBC-26	Peewee	1989-90	136	118	4	2	0	0	2	14
TBC-26	Peewee	1990-91	149	141	5	3	1	0	6	15
TBC-26	Peewee	1991-92	129	104	6	3	0	9	9	12
TBC-26	Peewee	1993-94	93	84	1	1	0	0	0	16
TBC-29	Casey	1990-91	151	53	2	1	0	16	0	0
TBC-29	Casey	1991-92	52	34	2	1	0	18	0	0
TBC-30	Maria	1990-91	119	52	2	1	0	27	0	0
TBC-31	Freddie	1990-91	151	55	2	1	0	33	0	0
TBC-31	Freddie	1991-92	152	135	2	1	0	73	0	0
TBC-32	Tomasina	1991-92	44	21	1	1	0	0	0	1
TBC-32	Tomasina	1992-93	10	6	0	0	0	0	0	0

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-32	Tomasina	1993-94	0	4	0	0	0	0	0	0
TBC-35	E-cow	1992-93	51	43	3	2	0	0	4	8
TBC-36	Sunshine	1992-93	151	131	3	1	0	0	36	0
TBC-36	Sunshine	1993-94	53	53	3	2	0	0	13	4
TBC-37	Pamela	1992-93	151	146	2	2	0	0	4	2
TBC-37	Pamela	1994-95	0	1	1	1	0	0	0	1
TBC-41	Scott	1994-95	100	97	2	1	0	44	0	0
TBC-42	Chessie	1994-95	79	70	2	1	0	0	0	8
TBC-42	Chessie	1995-96	40	39	2	2	1	0	0	4
TFK-01	Manny	1993-94	151	137	0	0	0	0	0	0
TFK-02	Stan	1993-94	131	111	0	0	0	0	0	0
TFK-03	Ollie	1993-94	107	103	0	0	0	0	0	0
TFP-02	Ross	1990-91	145	142	2	2	0	0	2	2
TFP-02	Ross	1991-92	152	128	3	2	0	0	13	3
TFP-02	Ross	1992-93	151	144	2	2	0	0	4	9

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TFP-03	Natalie	1991-92	36	35	2	2	0	0	1	2
TFP-03	Natalie	1992-93	11	11	2	1	0	0	6	0
TFP-03	Natalie	1993-94	73	73	2	2	0	0	9	4
TFP-04	Sophia	1991-92	29	31	2	2	0	0	1	1
TFP-04	Sophia	1993-94	106	104	2	2	0	0	2	5
TFP-04	Sophia	1994-95	40	38	2	2	0	0	6	5
TFP-04	Sophia	1995-96	77	74	3	2	0	0	4	6
TFP-05	Lani	1991-92	152	147	3	2	0	0	12	15
TFP-05	Lani	1992-93	72	63	1	1	0	0	0	3
TFP-06	Vanna	1991-92	12	12	1	1	0	0	7	0
TFP-06	Vanna	1992-93	151	141	3	2	0	0	45	11
TFP-06	Vanna	1993-94	104	94	3	2	0	0	4	7
TFP-06	Vanna	1994-95	57	10	2	2	0	0	3	2
TGA-01	Mary	1989-90	151	151	4	3	3	44	13	0
TGA-02	Tory	1994-95	22	22	2	1	11	0	0	0

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TGA-02	Tory	1995-96	0	1	0	0	0	0	0	0
TGA-03	Marmontel	1994-95	22	22	2	1	11	0	0	0
TGA-03	Marmontel	1995-96	93	92	2	1	70	0	0	0
TGA-03	Marmontel	1996-97	87	64	1	1	44	0	0	0
TGA-04	Mercury	1995-96	20	19	2	1	8	0	0	0
TGA-04	Mercury	1996-97	151	134	4	2	49	5	0	0
TGA-04	Mercury	1997-98	10	10	1	1	4	0	0	0
TGA-05	Bailey	1996-97	15	14	1	1	1	0	0	0
TGA-05	Bailey	1997-98	151	133	3	2	1	38	0	0
TGA-06	Savannah	1996-97	15	15	1	1	1	0	0	0
TGA-07	GP	1996-97	15	14	2	1	6	0	0	0
TJX-01	Connie	1990-91	126	73	6	4	1	30	1	4
TJX-01	Connie	1991-92	73	57	6	3	0	13	2	14
TJX-02	Patience	1991-92	102	98	2	1	0	35	0	0
TJX-02	Patience	1994-95	54	48	2	2	0	0	2	4

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North- Central	South- Central	South
TJX-03	Freckles	1993-94	151	138	2	1	0	76	0	0
TMI-01	Bob	1990-91	88	72	3	2	0	0	1	12
TMI-01	Bob	1992-93	50	46	3	1	0	0	0	23
TMI-01	Bob	1993-94	96	83	2	1	0	0	0	3
TMI-02	Fergie	1992-93	151	150	2	1	0	0	0	18
TMI-02	Fergie	1993-94	34	33	3	2	0	0	4	1
TMI-03	Clockwork	1993-94	49	45	1	1	0	0	0	4
TNC-01	Diane	1986-87	21	5	2	2	1	1	0	0
TNC-01	Diane	1987-88	152	106	3	3	0	6	2	3
TNC-01	Diane	1989-90	104	101	4	3	0	4	1	12
TNC-01	Diane	1990-91	39	36	2	1	0	5	0	0
TNC-02	Jesse	1986-87	21	15	2	1	9	0	0	0
TNC-03	Tammy	1987-88	36	7	2	1	5	0	0	0
TNC-03	Tammy	1988-89	0	3	1	1	3	0	0	0
TNC-03	Tammy	1995-96	20	18	3	1	7	0	0	0

