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Florida Manatees, Warm-Water Refuges, and an Uncertain Future

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Most Florida manatees depend on localized warm-water refuges in the southern two-thirds of Florida to survive winter; about 60% use outfalls from 10 power plants, whereas 15% use 4 natural warm-water springs. Future availability of these refuges is in doubt; most of these power plants may be retired within the next 20 years and groundwater withdrawals for human use threaten natural springs. This article examines possible effects on manatees from losing major warm-water refuges and alternative management actions. Because of manatee site-fidelity patterns, plant retirements may increase cold-stress-related deaths and significantly decrease manatee abundance. A forward-looking management strategy is urgently needed before decisions are made to retire plants now used by large numbers of manatees. Possible management alternatives include: gradually weaning manatees off plant outfalls, maintaining the flow of springs now used by manatees, enhancing access to suitable warm-water springs now little used or unused by manatees, constructing new non-industry dependent warm-water refuges, and creating new thermal basins to retain warm-water pockets able to support overwintering manatees.

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Introduction

The Florida manatee (*Trichechus manatus latirostris*), a subspecies of the West Indian manatee found only in the southeastern United States (Domning & Hayek, 1986; Lefebvre et al., 2001), is listed as endangered under both the U.S. Endangered Species Act and Florida state law (U.S. Fish and Wildlife Service, 2001). Its current abundance is probably at least 3,276 animals based on a Florida-wide count on January 5–6, 2001 (U.S. Fish and Wildlife Service, 2001). The most immediate threat to its survival is collisions with boats. In recent years watercraft have caused between a quarter and a third of all annual manatee deaths, with a record high 98 deaths (31%) in 2002 (Marine Mammal Commission, 2003). In the long term, however, loss of warm-water refuges essential for winter survival may be an even greater threat (Rose, 1997; Rathbun & Wallace, 2000).

Most manatees aggregate at confined warm-water refuges when coastal water temperatures begin to fall below 20ºC (68ºF) (Irvine, 1983; Bossart, 2001, 2002). Although some animals can survive temperatures a degree or two colder (Hartman, 1979; Glaser & Reynolds, 2003), river and coastal water temperatures throughout Florida routinely fall below 17–18ºC (61–64ºF) for at least short periods in winter (Hartman, 1974, 1979; Irvine, 1983). Even in southernmost Florida they can remain below those levels for two weeks at a time and briefly dip to as low as 10ºC (50ºF) in severe winters (Laist & Reynolds, in press). The precise thresholds at which manatees succumb to cold and die are uncertain but almost certainly vary between individuals (Reynolds, 2000). However, when extremely cold winter weather occurs, large numbers of manatees may die or have their health impaired. Ackerman et al. (1995) analyzed manatee mortality patterns and noted that during the extremely cold winter of 1989–1990, at least 61 manatee deaths were attributed to cold.

To survive cold periods, Florida manatees rely on two types of warm-water habitats or refuges (Laist & Reynolds, in press): (1) warm-water discharges, including natural springs and power plant outfalls, where warm water is continuously discharged, and (2) thermal basins where deep holes or other conditions slow local cooling processes and thereby temporarily retain pockets of relatively warm water. Most warm-water discharges are in northern and central Florida, whereas most major thermal basins able to support manatees through the winter are in the southern third of the peninsula. Most manatees use warm-water discharges rather than thermal basins to survive the coldest winter periods. There currently are 14 "major" warm-water discharges (i.e., sites with at least one winter count of 50 or more manatees; Figure 1); 10 are outfalls from power plant cooling systems, and 4 are warm-water springs. Although a few thermal basins also have had winter counts of more than 50 manatees, their ability to sustain manatees through prolonged periods of cold weather may be limited by the absence of an independent warm-water source and gradual cooling.

All power plant outfalls now used by manatees were built between the 1940s and early 1970s. Many of these plants have reached or are approaching the end of their planned operational lives and soon may be retired. Since they were built, regulations under the U.S. Clean Water Act have prohibited new facilities from discharging effluent substantially warmer than the receiving waterbodies. The older, pre-existing plants, however, were granted variances allowing them to continue discharging warm water. Unless the older units are "repowered," an expensive process of updating or replacing existing generating units with more efficient units, their retirement in the next 10 to 20 years will eliminate discharges on which most Florida manatees now depend for winter survival. Over the past decade, two of the ten plants used by large numbers of manatees (i.e., those in Fort Myers and Fort Lauderdale) have been repowered.

