Biological Information* on the West Indian Manatee (*Trichechus manatus*)

The West Indian manatee (*Trichechus manatus*) is one of the largest coastal mammals in North America. This unusual marine mammal with its massive, seal-like body, has been able to adapt well to its marine environment. Manatees migrate seasonally to adapt to changing water temperatures. West Indian manatees roam in fresh, brackish, and marine waters throughout Florida, the Greater Antilles, Central America, and South America. Intensive hunting pressures between the 1500s to 1800s reduced the number of manatees. The West Indian manatee is one of the most endangered marine mammals in coastal waters of the United States. This group includes a separate subspecies called the Florida manatee (*Trichechus manatus latirostris*) that appears to be divided into at least two somewhat isolated subpopulations-one along the Atlantic coast and the other on the Florida Gulf of Mexico coast. On March 11, 1967 the manatee was listed as an endangered species and in 1976, critical habitat was designated. In 1996 the USFWS published their West Indian Manatee Recovery Plan (USFWS 1996).

Description

The West Indian manatee is an aquatic mammal with a robust, fusiform body that is compressed dorsoventrally. Its grey to grey-brown, thick, tough skin is sparsely covered with small, thick hairs (3.0 to 4.5 mm) (Husar 1978) and is sometimes covered with barnacles and algae. The rounded body of the manatee has no hind limbs, but it has paddle-like forelimbs or flippers with three to four nails present on the dorsal surface of each flipper. The body tapers to a spatulate, dorsoventrally flattened tail. Females have a single prominent mamma or teat behind the axilla of each flipper and a relatively short anal-genital distance (Rathbun 1984). The urogenital opening in males is located just behind the navel.

The average adult manatee is 3.5 m long and weighs 1,000 kg. Male and female manatees are similar in size and appearance (Rathbun 1984). Newborn calves are, on average, 1.2 to 1.4 m long and weigh an average of 30 kg (Odell 1981).

Manatees have a dense skeleton. The massive skeletal bones lack marrow cavities in the ribs and forelimbs (Odell 1982). Similar to other marine mammals, manatees have large blubber stores.

The deeply-set, small eyes have no visible upper or lower lids, but instead have a nictitating inner membrane capable of covering the eyeball for protection. Manatees can see for considerable distances, although their depth perception may be limited (Reynolds 1979). Manatees can hear well even though their inconspicuous ears have no external

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pinnae or earlobe flaps (Gerstein 1994). Manatees communicate through different squeaks, chirps, grunts, and groans, that are within human audible range (Ketten *et al*. 1992). Two nostrils are located on the long upper snout that are capable of opening and closing by muscular valves. Manatees have an enlarged, lobed upper lip with short, stiff bristles and two muscular projections or prehensile pads that aid them in bottom feeding (Odell 1982).

To compensate for the excessive tooth wear caused by the tough vegetative matter they feed upon, manatees replace old, worn-down teeth with new ones. In a manner that is similar to a conveyor belt, their teeth move forward horizontally through their jawbones until worn-down teeth fall out and are replaced by new teeth in the back of their mouths. This replacement process occurs at a rate of about one mm per month. Manatees may use 30 or more molars in a lifetime (Domning and Hayek 1986).

Sea cows (*Protosiren*) first appeared during the Eocene period about 55 million years before the present when flowering plants first evolved. The family Trichechidae appeared in South America in the early Miocene (15 million years before present), about the same time as whales, apes and grazing animals (Domning 1982, Domning *et al.* 1982). During the Pliocene (12 million years before present), the time period when large carnivores evolved, members of Trichechidae first appeared in Atlantic North America (Reinhart 1951, 1959). Pleistocene *Trichechus* fossils have been recovered from the United States' east coast from Florida to Maryland (Simpson 1932).