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TNC-03	Tammy	1996-97	24	24	2	1	3	0	0	0
TNC-04	Pat	1987-88	36	9	1	1	6	0	0	0
TNC-05	Roseanne	1988-89	73	33	2	1	30	0	0	0
TNC-06	Nancy	1988-89	73	41	2	1	8	0	0	0
TNC-06	Nancy	1990-91	42	21	3	2	2	0	0	5
TNC-07	Whitie	1988-89	16	6	2	1	4	0	0	0
TNC-08	George	1988-89	16	4	1	1	2	0	0	0
TNC-08	George	1989-90	0	1	0	0	0	0	0	0
TNC-09	Janatee	1994-95	20	20	1	1	5	0	0	0
TNC-09	Janatee	1995-96	0	1	1	1	1	0	0	0
TNC-10	March	1994-95	20	20	2	1	7	0	0	0
TNC-10	March	1995-96	101	95	5	3	6	4	0	4
TNC-10	March	1996-97	151	148	3	2	1	41	0	0
TNC-11	Vale	1994-95	20	20	1	1	8	0	0	0
TNC-12	Mossie	1995-96	19	19	2	1	13	0	0	0

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TNC-12	Mossie	1996-97	85	53	2	2	2	6	0	0
TNC-12	Mossie	1997-98	17	16	2	1	0	4	0	0
TNC-13	Knicky	1996-97	26	25	1	1	10	0	0	0
TNC-13	Knicky	1997-98	151	141	8	4	22	3	5	38
TNC-14	Jeb	1996-97	26	26	2	1	6	0	0	0
TNC-14	Jeb	1997-98	66	64	1	1	43	0	0	0
TNC-15	Xena	1996-97	26	26	1	1	10	0	0	0
TNC-15	Xena	1997-98	110	104	5	2	26	24	0	0
TPE-01	Spot	1988-89	58	47	2	2	0	0	8	2
TPE-01	Spot	1989-90	101	89	2	2	0	0	5	12
TPE-01	Spot	1990-91	144	87	2	2	0	0	1	52
TPE-01	Spot	1991-92	127	76	1	1	0	0	0	28
TPE-01	Spot	1992-93	149	126	3	2	0	0	4	45
TPE-01	Spot	1993-94	122	101	1	1	0	0	0	39
TPE-02	Fireball	1988-89	45	41	1	1	0	0	0	5

Table B-1 (continued).

Id	Name	Year	Tracking Duration (days) ¹	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TPE-03	Sickle	1989-90	59	51	3	2	0	0	1	13
TPE-03	Sickle	1990-91	74	62	4	2	0	0	6	9
TPE-03	Sickle	1991-92	34	28	1	1	0	0	0	28
TPE-03	Sickle	1992-93	110	102	4	2	0	0	5	54
TPE-04	Susan	1990-91	151	147	2	1	0	48	0	0
TPE-04	Susan	1991-92	0	1	1	1	0	1	0	0
TRB-01	Sonny	1991-92	48	46	2	2	0	0	4	1
TRB-01	Sonny	1992-93	127	115	3	2	0	0	16	10
TRB-01	Sonny	1993-94	151	120	3	2	0	0	2	7
TRB-01	Sonny	1994-95	151	140	3	2	0	0	12	16
TRB-01	Sonny	1995-96	152	145	2	2	0	0	12	15
TRB-01	Sonny	1996-97	112	100	3	2	0	0	15	6

¹ Records with a tracking duration of 0 days indicate that the manatee was observed during the winter with a belt but was not carrying a functioning radio-tag.

Table B-2. Data for each radio-tagged manatee (N = 71) and year (November to March, n = 175 manatee-winters) on the number of days at each warm-water refuge and the number of days located outside of such refugia ("Away"). See footnote for abbreviations.

			North Region						North-central Region		South-Central Region			South Region				
Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-01	Dixie	1986-87	0	0	0	0	0	0	1	0	0	0	0	4	1	0	0	16
TBC-01	Dixie	1987-88	0	0	0	0	0	0	0	2	0	0	0	4	8	0	0	46
TBC-03	Moon	1986-87	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	25
TBC-03	Moon	1987-88	0	0	0	0	0	0	5	6	9	1	0	5	14	0	0	71
TBC-03	Moon	1988-89	0	0	0	0	0	0	0	0	18	1	0	0	1	0	0	44
TBC-03	Moon	1989-90	0	0	0	0	0	0	2	13	2	0	0	1	20	0	0	24
TBC-03	Moon	1990-91	0	0	0	0	0	0	12	17	3	0	1	0	3	0	0	85
TBC-03	Moon	1991-92	0	0	0	0	0	0	0	0	1	0	0	0	9	0	0	46
TBC-03	Moon	1992-93	0	0	0	0	0	0	5	12	3	4	2	1	5	0	0	76
TBC-03	Moon	1993-94	0	0	0	0	0	0	0	0	3	0	0	0	14	0	0	85
TBC-04	Eclipse	1986-87	0	0	0	0	0	0	0	0	0	0	0	1	12	0	0	78
TBC-05	Gyro	1986-87	0	0	0	0	0	0	52	5	0	0	0	0	0	0	0	62
TBC-05	Gyro	1987-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
TBC-05	Gyro	1988-89	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
TBC-06	Moe	1987-88	0	0	0	0	0	0	7	26	0	0	0	0	0	0	0	41