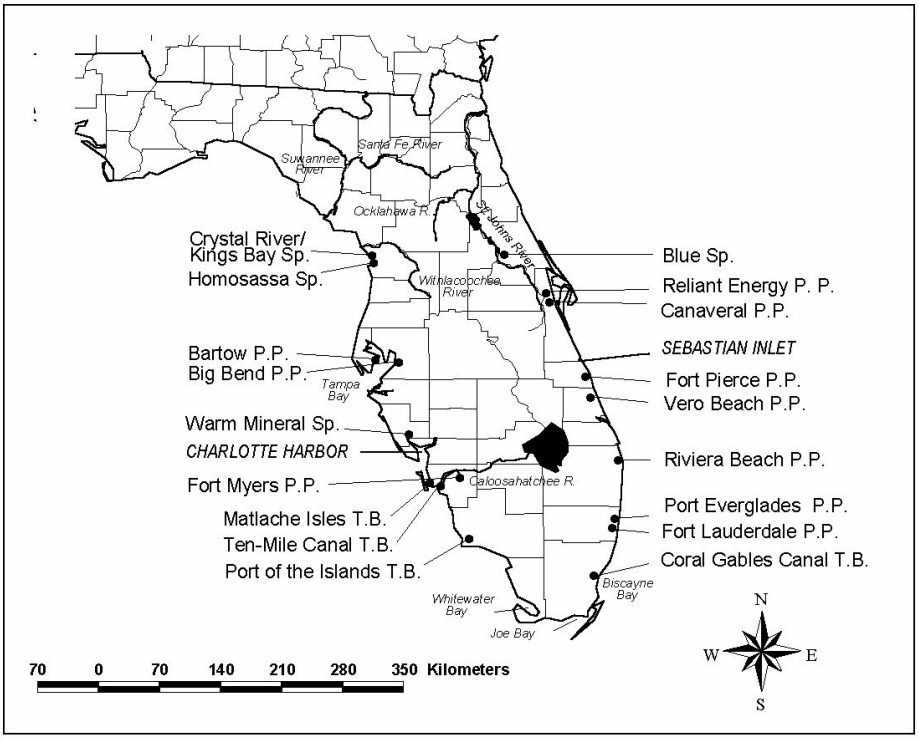

Figure 1. Location of warm-water refuges with recorded sightings of 50 or more manatees (Sp. = natural springs, P.P. = power plants, T.B. = thermal basin).

Precisely when individual power plants might be retired is unclear. Such decisions involve proprietary economic forecasts made by individual utilities based on dynamic hard-to-predict factors, such as the future cost and availability of alternative fuels, competition with rival power companies, projected trends in electricity demand, and the cost of renovation versus building new plants. Recent proposals to deregulate Florida's electric utility industry further complicate predictions about whether and when old plants might be retired. However, given increasing industry competition, rising fuel costs, and new, more efficient technology for generating electricity, industry representatives on the Warm-Water Task Force (a subcommittee of the Florida Manatee Recovery Team formed by the U.S. Fish and Wildlife Service to help implement measures to conserve manatees) have advised that economic forces will likely cause some older plants to close within a matter of years, and most to close within a matter of decades. Such closures could determine the fate of hundreds, or even thousands, of Florida manatees.

Natural springs used by manatees also face an uncertain future. Ground water withdrawals for domestic, industrial, and agricultural use, and development in groundwater recharge areas, have reduced flow rates at some springs, such as Blue Spring (Sucsy et al., 1998; Figure 2), which provides essential winter habitat for a discrete subpopulation of about 170 manatees in the upper St. Johns River (Laist & Reynolds, in press). Left unchecked, declining spring flows could reduce the size of thermal plumes to a point where they can no longer support current manatee numbers. This would be particularly problematic in drought years when water tables fall due to declining recharge levels.

Figure 2. Florida manatees aggregating at Blue Spring, Volusia County, Florida to thermoregulate. (Photograph Courtesy of the Daytona Beach News-Journal/David Tucker.)

If major power plant outfalls or warm-water springs are lost, manatees may be unable to find suitable alternative habitats. For example, during the winter of 1989–90, most of the record number of cold-related deaths that year occurred in a northern Florida County (Brevard) where manatees depend on two power plant outfalls. Apparently, during an exceptionally cold period in the last week of 1989, the plants were unable to maintain outfall temperatures warm enough to support all animals. When the outfall temperatures fell to potentially lethal levels, manatees nonetheless stayed in the area and failed to move to suitable alternative sites further south. Had the plants not operated at all and outfall temperatures fell even further, cold-related deaths likely would have been substantially higher that winter.

Even if manatees can move to alternative sites, food supplies, space, and temperatures for thermoregulating at alternative sites may be unable to support a large influx of displaced animals. Given the uncertain future of power plant outfalls and threats facing natural springs, there is an urgent need for wildlife managers to develop plans for assuring the continued availability of warm-water habitats for overwintering manatees. Ironically, this challenge comes at a time when steps are being considered to relax manatee

protection. Given apparent increases in manatee numbers over past decades (Langtimm et al., 1998; Craig et al., 1997; Glaser & Reynolds, 2003; Craig & Reynolds, in press), the Florida Fish and Wildlife Conservation Commission has been petitioned to down-list Florida manatees from endangered to threatened under state law. A similar action is possible at the federal level based on results of a manatee status review being scheduled by the Fish and Wildlife Service under provisions of the U.S. Endangered Species Act.

To help assess possible effects of power plant retirements on manatee recovery, a companion paper (Laist & Reynolds, in press) reviews information on (1) the existing network of warm-water habitats used by Florida manatees, (2) manatee behavior and site-fidelity patterns relative to those refuges, and (3) the possible effects of historic and prehistoric hunting and climate change on winter manatee distribution. Among the findings of that review are the following:

- natural winter habitat in southernmost Florida may be unable to support large numbers of manatees because of an absence of warm-water springs and thermal basins that may not retain elevated temperatures during especially cold winters;
- the best natural winter habitat for Florida manatees now, and perhaps in the past, appears to occur around networks of warm-water springs in the central and northern thirds of the Florida Peninsula;
- by the mid-1900s, prehistoric and historic hunting restricted manatee distribution to southernmost Florida;
- coastal power plants built between the 1940s and 1970s helped manatees to shift in their winter range northward and reduce the risk of cold-related mortality;
- perhaps 75% of all Florida manatees now rely on 14 warm-water refuges to survive cold winter periods, with at least 60% at 10 major power plant outfalls and about 15% at 4 major warm-water springs (Figure 1);
- strong patterns of site fidelity to individual refuges or regional networks of refuges bind Florida manatees into at least four relatively discrete subpopulations, including two on Florida's east coast and two on the west coast; and
- some natural springs possibly used as winter habitat by manatees in the past are no longer available to them due to dams and other human-related alterations.