Taxonomy

The mammalian Order Sirenia has two recent families, three recent genera and five recent species (Rathbun 1984). The two recent families: Dugongidae and Trichechidae have two genera with four living species and one extinct species. The Family Dugongidae contains two genera *Dugong* and *Hydrodamalis* and two species; of which *Dugong dugon* is the only living species of this family. The second species, Steller's sea cow (*Hydrodamalis giga)*, was hunted to extinction by 1768 (Reeves *et al.* 1992). The family Trichechidae was described by Gill in 1872 (Rathbun 1984). The second living genus, *Trichechus*, includes three allopatric species: the Amazonian manatee (*T. inunguis*), the West African manatee (*T. senegalensis*), and the West Indian manatee (*T. manatus*). The West Indian manatee is represented by two subspecies, the Florida manatee (*T.manatus latirostris*) and the Antillean manatee (*T. manatus manatus*) (Hatt 1934). *T. manatus* was described by Linneaus in 1758, and further distinguished as *T. m. latirostris* in 1924 (Harlan 1924). The four living sirenian species are geographically isolated, and listed as threatened or endangered (32 FR 4001, 35 FR 8495, 44 FR 42911). The closest, living terrestrial mammalian relative to the manatee is the elephant.

Distribution

The global distribution of sirenians, including dugongs and manatees, includes coastal waters, estuaries, and freshwater rivers. Dugongs can be found in marine habitats from eastern Africa to the Ryukyu Islands, Indo-Australian Archipelago, western Pacific and Indian oceans. Manatees can be found in tropical western Africa, including the Niger-Benue Basin, the tropical western Atlantic coast, the Caribbean Sea, and in the Amazon and Orinoco River basins (Rathbun 1984). The extinct Steller's sea cow range included the Bering Sea.

The present distribution of the West Indian manatee includes the coasts and rivers of Florida, the Greater Antilles, eastern Mexico and Central America and northern and eastern South America (Husar 1977, Lefebvre *et al.* 1989). *T.manatus latirostris* ranges from Texas to Rhode Island. The cooler winters along the U.S. coast of the Gulf of Mexico, in combination with the deep water and strong currents of the Straits of Florida, create a barrier between the Antillean and Florida manatee; the resulting isolation contributes to their status as subspecies (Domning and Hayek 1986).

The seasonal distribution of the manatee is affected by water temperatures. Waters colder than 20 degrees C increase the manatees' susceptibility to cold-stress and cold-induced mortality. Because of this temperature restriction, manatees seek out warm water refuges to help reduce energetic maintenance costs.

The manatee occurs throughout the southeastern United States. The only year-round populations of manatees occur throughout the coastal and inland waterways of peninsular Florida and Georgia (Hartman 1974). During the summer months, manatees may range as far north along the East Coast of the U.S. as Rhode Island, west to Texas, and, rarely, east to the Bahamas, (USFWS 1996, Lefebvre *et al.* 1989). There are reports of occasional manatee sightings from Louisiana, southeastern Texas, and the Rio Grande River mouth (Gunter 1941, Lowery 1974).

In Florida, manatees are commonly found from the Georgia/Florida border south to Biscayne Bay on the east coast and from Wakulla River south to Cape Sable on the west coast (Hartman 1974, Powell and Rathbun 1984) (Figure 1). Manatees are also found throughout the waterways in the Everglades and in the Florida Keys. Although temperatures are suitable for manatees in the Florida Keys, the low number of manatees has been attributed to the lack of fresh water (Beeler and O'Shea 1988). Manatees also occur in Lake Okeechobee.

In warmer months (April to November), the distribution of manatees along the east coast of Florida tends to be greater around the St. Johns River, the Banana and Indian rivers to Jupiter Inlet, and Biscayne Bay. On the west coast of Florida, larger numbers of manatees are found at the Suwannee, Crystal and Homosassa rivers, Tampa Bay, Charlotte Harbor/Matlacha Pass/San Carlos Bay area, the Caloosahatchee River and Estero Bay area, the Ten Thousand Islands, and the inland waterways of the Everglades.

On the west coast, manatees winter at Crystal River, Homosassa Springs, and other warm mineral springs (Powell and Rathbun 1984, Rathbun *et al.*1990). In the winter, higher numbers of manatees are seen on the east coast at the natural warm waters of Blue Spring and near man-made warm water sources on or near the Indian River Lagoon, at Titusville, Vero Beach, Ft.Pierce, Riviera Beach, Port Everglades, Ft. Lauderdale, and throughout Biscayne Bay and nearby rivers and canals (USFWS 1996). They also aggregate near industrial warm water outflows in Tampa Bay, the warmer waters of the

Caloosahatchee and Orange rivers (from the Ft. Myers power plant), and in inland waters of the Everglades and Ten Thousand Islands.