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-06	Moe	1988-89	0	0	0	0	1	0	14	36	0	0	0	0	0	0	0	86
TBC-06	Moe	1989-90	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	14
TBC-06	Moe	1990-91	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	5
TBC-09	C-cow	1987-88	0	0	0	0	0	0	0	0	2	1	0	0	13	22	0	28
TBC-09	C-cow	1988-89	0	0	0	0	0	0	0	0	1	0	0	0	13	27	0	54
TBC-09	C-cow	1989-90	0	0	0	0	0	0	0	0	0	1	0	1	32	1	0	67
TBC-09	C-cow	1990-91	0	0	0	0	0	0	0	0	0	2	0	0	12	2	0	17
TBC-09	C-cow	1991-92	0	0	0	0	0	0	0	0	0	1	0	1	42	12	0	90
TBC-09	C-cow	1992-93	0	0	0	0	0	0	0	0	0	1	2	1	33	14	0	62
TBC-09	C-cow	1993-94	0	0	0	0	0	0	0	0	1	3	1	0	27	23	0	85
TBC-09	C-cow	1994-95	0	0	0	0	0	0	0	0	0	0	0	0	10	21	0	103
TBC-10	Fran	1987-88	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0	25
TBC-10	Fran	1989-90	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
TBC-11	Gloria	1987-88	0	0	0	0	0	0	4	5	0	0	0	0	0	0	0	17
TBC-12	Heike	1987-88	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	1
TBC-12	Heike	1988-89	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
TBC-13	Irene	1987-88	0	0	0	0	0	0	13	9	0	0	0	2	0	0	0	53
TBC-13	Irene	1988-89	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
TBC-14	Jerome	1987-88	0	0	0	0	0	0	3	11	0	0	0	0	6	9	0	48

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-15	Karen	1987-88	0	0	0	0	0	0	20	17	0	0	0	0	0	0	0	37
TBC-15	Karen	1988-89	0	0	0	0	0	0	8	2	0	0	0	0	0	0	0	21
TBC-15	Karen	1989-90	0	0	0	0	0	0	1	11	0	0	0	0	0	0	0	2
TBC-16	Larry	1987-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
TBC-17	Madonna	1987-88	0	0	0	0	0	0	3	11	0	0	0	0	2	0	0	16
TBC-17	Madonna	1989-90	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
TBC-18	Leroy	1987-88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
TBC-18	Leroy	1988-89	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
TBC-18	Leroy	1989-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TBC-20	Ruth	1988-89	0	0	0	0	0	0	0	0	2	0	1	1	12	0	0	50
TBC-20	Ruth	1989-90	0	0	0	0	0	0	0	0	1	0	0	1	19	4	0	40
TBC-21	Willie	1988-89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TBC-21	Willie	1989-90	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	15
TBC-21	Willie	1990-91	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
TBC-23	Hillary	1988-89	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1
TBC-23	Hillary	1989-90	0	0	0	0	5	0	4	19	0	0	0	0	0	0	0	31
TBC-23	Hillary	1990-91	0	0	3	2	0	0	11	3	0	0	0	0	0	0	0	26
TBC-23	Hillary	1991-92	0	0	44	2	0	0	40	16	0	0	0	0	0	0	0	55
TBC-23	Hillary	1996-97	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	18

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-23	Hillary	1997-98	0	0	43	0	0	0	8	17	0	0	0	0	0	0	0	57
TBC-24	Betty	1989-90	0	0	0	0	0	0	0	0	2	0	4	0	28	0	6	75
TBC-24	Betty	1990-91	0	0	0	0	0	0	0	0	1	0	1	0	22	0	10	57
TBC-24	Betty	1991-92	0	0	0	0	0	0	0	0	4	0	0	0	14	0	34	94
TBC-24	Betty	1992-93	0	0	0	0	0	0	0	0	2	0	0	0	35	1	23	79
TBC-24	Betty	1993-94	0	0	0	0	0	0	3	8	2	1	0	1	16	0	20	77
TBC-24	Betty	1994-95	0	0	0	0	0	0	0	0	0	0	1	1	15	0	30	91
TBC-25	D-cow	1989-90	0	0	0	0	0	0	0	0	2	0	0	0	16	17	0	64
TBC-25	D-cow	1990-91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
TBC-26	Peewee	1989-90	0	0	0	0	0	0	0	0	1	0	1	1	13	0	0	102
TBC-26	Peewee	1990-91	0	0	0	0	1	0	0	0	4	0	2	2	13	0	0	119
TBC-26	Peewee	1991-92	0	0	0	0	0	0	2	7	8	0	1	2	10	0	0	76
TBC-26	Peewee	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	68
TBC-29	Casey	1990-91	0	0	0	0	0	0	13	3	0	0	0	0	0	0	0	37
TBC-29	Casey	1991-92	0	0	0	0	0	0	8	10	0	0	0	0	0	0	0	16
TBC-30	Maria	1990-91	0	0	0	0	0	0	23	4	0	0	0	0	0	0	0	25
TBC-31	Freddie	1990-91	0	0	0	0	0	0	26	7	0	0	0	0	0	0	0	22
TBC-31	Freddie	1991-92	0	0	0	0	0	0	51	22	0	0	0	0	0	0	0	68
TBC-32	Tomasina	1991-92	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	20