These findings cast an ominous shadow over manatee prospects if one or more key power plants are retired. Alternative habitats to sustain large numbers of manatees in cold winter periods appear to be few in number. To examine possible consequences and related planning needs arising from this situation, this article reviews information on the response of manatees to past shut-downs of industry-related warm-water refuges, considers the possible effect of losing one or more warm-water refuges on existing manatee subpopulations, and suggests possible anticipatory management actions. Many of the ideas presented have been discussed by the aforementioned. Warm-Water Task Force, which includes scientists, representatives of management agencies, and representatives of Florida's power companies. Although the Task Force has neither sought nor reached consensus on the ideas presented here, they generally reflect approaches that the Task Force has agreed to consider.

Manatee Responses to the Shutdown of Warm-Water Industrial Discharges

To date, there have been three opportunistic studies to document local changes in manatee distribution and abundance associated with shutdowns of thermal outfalls from industrial

facilities. These studies provide the only direct information on how manatees respond to the interruption or elimination of warm-water refuges.

Amelia Island Box Plant, Winter 1997–98

The best-studied case involves a secondary warm-water refuge formed by an outfall from a cardboard box manufacturing plant on Amelia Island near the Florida–Georgia border. A few manatees began overwintering at the plant's heated discharge in the late 1980s–early 1990s. To enhance the mixing of plant effluent with adjacent waters and meet water quality standards, the plant's waste discharge pipe was modified in the summer of 1997 by adding a long diffuser pipe with a series of widely spaced openings. By doing so, the small pocket of warm water previously used by manatees was eliminated. To determine how manatees would respond, telemetry studies, which fortuitously had been started in the region early in the 1990s, were expanded and manatee mortality reports were closely monitored.

Between 1995 and 1998, 15 manatees were tracked using satellite telemetry (Deutsch et al., 2000). During the first winter the diffuser pipe was used (i.e., the winter of 1997–98), manatees repeatedly visited the former heated outfall, apparently seeking warm water. Finding none, most animals turned to other more marginal warm-water sources in the surrounding area, including a paper mill in southern Georgia. None of the tagged animals that were in northern Florida or Georgia in early winter moved south to the nearest major warm-water refuges located more than a 160 km south in Brevard County (i.e., two power plants near Cape Canaveral).

Although the winter of 1997–98 was mild, mortality among manatees overwintering near the box plant increased sharply. Of the 15 animals tracked, 1 died of a boat collision before the new discharge system went into effect, while between October 1997 and March 1998 during the system's first winter of operation, 6 died of various causes (2 watercraft collisions, 1 cold stress-related, and 3 undetermined) and 2 were rescued. Two deaths involved tagged animals that had moved south to Brevard County in the summer of 1997, but migrated north to the area in mid-winter expecting to find warm water. Whether behavioral or other effects of cold stress contributed to the collisions and deaths due undetermined causes is unknown. However, in either case, the number of tagged animal deaths was unprecedented in the 15 years of manatee tracking experience in Florida before 1998 or since.

Fort Myers Power Plant, January 1–21, 1985

A study also was done during a 20-day shutdown at the Fort Myers power plant in southwestern Florida in January 1985 (Packard et al., 1989). Aerial surveys and telemetry were used to examine manatee occurrence and distribution before and during the shutdown. During the 20-day shutdown, a succession of three relatively mild cold fronts passed through the area. The study found that manatee abundance near the plant was similar in years before and during the shutdown, and that manatees did not abandon the area when the plant discharge was suspended. Instead, manatees remained near the plant or in parts of the adjacent Caloosahatchee River, particularly near Franklin Locks several kilometers up stream (see also Reynolds, 1985). When water temperatures at the locks and defunct outfall were about the same, the numbers of radio-tagged manatees at the two locations were about equal. However, when the temperature at the locks dropped below 17ºC, the number of tagged manatees at the power plant exceeded the number at

the locks, suggesting manatees were seeking areas they expected to be warmer. When the heated effluent was restored, manatees returned to the outfall within days.

Based on the study results, Packard et al. (1989) concluded that manatees using the outfall were dependent on the plant's thermal effluent and apparently had no other readily available warm-water source to which they could move. Thus, they concluded that where manatees have become dependent on artificial warm-water sources for winter thermoregulation, the cessation of industrial operations could affect survival during severe winters with detrimental consequences for population recovery.

Fort Myers Power Plant, January 2002

In January 2002, the Fort Myers power plant had to be shut down for work to repower the facility. To provide the outfall with warm water during the shutdown, plant operator temporarily installed an auxiliary oil-fired water-heating unit explicitly to heat water for manatees. The heated area was smaller than that produced by normal plant operations and a smaller group of manatees than usual used the outfall until the plant resumed operation later in the winter. Manatees not using the discharge were again observed during aerial overflights by one of the authors (Reynolds) in nearby areas of the Caloosahatchee River, including Franklin Locks, where they had occurred during the plant's 1985 shut down.