Manatees frequently migrate throughout the waterways in South Florida. The South Florida Ecosystem region is home to the most resident manatee populations and transient migrants in Florida. In South Florida, manatees are most prominent year-round in the following areas: Indian River, Biscayne Bay, Everglades and Ten Thousand Island area, Estero Bay and Caloosahatchee River area, and Charlotte Harbor area. Some of the largest winter aggregations (50 or more manatees) occur in south and central Florida (USFWS 1996).

Habitat

Manatees occur in both fresh- and saltwater habitats within tropical and subtropical regions. They depend on areas with access to natural springs or manmade warm water refugia and access to areas with vascular plants and freshwater sources (Humphrey 1992). Several factors contribute to the distribution of manatees in Florida. These factors are habitat-related and include proximity to warm water during cold weather, aquatic vegetation availability, proximity to channels of at least 2 m in depth, and location of fresh water sources (Hartman 1979).

Manatees are also dependent upon location of foraging sites. Normally, manatees feed on a variety of submergent, emergent, and natant (floating) vegetation. Manatees usually forage in shallow grass beds that are adjacent to deeper channels (Hartman 1979, Powell and Rathbun 1984). The proximity of these deeper channels may allow easy access to and from feeding areas.

Manatees often seek out quiet areas in canals, creeks, lagoons or rivers. These areas provide habitat not only for feeding, but also for resting, cavorting, mating, and calving. Deeper channels are often used as migratory routes (Kinnaird 1983). Natural or artificial freshwater sources are sought by manatees, especially manatees that spend time in estuarine and brackish waters (USFWS 1996).

Critical Habitat

Critical habitat was designated for the manatee in the early 1970s, although no specific primary or secondary constituent elements were included in the designation (50 CFR 17.95). Critical habitat for the manatee identifies specific areas occupied by the manatee, which have those physical or biological features essential to the conservation of the manatee and/or may require special management considerations.

Behavior

Manatees have low metabolic rates indicating a possible adaptation to their large size and low nutrient food sources, or to permit long dives, since manatees have less advanced diving abilities than other marine mammals. Manatees can remain submerged for several minutes, with the longest submergence record lasting 24 minutes (Reynolds 1981). Manatees increase submergence times while feeding and resting. Female manatees coordinate their breathing and submergence times with their calves. Manatees do not appear to be fast swimmers, but they usually swim 4 to 10 km an hour and may attain faster speeds in short bursts (Husar 1977).

Manatees are not overly gregarious, but they do aggregate at warm-water refugia and during mating. Manatees have been observed displaying playful behaviors such as chasing, tumbling, and nuzzling (Hartman 1979, Bernier 1985).

Reproduction

The manatee population sex ratio is considered to be 1:1 for both adults and calves (Rathbun *et al*. 1992). Females reach sexual maturity at 3 to 5 years of age (Marmontel 1993) and males may reach sexual maturity at 3 to 4 years of age. Individuals at least 275 cm in length may be reproductively mature, although the modal female may not successfully rear young until 6 years or older (Marmontel 1993). Manatee longevity has been estimated at 50 years or more and they appear to be able to reproduce their entire adult life (Marmontel *et al*. 1992). Odell *et al*. (1995) reported a captive female manatee reproduced throughout its 34 years at the Miami Seaquarium.

The combination of suitable seagrass beds, nearby deeper water access, and minimal boat traffic may be indicative of important mating, calving, and nursery grounds for manatees (Smith 1993). Reproduction can occur throughout the year, although sperm production in male manatees is low during the winter (Hernandez *et al*. 1995). Most manatee calves are born in the spring or early summer (Irving and Campbell 1978). Breeding usually commences when one or more males are attracted to an estrous female, but permanent pair bonds are not formed (Marmontel *et al*. 1992). Manatees may form large breeding herds. Larger, presumably older males, dominate mating herds and may be responsible for most pregnancies (Rathbun *et al*. 1992).