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-32	Tomasina	1992-93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
TBC-32	Tomasina	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
TBC-35	E-cow	1992-93	0	0	0	0	0	0	0	0	3	0	1	0	8	0	0	31
TBC-36	Sunshine	1992-93	0	0	0	0	0	0	0	0	15	17	4	0	0	0	0	95
TBC-36	Sunshine	1993-94	0	0	0	0	0	0	0	0	0	12	1	4	0	0	0	36
TBC-37	Pamela	1992-93	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	140
TBC-37	Pamela	1994-95	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
TBC-41	Scott	1994-95	0	0	0	0	0	0	6	38	0	0	0	0	0	0	0	56
TBC-42	Chessie	1994-95	0	0	0	0	0	0	0	0	0	0	0	1	7	0	0	62
TBC-42	Chessie	1995-96	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	34
TFK-01	Manny	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	137
TFK-02	Stan	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111
TFK-03	Ollie	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103
TFP-02	Ross	1990-91	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	138
TFP-02	Ross	1991-92	0	0	0	0	0	0	0	0	12	1	0	3	0	0	0	112
TFP-02	Ross	1992-93	0	0	0	0	0	0	0	0	4	0	0	9	0	0	0	131
TFP-03	Natalie	1991-92	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	32
TFP-03	Natalie	1992-93	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	6
TFP-03	Natalie	1993-94	0	0	0	0	0	0	0	0	0	9	0	4	0	0	0	60

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TFP-04	Sophia	1991-92	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	29
TFP-04	Sophia	1993-94	0	0	0	0	0	0	0	0	0	0	2	5	0	0	0	97
TFP-04	Sophia	1994-95	0	0	0	0	0	0	0	0	0	0	6	5	0	0	0	27
TFP-04	Sophia	1995-96	0	0	0	0	0	0	0	0	0	0	4	5	1	0	0	64
TFP-05	Lani	1991-92	0	0	0	0	0	0	0	0	0	1	11	0	15	0	0	120
TFP-05	Lani	1992-93	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	60
TFP-06	Vanna	1991-92	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	5
TFP-06	Vanna	1992-93	0	0	0	0	0	0	0	0	4	0	41	0	11	0	0	85
TFP-06	Vanna	1993-94	0	0	0	0	0	0	0	0	0	0	4	4	3	0	0	83
TFP-06	Vanna	1994-95	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	5
TGA-01	Mary	1989-90	0	0	3	0	0	0	10	34	13	0	0	0	0	0	0	92
TGA-02	Tory	1994-95	0	1	0	10	0	0	0	0	0	0	0	0	0	0	0	11
TGA-02	Tory	1995-96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TGA-03	Marmontel	1994-95	0	1	0	10	0	0	0	0	0	0	0	0	0	0	0	11
TGA-03	Marmontel	1995-96	0	0	1	69	0	0	0	0	0	0	0	0	0	0	0	23
TGA-03	Marmontel	1996-97	0	0	0	44	0	0	0	0	0	0	0	0	0	0	0	18
TGA-04	Mercury	1995-96	0	1	0	7	0	0	0	0	0	0	0	0	0	0	0	11
TGA-04	Mercury	1996-97	0	8	0	41	0	0	3	2	0	0	0	0	0	0	0	81
TGA-04	Mercury	1997-98	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	6

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TGA-05	Bailey	1996-97	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	13
TGA-05	Bailey	1997-98	0	1	0	0	0	0	3	35	0	0	0	0	0	0	0	96
TGA-06	Savannah	1996-97	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	14
TGA-07	GP	1996-97	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	8
TJX-01	Connie	1990-91	0	0	0	0	0	1	23	7	0	0	1	1	3	0	0	37
TJX-01	Connie	1991-92	0	0	0	0	0	0	10	3	1	0	1	2	12	0	0	30
TJX-02	Patience	1991-92	0	0	0	0	0	0	12	23	0	0	0	0	0	0	0	69
TJX-02	Patience	1994-95	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	42
TJX-03	Freckles	1993-94	0	0	0	0	0	0	20	56	0	0	0	0	0	0	0	71
TMI-01	Bob	1990-91	0	0	0	0	0	0	0	0	1	0	0	1	11	0	0	59
TMI-01	Bob	1992-93	0	0	0	0	0	0	0	0	0	0	0	1	5	0	17	23
TMI-01	Bob	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	80
TMI-02	Fergie	1992-93	0	0	0	0	0	0	0	0	0	0	0	0	4	0	14	132
TMI-02	Fergie	1993-94	0	0	0	0	0	0	0	0	3	1	0	0	1	0	0	28
TMI-03	Clockwork	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	41
TNC-01	Diane	1986-87	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	3
TNC-01	Diane	1987-88	0	0	0	0	0	0	0	6	2	0	0	0	3	0	0	95
TNC-01	Diane	1989-90	0	0	0	0	0	0	1	3	0	0	1	0	12	0	0	84
TNC-01	Diane	1990-91	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	31