Possible Effects of Losing Major Warm-water Discharges

As noted earlier, although it is clear that exposure to cold can be lethal to manatees (Ackerman et al., 1995), the temperatures and exposure periods manatees can tolerate without dying or becoming ill are uncertain. Further, it is unlikely that there is a single temperature or duration threshold at which all manatees succumb, because of factors, such as body size, body condition, and nutritional state, that are likely to affect resistance to cold. However, given empirical data that documents occasional high levels of cold-related mortality, as occurred in the winter of 1989–90 in northern areas with power plant discharges, and the high degree of site fidelity to individual discharges indicated above, it seems appropriately precautionary to develop mitigation measures in advance of the loss or reduction of warm-water sources.

At some point in the future, all power plants now used by manatees will be closed. Because manatees apparently thrived in Florida in the distant past, many people assume that they would continue to do so after those plants are retired. Some of the first studies of manatees in Florida (Moore, 1951a, 1951b) concluded that winter manatee distribution was centered in southern Florida south of Charlotte Harbor on the west coast and Sebastian Inlet on the east coast (Figure 1). As most power plants now used by manatees had not yet been built at that time, some assume that, if power plants were closed, manatees would simply move south to warmer areas in Florida with no effect on overall manatee abundance.

Such assumptions, however, may be overly simplistic and largely incorrect. Based on site-fidelity to winter refuges and manatee responses to past outfall shut-downs, it seems questionable, if not doubtful, that all or even many manatees would move to southernmost Florida or to natural springs that lie outside of their familiar range. Also, as noted by Laist and Reynolds (in press), southernmost Florida may be unable to support a substantial increase in manatee abundance due to an absence of warm-water springs and water temperatures that periodically fall below manatee thermal tolerances. Instead, warm-water springs in central and northern Florida appear to provide the best habitat for

overwintering manatees and perhaps the only natural winter habitats capable of supporting large and increasing numbers of manatees.

Even if manatees do move south as plants are retired, those areas may be unable to support large numbers of displaced manatees due to limitations in the number of alternative warm-water habitats, their available space for manatee thermoregulation, or nearby food resources. Such limitations also could affect the health, nutrition, and even reproductive status of the survivors (Glaser & Reynolds, 2003). Along Florida's east coast, displacement of manatees from the Cape Canaveral area to points further south also would place them in a part of the State with the largest concentration of both people and recreational boats. Given that Florida manatees are thought to occur in at least four relatively discrete subpopulations (Figure 3), we suggest that the loss of warm-water power plant discharges could cause the following changes for each subpopulation.

East Coast Subpopulations

Along Florida's east coast, two manatee subpopulations have been identified. One, numbering about 1,500 animals, occurs along the Atlantic Coast and appears to be either stable or slightly declining (Langtimm et al., 1998), or perhaps slightly increasing (Craig and Reynolds, in press). Perhaps 90% of the Atlantic Coast subpopulation relies to varying

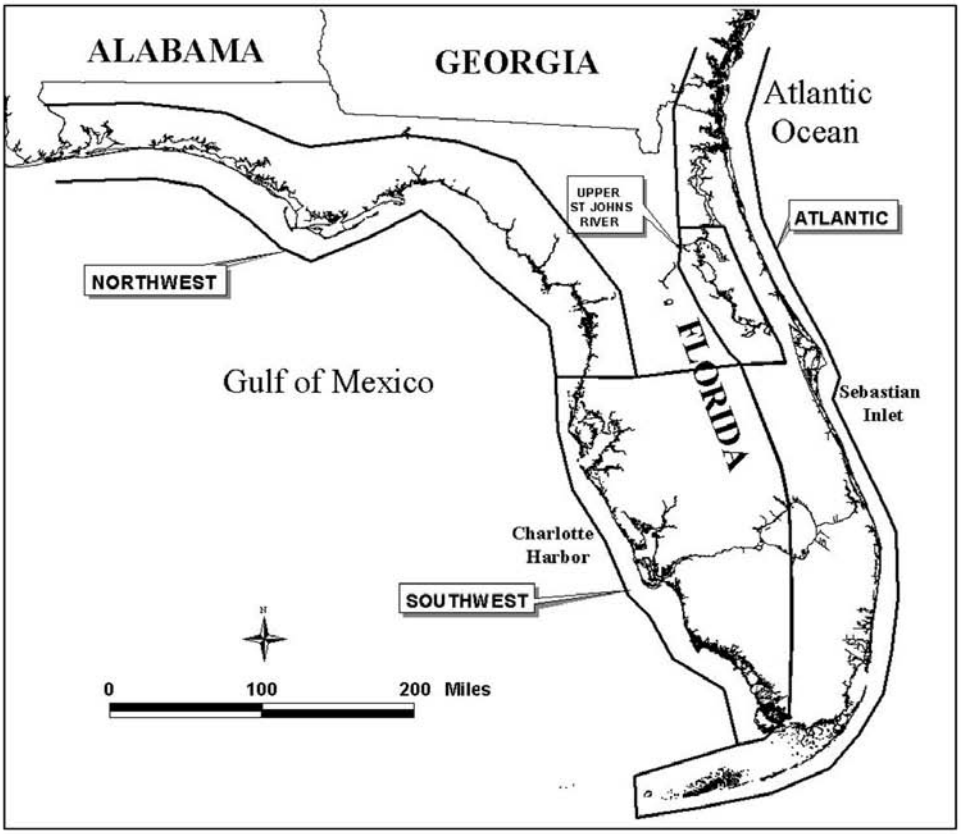

Figure 3. Geographic boundaries defining the principal range of four identified Florida manatee subpopulations (U.S. Fish and Wildlife Service, 2001).

degrees on 7 power plant outfalls along a 260 km stretch of coast between Cape Canaveral and Ft. Lauderdale in what is now the northern three-fourths of that subpopulation's winter range (Laist & Reynolds, in press). The second subpopulation, which has been increasing steadily, numbers about 170 manatees (W. Hartley, pers. com.[1]) and relies on a single natural spring (i.e., Blue Spring) along the upper St. Johns River.