The minimum interval between manatee birth is 2 years, but not all female manatees are this fecund. On average, 33 percent of mature, female manatees may be pregnant, which suggests a 3-year interval between calving (Marmontel 1993). If the interval between calving is 3 years and continues over a 36-year period, a female manatee could produce approximately 12 calves during her lifespan (Marmontel 1993). Calving intervals may be affected by the age and health of the female manatee. Although sexual activity may occur, female manatees may experience infertile estrous periods (Hartman 1979). Injuries caused by watercraft may also disrupt the manatee’s estrous cycle (Marmontel 1993).

Gestation of the single calf takes 12 to 14 months (Reid *et al*. 1992). Age to weaning varies from 1 to 2 years. Calves usually stay close to their mothers during their first several years. Twin calves have been reported (D. O’Dell, Sea World, personal communication 1998).

Per capita reproductive rates in Florida manatees have been estimated from a low of 0.15 (+0.060) in the Blue Spring population to a high of 0.19 (+0.009) in the Atlantic coast population (Eberhardt and O’Shea 1995). The maximum potential rate of population increase has been estimated at 2.0 to 7.0 percent; this rate is most sensitive to changes in adult survival and, secondarily, subadult survival (Packard 1985, Marmontel 1993). For many years, various governmental and private agencies have expressed concern about how the mortality rate will affect the survival and recovery of the manatee. These concerns were confirmed by the population viability analysis conducted by Marmontel (1993), which evaluated the probability of the manatee's persistence and the mean time to its extinction.

Foraging

Manatees feed with the help of their two muscular lips, which are flexible and move independently, in a fashion similar to an elephant's trunk or human fingers. The lips are capable of manipulating food: grasping and moving food into the mouth. Manatees also use their forelimbs to dig into the sediment to remove seagrass rhizomes or roots (Hartman 1979, Provancha and Hall 1991, Lefebvre and Powell 1990). Manatees usually spend more time foraging in the late autumn (6.9 hours/day) than in early spring (3.2 hours/day)(Bengston 1983). Manatees must eat large amounts of aquatic vegetation to meet their metabolic requirements and may consume up to 20 percent of their body weight per day in aquatic plants (Zieman 1982).

These animals frequently forage at depths of 1 to 3 meters where aquatic vegetation is abundant. Manatees are opportunistic herbivores and feed on a variety of submerged, emergent, or floating aquatic plant species, including seagrasses, bank grasses, and overhanging mangroves (see Hurst and Beck 1988, and Smith 1993 for complete review). They may also feed on algal complexes attached to rocks, pilings, and dams (Reynolds 1981), and may occasionally eat fish or invertebrates while feeding on floating or submerged vegetation (Powell 1978, Smith 1993). In South Florida, manatees feed primarily on submerged vegetation such as turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), Cuban shoal grass (*Halodule wrightii*), and *Halophila* spp., although a variety of other emergent and floating vegetation is also eaten. Manatees may also forage on a variety of shoreline vegetation including red mangrove (*Rhizophora mangle*) leaves and cordgrass (*Spartina alterniflora*) (Longieliere 1994). In fresh water, manatees feed primarily on submerged aquatic macrophytes such as *Myriophyllum* spp. And hydrilla (*Hydrilla verticillata*).

Preferred manatee habitat in South Florida is characterized by the availability of submerged aquatic vegetation (SAV) (Smith 1993). Due to light limitations, most SAV, such as seagrass beds, are limited to shallow, nearshore waters. Seagrasses comprise the largest component of the manatee's diet, especially in South Florida (Hartman 1979, Zieman 1982, Smith 1993). Some manatees have been observed to return to the same seagrass beds to feed year after year and may show preferences for certain areas (USGS/BRD 1993, Smith 1993). Preference may also be shown for areas with healthy seagrass beds adjacent to relatively deeper waters with little boat traffic (Kadal and Patton 1991,USGS/BRD 1993). Manatees exhibit diel feeding patterns during the winter; they rest in warm waters during the day and head out in the late afternoon to feed in surrounding, sometimes, cooler areas (Bengston 1981).