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TNC-02	Jesse	1986-87	0	0	8	1	0	0	0	0	0	0	0	0	0	0	0	6
TNC-03	Tammy	1987-88	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	3
TNC-03	Tammy	1988-89	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
TNC-03	Tammy	1995-96	0	1	0	5	1	0	0	0	0	0	0	0	0	0	0	11
TNC-03	Tammy	1996-97	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	21
TNC-04	Pat	1987-88	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	3
TNC-05	Roseanne	1988-89	0	0	29	1	0	0	0	0	0	0	0	0	0	0	0	3
TNC-06	Nancy	1988-89	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	33
TNC-06	Nancy	1990-91	0	0	0	0	0	2	0	0	0	0	0	1	4	0	0	14
TNC-07	Whitie	1988-89	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2
TNC-08	George	1988-89	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
TNC-08	George	1989-90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
TNC-09	Janatee	1994-95	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	15
TNC-09	Janatee	1995-96	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
TNC-10	March	1994-95	0	0	5	2	0	0	0	0	0	0	0	0	0	0	0	14
TNC-10	March	1995-96	0	0	1	5	0	0	2	2	0	0	0	0	4	0	0	81
TNC-10	March	1996-97	0	0	1	0	0	0	6	35	0	0	0	0	0	0	0	110
TNC-11	Vale	1994-95	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	12
TNC-12	Mossie	1995-96	0	8	0	5	0	0	0	0	0	0	0	0	0	0	0	6

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TNC-12	Mossie	1996-97	0	0	0	2	0	0	0	6	0	0	0	0	0	0	0	45
TNC-12	Mossie	1997-98	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	12
TNC-13	Knicky	1996-97	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	15
TNC-13	Knicky	1997-98	22	0	0	0	0	0	1	2	2	1	2	1	37	0	0	73
TNC-14	Jeb	1996-97	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	20
TNC-14	Jeb	1997-98	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0	21
TNC-15	Xena	1996-97	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	16
TNC-15	Xena	1997-98	0	0	24	0	1	1	2	22	0	0	0	0	0	0	0	56
TPE-01	Spot	1988-89	0	0	0	0	0	0	0	0	8	0	0	0	2	0	0	37
TPE-01	Spot	1989-90	0	0	0	0	0	0	0	0	0	0	5	0	12	0	0	72
TPE-01	Spot	1990-91	0	0	0	0	0	0	0	0	1	0	0	0	52	0	0	34
TPE-01	Spot	1991-92	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	48
TPE-01	Spot	1992-93	0	0	0	0	0	0	0	0	1	3	0	0	45	0	0	77
TPE-01	Spot	1993-94	0	0	0	0	0	0	0	0	0	0	0	0	39	0	0	62
TPE-02	Fireball	1988-89	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	36
TPE-03	Sickle	1989-90	0	0	0	0	0	0	0	0	0	1	0	3	10	0	0	37
TPE-03	Sickle	1990-91	0	0	0	0	0	0	0	0	2	2	2	0	9	0	0	47
TPE-03	Sickle	1991-92	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0
TPE-03	Sickle	1992-93	0	0	0	0	0	0	0	0	0	4	1	1	53	0	0	43

Table B-2 (continued).

Id	Name	Year	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TPE-04	Susan	1990-91	0	0	0	0	0	0	24	24	0	0	0	0	0	0	0	104
TPE-04	Susan	1991-92	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
TRB-01	Sonny	1991-92	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	41
TRB-01	Sonny	1992-93	0	0	0	0	0	0	0	0	0	1	15	10	0	0	0	89
TRB-01	Sonny	1993-94	0	0	0	0	0	0	0	0	0	1	1	7	0	0	0	111
TRB-01	Sonny	1994-95	0	0	0	0	0	0	0	0	0	1	11	16	0	0	0	112
TRB-01	Sonny	1995-96	0	0	0	0	0	0	0	0	0	0	12	15	0	0	0	118
TRB-01	Sonny	1996-97	0	0	0	0	0	0	0	0	0	1	14	6	0	0	0	79

NOTE: Abbreviations are as follows: CGW = Coral Gables Waterway; FPL-CC = Florida Power and Light Canaveral power plant; FPL-FL = Florida Power and Light Fort Lauderdale power plant; FPL-PE = Florida Power and Light Port Everglades power plant; FPL-RB = Florida Power and Light Riviera Beach power plant; FtP = Henry D. King Municipal power plant in Fort Pierce, FL; Gilm = Gilman Paper Co. pulp mill; GP-BR = Georgia Pacific pulp mill in Brunswick, GA; JEA-KN = Jacksonville Electric Authority Kennedy power plant (also includes the adjacent Jefferson-Smurfit Corp. pulp mill in Jacksonville); JEA-SS = Jacksonville Electric Authority Southside power plant; JS-FB = Jefferson-Smurfit Corp. pulp mill in Fernandina Beach, FL; Kem = Kemira gypsum plant; OUC-IR = Orlando Utilities Commission Indian River power plant; SEB RIV = north fork of Sebastian River; and VB = Vero Beach power plant.