If power plants along the Atlantic Coast were closed, we suggest that ingrained site fidelity patterns would result in moderate numbers of animals moving to southernmost Florida (e.g., to points south of Miami in Biscayne Bay where thermal basins could be used to survive most cold periods) and perhaps none to Blue Spring on the upper St. Johns River. Rather, cold stress during severe winters likely would cause a significant reduction in the size of the subpopulation. Given the rarity of manatee movements between the east and west coasts of Florida, it is very unlikely that east coast manatees would move to the west coast. Instead, most manatees would probably remain near their accustomed winter refuges and sustain increasing levels of cold-related deaths that would reduce the size of the regional subpopulation. The reduction likely would proceed gradually, with retirements of each power plant causing an incremental decrease in abundance roughly proportional to their level of use by manatees. The loss of power plants that now operate intermittently in winter and are used sporadically by manatees (i.e., the Fort Pierce, Vero Beach, and Reliant Energy plants) may have little immediate effect on the subpopulation's abundance. However, the loss of plants used regularly by larger numbers of manatees could cause significant losses due to cold stress.

If all east coast plants were closed, the winter range of Atlantic Coast manatees likely would be centered in Biscayne Bay and the southern margin of the Everglades, with a few animals roaming as far north as Sebastian Inlet in warm winter periods. Given the risk of cold stress in severe winters even in southernmost Florida, the Atlantic Coast subpopulation could be substantially reduced—perhaps to only a few hundred animals or less.

Conversely, the small subpopulation in the upper St. Johns River should be unaffected by power-plant shutdowns given its reliance on Blue Spring to meet winter thermoregulatory needs. However, if discharge volumes at Blue Spring continue to decline as they have in the past due to groundwater withdrawals (Sucsy et al., 1998), the St. Johns River subpopulation likely would decrease gradually as the warm-water area at the spring decreased; in fact, Vergara (1994) suggested that the reduction in flow could be approximately 16% between 1988 and 2010. If Blue Spring were reduced from a first-order magnitude spring (>100 ft^3/s) to a mid or low level second-order spring (10–100 ft^3/s), the subpopulation could be reduced significantly because of the northerly location and cold ambient temperatures of waters outside the spring run and the uncertain ability of manatees to find suitable alternative warm-water springs in the region. If the spring's flow rate is maintained at current levels, available space for manatees to thermoregulate might allow the subpopulation to double.

West Coast Subpopulations

Two manatee subpopulations also exist on Florida's west coast. The subpopulation in southwestern Florida has a winter range that extends north to Tampa Bay. Currently numbering about 1,400 animals, it appears to be stable or perhaps slightly declining. More than half (812 manatees) of the 1,379 manatees counted in this region during the January 2001 statewide survey were at power plants in the northern half of the subpopulation's winter range; most of the others were at a large thermal basin in the Ten Thousand Islands

area and a small spring (i.e., Warm Mineral Springs) that is the only natural warm-water refuge south of Tampa Bay (Fish and Wildlife Research Institute, unpublished data; Laist & Reynolds, in press). The other west coast subpopulation, numbering about 400 manatees, is in northwestern Florida and appears to be steadily increasing (Langtimm et al., 1998). Its winter range is centered north of Tampa Bay around warm-water springs on the Crystal and Homosassa Rivers.

As with the Atlantic coast subpopulation, the gradual retirement of power plants in southwestern Florida likely would cause a decline in the size of the regional subpopulation at rates roughly proportional to a plant's level of manatee use. However, because the power plant used by the largest number of manatees (i.e., the Fort Myers power plant) was recently repowered, its availability for manatees seems assured for at least the next several decades. If plants around Tampa Bay were closed and replaced by new plants without warm-water discharges, some animals may move to the Ft. Myers plant, but few would likely move north to the Crystal River area. Most may remain in Tampa Bay at marginal warm-water habitats and eventually succumb to cold stress during the next severe winter.

If all plants were eliminated, warm-water habitats in southwestern Florida would be limited to thermal basins in the southern half of the winter range and Warm Mineral Springs. This spring is too small to accommodate a large number of manatees and it is uncertain whether thermal basins further south could prevent significant levels of cold stress-related deaths in severe winters. Currently, manatees using thermal basins near Matlache Pass move to the power plant at Fort Myers about 40 km away during the coldest weather. Thus, the northern half of the subpopulation's current winter range, including Tampa Bay, likely would be used only during extended periods of mild winter weather and in summer months. Overall, the subpopulation might decline by 50% or more in the absence of all power plants.

Because the northwestern subpopulation relies on natural springs at the head of the Crystal and Homosassa Rivers, elimination of power plant outfalls should have little effect on its abundance. If spring flows remain at current levels, this subpopulation should continue to grow and perhaps reoccupy other regional warm-water springs now unused or little used by manatees. Given the large size of warm-water springs in Kings Bay and the upper Homosassa River and a number of other factors (e.g., an abundance of nearby aquatic vegetation, a large network of protected habitat, relatively low numbers of boats, and a relatively small human population), the size of this subpopulation could substantially increase.