Migration

Manatees normally migrate along shorelines and use deeper corridors to access shallow-water feeding and resting areas (Kinnaird 1983). Telemetry research suggests that calves learn migratory patterns from their mothers (USGS/BRD 1993). Migration patterns often vary between individuals. Some manatees may undertake extensive migrations along the coast and up rivers and canals (Reeves *et al*. 1992). Manatees may travel 40 km/day for several consecutive days, usually traveling directly and rapidly to a particular destination site, with males ranging longer distances than females (Bengston 1981, USGS/BRD 1993). On the east coast manatees migrate northward in the springtime and southward in the fall and winter (Moore 1951). Manatees do not range far offshore, but may travel along the coast (Beeler and O'Shea 1988).

The increase in the number of manmade warm-water sources over the years has influenced manatee migratory patterns. Manatees frequent coastal, estuarine, and riverine habitats and are capable of extensive north-south migrations throughout the year (Reeves *et al*. 1992). Manatees have been observed migrating great distances northward in the springtime and southward in the fall and winter (Longieliere 1994); and as a result, abundances in regional populations change seasonally (Hartman 1974). There are 17 major aggregation sites in Florida (Garrott *et al.* 1994). These aggregation sites occur at or near manmade or natural warm-water refugia. Manatees will migrate to these warmer areas when water temperatures drop below 20 degrees C. Large aggregations of manatees occur at these warm-water areas. With the rise in water temperatures in the spring, some manatees may begin to migrate away from their winter refugia, while others remain relatively close. Manatees often return to the same winter refugia each year (Powell and Rathbun 1984, Reid *et al*. 1991). In the winter, manatees stay closer to warm-water during the day, then move to vegetated areas in the late afternoon or at dusk to feed.

Warm-water sources offer manatees refugia to escape the stresses of cold water temperatures. Most research has concentrated on developing methods to determine population trends at these sites, but little work has investigated manatee behavior in relation to man-made water sources.

Boat channels are often used by manatees to travel from one region to another (Curran 1989, USGS/BRD 1993). Although these channels may provide deeper waters for manatees to avoid or escape oncoming boats, for reasons not yet understood, they do not always move out of the way of approaching boats. Manatees are also vulnerable to collisions with boats in narrow waterways and shallow water areas. During high tide, manatees are able to access foraging habitat that is normally inaccessible during low tide (Smith 1993). Although watercraft may utilize deeper navigation channels, coastal shallow areas are used intensively for fishing and general sightseeing. The shallow depths of these areas increase the likelihood of manatee injury or death if a powerboat passes over them.

Relationship to Other Species

The manatee is an indicator species for aquatic habitats, including seagrasses and mangroves, in the South Florida Ecosystem. Because this species is dependent upon the health of its entire habitat, the status of the manatee acts as a signal for the condition of many of the other flora and fauna that rely upon aquatic systems. For example, seagrass beds and mangroves provide important areas for manatee foraging, calving, resting, and mating. They also provide important habitat resources for other aquatic species such as wading birds, crocodiles *(Crocodylus acutus)*, turtles, fish and invertebrates. The stability of these aquatic communities is essential for manatees and many other species.

Manatees have no known predators, except for humans. Manatees and their habitats are continually threatened by human activities, such as habitat loss for residential and commercial purposes, increased turbidity levels from upland urbanization activities, pollution from sewage discharge and stormwater runoff, aquatic recreational and commercial activities, (O'Shea 1995) and alterations of natural hydrology. Several threatened and endangered sea turtles use the same seagrass beds as manatees for juvenile refugia and feeding. In addition, many migratory birds, and fish rely on the aquatic habitats manatees use. Habitat requirements of all of these species need to be considered and balanced in order to conserve and protect these resources.

Human interferences with natural water flows have affected the dynamics of vegetative communities in the South Florida Ecosystem. Changes in these flow regimes may affect not only manatees but other species as well, including the endangered American crocodile and pink shrimp (*Penaeus duorarum*), an important fishery species. Returning hydrologic flows to mimic more natural conditions will allow more fresh water into northeastern Florida Bay and may increase the amount of suitable crocodile nesting habitat. A decline in the pink shrimp fishery has been attributed to a lack of freshwater inflow into Florida Bay and a loss of seagrass habitat. The effects of hydrologic conditions on manatees is not well known; but effects on habitat have been observed.