Table B-3. Data for 71 radio-tagged manatees over their entire tracking periods on winter tracking effort (November to March), number of warm-water refugia visited, number of regions (see Fig. 1) where refugia were visited, and the number of days at refugia in each region.

Id	Name	No. of Winters Tracked ¹	Tracking Duration (days)	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-01	Dixie	2	133	82	4	2	0	3	0	17
TBC-03	Moon	8	756	652	7	3	0	72	48	81
TBC-04	Eclipse	1	144	91	2	1	0	0	0	13
TBC-05	Gyro	2 (3)	142	123	2	1	0	58	0	0
TBC-06	Moe	4	331	229	3	2	1	88	0	0
TBC-09	C-cow	8	1047	827	6	2	0	0	16	307
TBC-10	Fran	1 (2)	67	33	3	2	0	8	0	1
TBC-11	Gloria	1	59	26	2	1	0	9	0	0
TBC-12	Heike	1 (2)	16	8	1	1	0	7	0	0
TBC-13	Irene	1 (2)	136	78	3	2	0	23	0	2
TBC-14	Jerome	1	131	77	4	2	0	14	0	15
TBC-15	Karen	3	180	117	2	1	0	59	0	0
TBC-16	Larry	1	4	3	0	0	0	0	0	0

Table B-3 (continued).

Id	Name	No. of Winters Tracked ¹	Tracking Duration (days)	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-17	Madonna	1 (2)	38	31	3	2	0	14	0	3
TBC-18	Leroy	1 (3)	2	5	1	1	0	2	0	0
TBC-20	Ruth	2	184	131	5	2	0	0	4	37
TBC-21	Willie	1 (3)	22	19	2	2	0	0	2	1
TBC-23	Hillary	6	489	397	6	2	108	118	0	0
TBC-24	Betty	6	871	757	9	3	0	11	18	256
TBC-25	D-cow	2	163	103	3	2	0	0	2	33
TBC-26	Peewee	4	507	447	7	4	1	9	17	57
TBC-29	Casey	2	203	87	2	1	0	34	0	0
TBC-30	Maria	1	119	52	2	1	0	27	0	0
TBC-31	Freddie	2	303	190	2	1	0	106	0	0
TBC-32	Tomasina	2 (3)	54	31	1	1	0	0	0	1
TBC-35	E-cow	1	51	43	3	2	0	0	4	8
TBC-36	Sunshine	2	204	184	4	2	0	0	49	4
TBC-37	Pamela	1 (2)	151	147	2	2	0	0	4	3

Table B-3 (continued).

Id	Name	No. of Winters Tracked ¹	Tracking Duration (days)	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TBC-41	Scott	1	100	97	2	1	0	44	0	0
TBC-42	Chessie	2	119	109	3	2	1	0	0	12
TFK-01	Manny	1	151	137	0	0	0	0	0	0
TFK-02	Stan	1	131	111	0	0	0	0	0	0
TFK-03	Ollie	1	107	103	0	0	0	0	0	0
TFP-02	Ross	3	448	414	3	2	0	0	19	14
TFP-03	Natalie	3	120	119	3	2	0	0	16	6
TFP-04	Sophia	4	252	247	3	2	0	0	13	17
TFP-05	Lani	2	224	210	3	2	0	0	12	18
TFP-06	Vanna	4	324	257	4	2	0	0	59	20
TGA-01	Mary	1	151	151	4	3	3	44	13	0
TGA-02	Tory	1 (2)	22	23	2	1	11	0	0	0
TGA-03	Marmontel	3	202	178	3	1	125	0	0	0
TGA-04	Mercury	3	181	163	4	2	61	5	0	0
TGA-05	Bailey	2	166	147	3	2	2	38	0	0

Table B-3 (continued).

Id	Name	No. of Winters Tracked ¹	Tracking Duration (days)	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TGA-06	Savannah	1	15	15	1	1	1	0	0	0
TGA-07	GP	1	15	14	2	1	6	0	0	0
TJX-01	Connie	2	199	130	7	4	1	43	3	18
TJX-02	Patience	2	156	146	4	3	0	35	2	4
TJX-03	Freckles	1	151	138	2	1	0	76	0	0
TMI-01	Bob	3	234	201	4	2	0	0	1	38
TMI-02	Fergie	2	185	183	4	2	0	0	4	19
TMI-03	Clockwork	1	49	45	1	1	0	0	0	4
TNC-01	Diane	4	316	248	6	4	1	16	3	15
TNC-02	Jesse	1	21	15	2	1	9	0	0	0
TNC-03	Tammy	3 (4)	80	52	4	1	18	0	0	0
TNC-04	Pat	1	36	9	1	1	6	0	0	0
TNC-05	Roseanne	1	73	33	2	1	30	0	0	0
TNC-06	Nancy	2	115	62	5	2	10	0	0	5
TNC-07	Whitie	1	16	6	2	1	4	0	0	0

Table B-3 (continued).