Development of a Management Strategy

The U.S. Fish and Wildlife Service is the lead Federal agency responsible for conserving Florida manatees under the Endangered Species Act and the Marine Mammal Protection Act. In the early 1980s, the state of Florida assumed a co-leadership role with the Service by providing funding and staff for key recovery tasks. The state's activities are now carried out by the Florida Fish and Wildlife Conservation Commission. As discussed later, joint efforts by both agencies and involved Florida utilities are essential parts of the Florida manatee recovery program.

Past Management Efforts

When the Service began a dedicated manatee recovery program in the mid-1970s, the attraction of manatees to power plants outfalls was well known. It was considered to be

harmless at least, and possibly beneficial. There was (and continues to be) no evidence of plant outfalls exposing manatees to contaminants or other agents that could cause deleterious effects. Given their thermal preference for these sites, it was thought that the outfalls could even enhance manatee survival by providing them safe, warm areas to rest and thermoregulate.

As a result, wildlife managers in the late 1970s and early 1980s took no steps to curtail manatee use of outfalls. Instead, as recommended in manatee recovery plans prepared under provisions of the Endangered Species Act (U.S. Fish and Wildlife Service 1980, 1989, 1996), steps were taken to assure safe, reliable discharges at power plants used by manatees. Under state law, most outfalls used by large numbers of manatees were closed to boat traffic in the 1980s to prevent animals from being hit or chased into cold waters. As a condition of effluent discharge permits required under the Clean Water Act, plant operators also were required to prepare manatee protection plans setting forth steps to maintain winter outfalls at temperatures suitable for manatees and to avoid discharge interruptions during winter months.

The approach worked well. With most plants discharging warm water reliably throughout the winter, the number of manatees using them increased steadily. At some plant outfalls manatees have become local attractions for school groups and the public at large. One utility, Florida Power & Light Company, which operates five of the major plants used by manatees, became a particularly constructive partner, earning awards and praise from both federal and state agencies. Among other things, it has provided funding for annual winter manatee surveys at its plants, supported work to develop a manatee photo-identification system, and carried out public education programs (Marine Mammal Commission, 1984).

In hindsight, actions to allow and enhance manatee use of power plant outfalls appear to have been a major factor in bringing about an increase in manatee abundance. This may be due to at least three reasons. First, by creating safe, reliable warm-water refuges, they reduced the risk of cold-related death, thereby improving winter manatee survival. Second, by providing winter habitat between natural springs to the north and manatee concentrations confined by past hunting to southernmost Florida, they may have hastened the reestablishment of subpopulations at springs in the Crystal and upper St. Johns Rivers. Third, power plants opened new winter and summer foraging areas. This could have been particularly important given significant declines in seagrasses, manatees' preferred food, throughout Florida in the mid- to late 1900s. Since the 1950s, Florida has lost some 2 million acres of seagrasses due to nutrient loading, salinity changes induced by water control projects, propeller damage from recreational boats, and other human-related causes (Sargent et al., 1994). Estimated declines in the extent of seagrasses include 40% in the Indian River Lagoon, 40% in northern Biscayne Bay, 80% in Tampa Bay, and nearly 30% in Charlotte Harbor (Durako et al., 1987). If manatees had not been distributed over a wider area, declining food supplies may not have been sufficient to support the growth in manatee abundance that has occurred over the past 40 years.

Although power plants may have helped enhance manatee recovery in Florida, they also have caused large numbers of manatees to overwinter in areas where they otherwise would have been far less abundant, which in turn may have increased their local abundance in non-winter periods. Many of these areas are also heavily used by recreational and commercial boats. As noted earlier, collisions with watercraft are the largest source of human-related manatee mortality. To reduce such deaths, steps have been taken to establish boat speed zones and limit new boating facilities in areas where manatee numbers are high. Such speed zones and development restrictions have become intensely contentious in recent years.

Although management agencies have taken constructive steps to protect manatees overwintering at power plants, very little has been done to identify what could or should be done to address potential impacts associated with impending power plant closures. This is particularly unfortunate given that this problem was identified over a decade ago. A promising start was made in August 2000, when the Fish and Wildlife Service, in cooperation with the State of Florida and Florida Power & Light Company, convened a workshop to examine related research and management needs (U.S. Fish and Wildlife Service, 2000). That workshop prompted the formation of a Warm-Water Task Force composed of members from concerned agencies, industries, and environmental groups. However, despite regular task force meetings, the group has served mainly as a forum to exchange information on related research and management activities and to pursue steps to protect natural springs used by manatees. Although part of its charter and a priority task identified in the manatee recovery plan involves the development of long-range goals and potential management alternatives for protecting warm-water manatee habitats (U.S. Fish and Wildlife Service 2001), the task force is only now beginning to address this need.

Future Management Needs

The two largest Florida manatee subpopulations, the Atlantic Coast and southwestern subpopulations, include perhaps 85% of all animals and depend to a high degree on power plant outfalls for winter survival. Plant retirements in those regions therefore pose a potentially devastating threat to the Florida manatee population as a whole. Most of the remaining manatees depend on natural springs threatened by escalating ground water withdrawals and development of recharge areas, and thermal basins that may offer limited protection during particularly cold winters. Unless an effective, forward-looking management strategy is developed and implemented to counter these threats before decisions are made to close power plants, the long-term survival of Florida manatees will be in grave doubt.