Although reactions may be different, manatees are susceptible to the same natural and human disturbances other aquatic organisms experience, such as changes in water quality, loss of habitat, and susceptibility to diseases and natural catastrophes. Considering man is the only known predator of manatees, it is our responsibility to ensure our actions do not jeopardize the continued existence of this species nor those other species that share its home.

Status and Trends

The West Indian manatee was first listed as an endangered species in 1967 under the Endangered Species Preservation Act of 1966 (16 U.S.C. 668aa(c)) (32 FR 48:4001). The Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa(c)) continued to recognize the West Indian manatee as an endangered species (35 FR 16047), and the West Indian manatee was also among the original species listed as endangered pursuant to the Endangered Species Act of 1973. Critical habitat was designated for the manatee in 1976. The justification for listing as endangered included impacts to the population from harvesting for flesh, oil, and skins as well as for "sport," loss of coastal feeding grounds from siltation, and the volume of injuries and deaths resulting from collisions with the keels and propellers of powerboats. Manatees are also protected under the provisions of the Marine Mammal Protection Act of 1972, as amended (16 U.S.C. 1361 *et seq*.) and have been protected by Florida law since 1892.

Historic information on *T. manatus* distribution indicates manatees were once more common in pre-Colombian times. Manatees were highly utilized for their meat, oil, bones, and hide; hence, their early decline has been attributed to overhunting (Lefebvre *et al*. 1989). Extirpation and range contraction is evident throughout the manatee's range; areas previously with abundant populations now contain few or none. For example, manatees have been extirpated from some coastal areas in Mexico, Virgin Islands, and Honduras.

Florida is at the northern limit of the year-round range of *T. manatus*. Exact estimates of the historic manatee population are uncertain, but overhunting between the 1700s and 1900s is believed to be responsible for reducing the manatee population to only a few relict groups (Hartman 1979).

The geographic distribution of manatees within Florida has changed since the 1950s and 60s (Lefebvre *et al.* 1989) and prominent shifts in seasonal distribution are also evident. Before man introduced warm effluents from power plants to the natural environment in the early 1950s, the winter range of the manatee in Florida was most likely limited on its northern bounds by the Sebastian River on the east coast and Charlotte Harbor on the west coast (Moore 1951). Since that time, manatees altered their normal migration patterns and appreciable numbers of manatees began aggregating at new sites. As new powerplants became operational, more and more manatees began taking advantage of the sites by traveling great distances just to bask in the warm waters. The introduction of powerplants and paper mills in northern Florida, southern Georgia, Louisiana, and Texas has given manatees the opportunity to expand their winter range to areas not previously frequented (Hartman 1979).

As discussed earlier, determining exact population estimates or trends is difficult for this species. The best indicator of population trends is derived from mortality data and aerial surveys (Ackerman *et al.* 1992, Ackerman *et al.* 1995, Lefebvre *et al.* 1995). Aerial surveys conducted over the past 19 years have shown an increase in numbers, but this information is not an accurate account of trends since data have been obtained using different survey methods. O'Shea (1988) found no firm evidence of a decrease or increase between the 1970s and 1980s, even though aerial survey counts have increased. Increases in the number of recovered dead manatees have been interpreted as evidence of increasing mortality rates (Ackerman *et al*. 1992, Ackerman *et al.* 1995). Because manatees have low reproductive rates, these increases in mortality may lead to a decline in the population (O'Shea *et al.* 1985, 1992). Until better survey techniques are developed, efforts to reduce human-caused manatee deaths, like boat strikes, need to continue.