Id	Name	No. of Winters Tracked ¹	Tracking Duration (days)	Total No. of Days Located	No. WW Refugia Visited	No. Regions where Refugia Visited	No. Days at WW Refugia by Region			
							North	North-Central	South-Central	South
TNC-08	George	1 (2)	16	5	1	1	2	0	0	0
TNC-09	Janatee	1 (2)	20	21	1	1	6	0	0	0
TNC-10	March	3	272	263	5	3	14	45	0	4
TNC-11	Vale	1	20	20	1	1	8	0	0	0
TNC-12	Mossie	3	121	88	4	2	15	10	0	0
TNC-13	Knicky	2	177	166	9	4	32	3	5	38
TNC-14	Jeb	2	92	90	2	1	49	0	0	0
TNC-15	Xena	2	136	130	6	2	36	24	0	0
TPE-01	Spot	6	701	526	4	2	0	0	18	178
TPE-02	Fireball	1	45	41	1	1	0	0	0	5
TPE-03	Sickle	4	277	243	5	2	0	0	12	104
TPE-04	Susan	1 (2)	151	148	2	1	0	49	0	0
TRB-01	Sonny	6	741	666	3	2	0	0	61	55

¹ The number in parentheses includes winters in which the manatee was sighted wearing a belt but was not carrying a functioning radio-tag.

Table B-4. Data for 71 radio-tagged manatees over their entire tracking periods on the number of days at each warm-water refuge and the number of days located outside of such refugia ("Away"). See footnote for abbreviations.

			North Region						North-central Region		South-Central Region			South Region				
Id	Name	No. of Winters ¹	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-01	Dixie	2	0	0	0	0	0	0	1	2	0	0	0	8	9	0	0	62
TBC-03	Moon	8	0	0	0	0	0	0	24	48	39	6	3	7	74	0	0	456
TBC-04	Eclipse	1	0	0	0	0	0	0	0	0	0	0	0	1	12	0	0	78
TBC-05	Gyro	2 (3)	0	0	0	0	0	0	53	5	0	0	0	0	0	0	0	68
TBC-06	Moe	4	0	0	0	0	1	0	23	65	0	0	0	0	0	0	0	146
TBC-09	C-cow	8	0	0	0	0	0	0	0	0	4	9	3	3	182	122	0	506
TBC-10	Fran	1 (2)	0	0	0	0	0	0	6	2	0	0	0	1	0	0	0	25
TBC-11	Gloria	1	0	0	0	0	0	0	4	5	0	0	0	0	0	0	0	17
TBC-12	Heike	1 (2)	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	1
TBC-13	Irene	1 (2)	0	0	0	0	0	0	14	9	0	0	0	2	0	0	0	53
TBC-14	Jerome	1	0	0	0	0	0	0	3	11	0	0	0	0	6	9	0	48
TBC-15	Karen	3	0	0	0	0	0	0	29	30	0	0	0	0	0	0	0	60
TBC-16	Larry	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
TBC-17	Madonna	1 (2)	0	0	0	0	0	0	3	11	0	0	0	0	3	0	0	16
TBC-18	Leroy	1 (3)	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3

Table B-4 (continued).

Id	Name	No. of Winters ¹	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TBC-20	Ruth	2	0	0	0	0	0	0	0	0	3	0	1	2	31	4	0	90
TBC-21	Willie	1 (3)	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	16
TBC-23	Hillary	6	0	7	92	4	5	0	63	55	0	0	0	0	0	0	0	188
TBC-24	Betty	6	0	0	0	0	0	0	3	8	11	1	6	2	130	1	123	473
TBC-25	D-cow	2	0	0	0	0	0	0	0	0	2	0	0	0	16	17	0	68
TBC-26	Peewee	4	0	0	0	0	1	0	2	7	13	0	4	5	52	0	0	365
TBC-29	Casey	2	0	0	0	0	0	0	21	13	0	0	0	0	0	0	0	53
TBC-30	Maria	1	0	0	0	0	0	0	23	4	0	0	0	0	0	0	0	25
TBC-31	Freddie	2	0	0	0	0	0	0	77	29	0	0	0	0	0	0	0	90
TBC-32	Tomasina	2 (3)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	30
TBC-35	E-cow	1	0	0	0	0	0	0	0	0	3	0	1	0	8	0	0	31
TBC-36	Sunshine	2	0	0	0	0	0	0	0	0	15	29	5	4	0	0	0	131
TBC-37	Pamela	1 (2)	0	0	0	0	0	0	0	0	0	0	4	3	0	0	0	140
TBC-41	Scott	1	0	0	0	0	0	0	6	38	0	0	0	0	0	0	0	56
TBC-42	Chessie	2	0	0	0	0	0	1	0	0	0	0	0	1	11	0	0	96
TFK-01	Manny	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	137
TFK-02	Stan	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111
TFK-03	Ollie	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103
TFP-02	Ross	3	0	0	0	0	0	0	0	0	16	3	0	14	0	0	0	381

Table B-4 (continued).