To assure the continued availability of warm-water habitats for manatees, we believe the Fish and Wildlife Service and the Florida Fish and Wildlife Conservation Commission must exercise a stronger leadership role. Their actions taken to date fall far short of addressing foreseeable threats and the future availability of adequate warm-water manatee habitats. To establish a long-term network of warm-water habitats capable of sustaining Florida manatees at levels of abundance high enough to allow for their eventual removal from the list of endangered and threatened species, we suggest that the Service and Florida Commission, in consultation with the Warm-Water Task Force, take immediate steps to:

1. identify possible management alternatives for evaluating, testing, and use as warranted;
2. develop a warm-water refuge policy or strategy statement that sets forth (a) long-term and interim goals and (b) a schedule of research and management actions to accomplish them; and
3. establish a dedicated funding source to carry out identified research and management actions.

Management Alternatives

As an initial step, the Service, in consultation with its Warm-Water Task Force, should identify possible management options to mitigate effects of impending power plant retirements or declining spring flows. Once such a list is developed, it should then be

possible to craft a responsive management approach. With regard to potential management alternatives, at least six options, which are not necessarily mutually exclusive, seem possible.

First, managers could elect to do nothing other than monitor plant closures and attempt to rescue manatees that remain near plants and show signs of cold stress. This might be appropriate when other refuges are available nearby to support displaced animals or when industry outfalls are located in an area deemed inappropriate. This option was followed when the Amelia Island outfall was closed in 1997 (see earlier) because the outfall was believed to be too far north of the manatees historic winter range. However, if this option was used in all cases, site-fidelity patterns and cold stress likely would cause many manatee deaths. Although this might be seen as a way to establish a more "natural" manatee distribution, it also must be recognized that development over the past 50 years has significantly altered "natural" manatee habitat in ways that have almost certainly reduced their historic carrying capacity through the loss of seagrass beds, changed surface flow patterns throughout the Everglades, obstructed access to natural springs, and degraded spring discharges.

Second, managers could attempt to wean manatees off industrial outfalls before they are closed. This might be done by constructing a fence around an outfall and gradually moving it further from the discharge over a series of months or years. The goal would be to slowly move manatees away from the refuge so that, at some point, they would abandon the area on their own and move to an alternative site. Whether such an approach could succeed seems uncertain at best. Also, like the no response option, this approach by itself would eventually confine manatees to historical winter habitats that have been reduced in number and altered in ways that have reduced their ability to support large numbers of manatees.

Third, steps could be taken to protect the natural warm-water springs now used by manatees. As indicated earlier, the Service and the state have already taken important steps in this regard. At springs used by the largest numbers of manatees (i.e., Blue Spring, Crystal River, and Homosassa Springs), restrictions on vessel speed and human use have been adopted and strengthened over the past several decades to protect manatees. More recently, the Service and the Florida Commission have worked closely with a Florida Springs Task Force established in 1999 by the Florida Department of Environmental Protection. With an exceptional wealth of large natural springs in Florida, that task force was charged with assessing threats to the discharge rates and water quality of springs throughout Florida. Because of their importance as manatee habitat, two of the first four springs targeted for special study were Blue Spring and Homosassa Springs. Work at Blue Spring has included efforts to set a minimum spring discharge rates based on estimated flow rates necessary to support overwintering manatees.

A fourth option is eliminating obstructions or activities impeding manatee use of warm-water springs now little used or unused by manatees. This might be done by deepening silt-clogged spring runs, removing barriers (e.g., dams, locks, or fences) that block the movement of animals in and out of springs, and working with local residents to manage human activities in spring areas. To assess such possibilities, we suggest that a study be undertaken to (1) assess past and potential manatee use of natural warm-water springs that discharge water at temperatures of 22ºC or higher (i.e., the temperature of springs now used by large numbers of manatees), and (2) identify potential site-specific opportunities to remove barriers restricting manatee access. Where opportunities exist to improve manatee access, serious consideration should be given to making such modifications. In addition, steps should be taken to (1) monitor discharge rates at warm-

water springs frequently used by manatees, and (2) continue working with appropriate government agencies to identify and maintain minimum flow rates necessary to support manatees throughout the winter.

A fifth option might be establishing non-industry-dependent warm-water refuges to maintain or alter winter manatee distributions. Such refuges would discharge warm water similar to industrial outfalls, but would not rely on commercial facilities. They would seek to discharge only enough warm water to heat a small area designed to allow manatee access, while minimizing heat dissipation into adjacent waters. Such facilities might be operated by government agencies or a non-profit entity.

To investigate this option, Florida Power & Light Company has funded several efforts. In 2000 it sponsored a contest for engineering students to develop a cost-effective conceptual design for discharging warm water into a hypothetical winter manatee refuge. The winning design, a solar-powered heating system, was then studied to assess the concept's feasibility and cost. The follow-up study examined available solar heating technology and estimated the cost of a solar panel array adequate to heat an embayment at one of the company's power plants located in the middle of the winter range for the Atlantic coast manatee subpopulation. Depending on the refuge's desired temperature, the cost of a solar array was estimated to range from $135,000–$730,000 depending on the target temperature (Goswami & Kearney, 2002). The company also funded a study to assess possible locations for such a refuge along Florida's east coast, where most of its plants are located (Reynolds, 2001), and another company, Reliant Energy, is supporting a similar study in southwestern Florida. The Marine Mammal Commission, in cooperation with the Fish and Wildlife Service and the Florida Fish and Wildlife Conservation Commission, is currently supporting a follow-up study to further assess the feasibility and cost of such refuges in different parts of the manatee's winter range.