Although there are no accurate estimates of manatee population size, FDEP's 1996 synoptic aerial surveys conducted between February 18-19, determined there were at least 2,639 manatees in Florida's waters. FDEP conducted two synoptic surveys in 1997. The January survey determined that 2,229 manatees were present in Florida's waters: 900 on the east coast and 1,329 manatees on the west coast. The February survey determined that 1,709 manatees were present in Florida's waters: 791 manatees on the east coast and 918 on the west coast. Surveys conducted by FDEP in 1996 and 1997 determined that numbers of manatees on the east coast and west coasts of Florida are almost equal (Rathbun *et al.* 1992). These estimates represent the minimum number of manatees in Florida waters and may not represent the total population size (for discussions on bias in aerial surveys, see Garrott *et al.* 1995 and Lefebvre *et al.* 1995). Although this has been the highest estimate of manatees since the synoptic surveys were started, the results of these surveys may vary because of such factors as sampling methodology, manatee behavior, and weather conditions. Because of this variation and the high degree of uncertainty in surveying, it is difficult to correlate these manatee population estimates with overall manatee population trends (Ackerman *et al.* 1995).

Despite the lack of accurate estimates of the manatee population size, human activities have significantly affected manatees by eliminating or modifying suitable habitat, altering migratory access routes, increasing mortality, and decreasing abundance, all of which in turn, can affect manatee reproduction, recruitment, distribution, and behavior. To understand manatee mortality trends in Florida, Ackerman *et al.* (1995) evaluated the number of recovered carcasses between 1974 and 1992 and categorized the causes of death. During that time interval, the number of manatees killed in collisions with watercraft increased each year by 9.3 percent. The number of manatees killed in collisions with watercraft each year correlated with the total number of pleasure and commercial watercraft registered in Florida (Ackerman *et al.* 1995). Other human-related threats include manatee death or injury from flood-control structures and navigational locks, entanglement in fishing line, entrapment in culverts, and poaching. These other threats accounted for 162 known mortalities between 1974 and 1993.

Deaths from flood control structures and other human-related deaths did not change significantly but deaths due to these categories decreased more than deaths from other causes (Table 1). Of interest is the increase in the number of perinatal deaths of 11.9 percent/year. The frequency of perinatal deaths (stillborn and newborn calves) has been consistently high over the past 5 years and represented 24 percent of all manatee deaths in 1994. This estimate may not be a true representation of the actual number of perinatal deaths that occur because the carcasses of these young animals may not be recovered. The cause of the increase in perinatal deaths is uncertain, but may result from a combination of factors that includes pollution, disease, or environmental change (Marine Mammal Commission 1992). It may also result from the increase in collisions between manatees and watercraft because some newborn calves may die when their mothers are killed or seriously injured by boat collisions, when they become separated from their mothers while dodging boat traffic, or when stress from vessel noise or traffic induces premature births (Marine Mammal Commission 1992). As a result of the high perinatal death rate, there are fewer young age classes present in the population.

Of the 1,907 manatee carcasses that have been recovered in Florida between 1989 and 1997, (FDEP 1998) nearly half were female. The reduction of mature females places an additional burden and pressure on younger, less- experienced females to be the foundation for population growth. Younger females may be more apt to abandon their calves and less successful in calf rearing (Marine Technical Advisory Council 1994). A loss of mature, experienced males may also reduce the likelihood of successful mating.

The greatest present threat to manatees is the high rate of manatee mortalities caused by watercraft collisions. O'Shea (1995) and O'Shea *et al.* (1985) recognized the dramatic increase in the rate of boat use in manatee habitat and, consequently, the increase in the potential of boat-related manatee injury or death. Between 1986 and 1992, watercraft collisions accounted for 37.3 percent of all manatee deaths, where the cause of death could be determined (Ackerman *et al.* 1995).

The significance of manatee mortalities related to watercraft appears to be the result of dramatic increases in vessel traffic. Ackerman *et al.* (1995) showed a strong correlation between the increase in recorded manatee mortality and increasing boat registrations. In 1960, there were approximately 100,000 registered boats in Florida; by 1990, there were more than 700,000 registered vessels in Florida (Marine Mammal Commission 1992, Wright *et al.* 1995). Approximately 97 percent of these boats are registered for recreational use. The most abundant number of registered boats are in the 16 foot to 26 foot size class. Between 1974 and 1997, there were 3,270 known manatee mortalities in Florida. Of these, 749 were watercraft-related. Since 1974, an average of 31 manatees have died from watercraft-related injuries each year; between 1983 and 1993, manatee mortalities resulting from collisions with watercraft reached record levels (FDEP 1994). Approximately twice as many manatees died from impacts suffered during collisions with watercraft than from propeller cuts; this has been a consistent trend over the last several years. Most lethal propeller wounds are caused by medium or large-sized boats, while impact injuries are caused by fast, small to medium-sized boats (Wright *et al.* 1992). Watercraft-related mortalities were most significant in the southwest and northeast regions of Florida; deaths from watercraft increased from 11 to 25 percent in southwestern Florida. In all of the counties that had high watercraft-related manatee deaths, the number of watercraft and the seasonal abundance of manatees was high (Ackerman *et al.* 1995).