Id	Name	No. of Winters ¹	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TFP-03	Natalie	3	0	0	0	0	0	0	0	0	0	11	5	6	0	0	0	98
TFP-04	Sophia	4	0	0	0	0	0	0	0	0	0	0	13	16	1	0	0	217
TFP-05	Lani	2	0	0	0	0	0	0	0	0	0	1	11	0	18	0	0	180
TFP-06	Vanna	4	0	0	0	0	0	0	0	0	4	0	55	4	16	0	0	178
TGA-01	Mary	1	0	0	3	0	0	0	10	34	13	0	0	0	0	0	0	92
TGA-02	Tory	1 (2)	0	1	0	10	0	0	0	0	0	0	0	0	0	0	0	12
TGA-03	Marmontel	3	0	1	1	123	0	0	0	0	0	0	0	0	0	0	0	52
TGA-04	Mercury	3	0	9	0	52	0	0	3	2	0	0	0	0	0	0	0	98
TGA-05	Bailey	2	0	2	0	0	0	0	3	35	0	0	0	0	0	0	0	109
TGA-06	Savannah	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	14
TGA-07	GP	1	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	8
TJX-01	Connie	2	0	0	0	0	0	1	33	10	1	0	2	3	15	0	0	67
TJX-02	Patience	2	0	0	0	0	0	0	12	23	0	0	2	4	0	0	0	111
TJX-03	Freckles	1	0	0	0	0	0	0	20	56	0	0	0	0	0	0	0	71
TMI-01	Bob	3	0	0	0	0	0	0	0	0	1	0	0	2	18	0	18	162
TMI-02	Fergie	2	0	0	0	0	0	0	0	0	3	1	0	0	5	0	14	160
TMI-03	Clockwork	1	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	41
TNC-01	Diane	4	0	0	0	1	0	0	6	10	2	0	1	0	15	0	0	213
TNC-02	Jesse	1	0	0	8	1	0	0	0	0	0	0	0	0	0	0	0	6

Table B-4 (continued).

Id	Name	No. of Winters¹	Kem	GP BR	Gilm	JS FB	JEA KN	JEA SS	OUC IR	FPL CC	SEB RIV	VB	FtP	FPL RB	FPL PE	FPL FL	CGW	Away
TNC-03	Tammy	3 (4)	0	2	7	8	1	0	0	0	0	0	0	0	0	0	0	35
TNC-04	Pat	1	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	3
TNC-05	Roseanne	1	0	0	29	1	0	0	0	0	0	0	0	0	0	0	0	3
TNC-06	Nancy	2	0	0	5	3	0	2	0	0	0	0	0	1	4	0	0	47
TNC-07	Whitie	1	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2
TNC-08	George	1 (2)	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3
TNC-09	Janatee	1 (2)	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	15
TNC-10	March	3	0	0	7	7	0	0	8	37	0	0	0	0	4	0	0	205
TNC-11	Vale	1	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	12
TNC-12	Mossie	3	0	8	0	7	0	0	3	7	0	0	0	0	0	0	0	63
TNC-13	Knicky	2	22	0	0	10	0	0	1	2	2	1	2	1	37	0	0	88
TNC-14	Jeb	2	0	0	44	5	0	0	0	0	0	0	0	0	0	0	0	41
TNC-15	Xena	2	0	0	24	10	1	1	2	22	0	0	0	0	0	0	0	72
TPE-01	Spot	6	0	0	0	0	0	0	0	0	10	3	5	0	178	0	0	330
TPE-02	Fireball	1	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	36
TPE-03	Sickle	4	0	0	0	0	0	0	0	0	2	7	3	4	100	0	0	127
TPE-04	Susan	1 (2)	0	0	0	0	0	0	25	24	0	0	0	0	0	0	0	104
TRB-01	Sonny	6	0	0	0	0	0	0	0	0	0	4	57	55	0	0	0	550

¹ The number in parentheses includes winters in which the manatee was sighted wearing a belt but was not carrying a functioning radio-tag.

Table B-4 (continued).

NOTE: Abbreviations are as follows: CGW = Coral Gables Waterway; FPL-CC = Florida Power and Light Canaveral power plant; FPL-FL = Florida Power and Light Fort Lauderdale power plant; FPL-PE = Florida Power and Light Port Everglades power plant; FPL-RB = Florida Power and Light Riviera Beach power plant; FtP = Henry D. King Municipal power plant in Ft. Pierce, FL; Gilm = Gilman Paper Co. pulp mill; GP-BR = Georgia Pacific pulp mill in Brunswick, GA; JEA-KN = Jacksonville Electric Authority Kennedy power plant (also includes the adjacent Jefferson-Smurfit Corp. pulp mill in Jacksonville); JEA-SS = Jacksonville Electric Authority Southside power plant; JS-FB = Jefferson-Smurfit Corp. pulp mill in Fernandina Beach, FL; Kem = Kemira gypsum plant; OUC-IR = Orlando Utilities Commission Indian River power plant; SEB RIV = north fork of Sebastian River; and VB = Vero Beach power plant.