A sixth option would be creating new thermal basins by dredging new or deepened basins in coastal waters that could naturally retain heat from solar radiation. This may be most useful in southernmost Florida where the number or physical attributes of thermal basins may be able to sustain many manatees through most cold winter periods. To assess the potential value of new thermal basins, a study should be done to identify the temperature fluctuations in thermal basins known to be used by manatees during cold winter periods and the physical features that optimize heat retention in those areas. In addition, we suggest that studies be undertaken to track manatees in southernmost Florida using GPS satellite–linked tags with temperature sensors to identify the precise locations, number, and nature of thermal basins used by manatees during cold winter periods.

Development of a Warm-Water Refuge Strategy/Policy Statement

Once a list of management options is prepared, we suggest that the Service and the Florida Fish and Wildlife Conservation Commission, in cooperation with the Warm-Water Task Force, develop a warm-water strategy/policy statement. In part, such a statement should summarize information on warm-water refuges and thermal basins presently available to sustain each of the four recognized Florida manatee subpopulations. It also should identify long-term (e.g., 50 year) and interim (e.g., the next 20 years) goals with regard to the envisioned networks of winter manatee habitats necessary to recovery and maintain each subpopulation. Because those networks may involve significant changes in winter distribution, which could have implications for local manatee protection measures (e.g., boat speed zones or waterway development restrictions), the development of such a statement should involve opportunities for public review and comment.

As a long-term goal, mangers might seek to establish a winter range based principally or entirely on natural warm-water springs in northwestern and central Florida, and thermal basins in southernmost Florida. Because of uncertainties about the feasibility and effectiveness of possible management options and the extent to which thermal basins in southern Florida can sustain manatees, any long-term goals would, of necessity, be subject to revision as new information becomes available. To the extent possible, articulation of such a goal should identify specific warm-water refuges that might figure prominently in an envisioned network of winter habitats.

With regard to an interim goal, we suggest that managers seek to maintain the current winter range between Miami and Cape Canaveral on the Atlantic coast and between the Fort Meyers and Tampa Bay on the Gulf Coast by developing and maintaining non-industry-dependent warm-water refuges to replace retired power plants now used by manatees. This seems important given the large proportion of manatees that now rely on power plant outfalls in these areas and the likelihood of high mortality levels should several major power plants in those areas be retired in the next 10–20 years.

The strategy/policy statement also should identify and describe research and management actions that will be pursued to achieve both the long-term and interim goals. These could include research projects to improve understanding of the availability and adequacy of thermal basins in different parts of the species range, particularly southernmost Florida, as well as projects to evaluate, and where possible test, alternative management options, such as those mentioned earlier. Based on results of that work, it may become necessary to revise interim and long-term goals over time.

Development of a Dedicated Funding Source

Research to evaluate and implement management options will be expensive and require a long-term funding commitment. To meet this need, we suggest that a dedicated warm-water refuge fund be created with revenue from the electric utility industry, as well as public, state, and federal sources. Given the role Florida's power industry has played in creating the current dilemma arising from the prospective retirement of power plants now used by manatees, we believe that operators of plants that provide winter manatee refuges should be required to immediately begin contributing to a fund dedicated to research and management actions to resolve that dilemma. Public contributions might come from a nominal fee, surcharge, or voluntary contributions for visiting warm-water refuges to view manatees. State and federal agency contributions also are warranted given their statutorily required stewardship responsibilities for manatees.

Conclusions

Most Florida manatees depend on either warm-water springs or heated outfalls from power plants to survive cold winter periods. Perhaps 75% or more depend to varying degrees on power plant outfalls alone. Many of these power plants are likely to be retired within the next few decades. Experience with temporary and permanent shutdowns of industry-based refuges suggests that many manatees are likely to remain near those outfalls after they are retired because of ingrained site-fidelity patterns and die of cold stress. This could significantly reduce the two largest Florida manatee subpopulations (i.e., those along the Atlantic coast and in southwestern Florida). Warm-water springs used by manatees are also threatened by increasing ground water withdrawals for human use. Two smaller populations—one in the upper St. Johns and the other in northwestern

Florida—depend almost entirely on natural springs. Reduced spring discharges could limit or preclude opportunities for manatees to thermoregulate during winter.

To assure the availability of suitable winter manatee habitat, the Fish and Wildlife Service and Florida Fish and Wildlife Conservation Commission must exert a stronger leadership role to identify and protect a network of warm-water manatee habitats. To do so, steps should be taken to (1) identify and evaluate potential management alternatives to mitigate or prevent effects of plant closures and ground water withdrawals from spring aquifers, (2) develop a strategy/policy statement through a public review process to articulate long-term and interim approaches for maintaining a network of warm-water habitats for each Florida manatee subpopulation, and (3) establish a long-term funding source based largely on industry and public contributions for carrying out related research and management activities. Given the long period of time it will take to develop, test, and implement needed actions, and the potential consequences if effective mitigation approaches are not available or in place before decisions are made to retire power plants, we believe these efforts constitute one of the most urgent matters now confronting Florida manatee conservation.

Note

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