In addition to direct collisions with boats, secondary effects from boating activity include such stresses as disruption of normal breeding behavior, disruption of cow-calf bonding, interference with migration routes and patterns, and the loss of feeding areas. An increase in these effects is likely to increase the probability of unsuccessful mating, perinatal mortality, prevention of reaching freshwater resources and warm-water refugia, and decreasing the availability of food resources. In addition, these effects are likely to decrease the recruitment of young manatees into the breeding population and decrease the number of successful reproductions.

The second most significant threat to manatees is the loss and degradation of habitat, due primarily to direct damage by aquatic recreational and commercial boating activity, coastal construction, and pollution from sewage discharge and stormwater runoff (Marine Mammal Commission 1992, Smith 1993). Coastal land conversion accompanying the growth of Florida's human population has occurred largely along coastal waters and rivers used by manatees. Siltation, eutrophication, other forms of water pollution, and the destruction or degradation of wetlands to promote shoreline development degrade the coastal and riverine communities. This degradation reduces manatee food supplies and eliminates the secluded areas that are used by manatees to mate, calve, and nurse (Marine Mammal Commission 1992).

In Florida, manatees rely primarily on seagrass beds for foraging, mating, and calving. These seagrass beds incur most of their direct damage from boat propellers (Zieman 1982). Boat-induced turbidity results from propeller dredging of bottom habitats and propeller wash and wave wake disturbance. Sediments around seagrasses become unconsolidated and suspended, delaying recolonization for 2 to 5 years or longer, depending upon species type. Several bays in Florida formerly possessed extensive seagrass resources, but dredge and fill operations as well as other human disturbances have greatly reduced their extent (Zieman 1982).

Seagrasses along the coast of Florida have been declining since the 1950s. In Tampa Bay, about 16,188 ha of seagrass flourished along the shallow shelf of the bay. By 1982, only 8,741 ha remained baywide (Tampa Bay National Estuary Program 1995). In Sarasota Bay, seagrasses have declined by 30 percent (Sarasota Bay National Estuary Program 1994). From 1945 to 1982, seagrass acreage declined by 29 percent in Charlotte Harbor; with an additional 809 to 3,238 ha of seagrasses destroyed or damaged by boat propellers (Haddad and Sargent 1994). More than 100,000 acres of seagrasses have "died off" in Florida Bay since 1987 (USFWS 1996). For the Indian River Lagoon, the total coverage of submerged aquatic vegetation (seagrasses and macroalgae) in the 1970s was 31,777 ha. In 1992, the total coverage decreased to 28,385 ha, an 11 percent reduction in seagrass distribution (Indian River Lagoon National Estuary Program 1994).

An unusual manatee mortality event was detected in southwest Florida in 1996. Between March 5 and April 29, 149 manatee deaths were attributed to this unusual die-off. Most of the manatee carcasses were recovered from Lee County followed by Collier, Charlotte, and Sarasota counties. After thorough investigations, red tide was indicated as the cause. Final reports on the 1996 manatee die-off concluded that brevetoxins from a bloom of dinoflagellates (*Gymnodinium brevii*), more commonly known as red tide, were responsible for the deaths of those manatees. Brevetoxins were found in the manatee carcasses in liver, kidney, and lung tissues and also in stomach contents. The majority of animals that died were large animals (greater than 275 cm long), although some smaller (younger) animals also died. The sex ratio of dead manatees was nearly one to one. High concentrations of red tide organisms were also found in water samples taken in the geographic vicinity of the die-off. Researchers continue to look for the cause of the red tide outbreak, method of toxicity, organ selection of the toxin, and most importantly, ways to minimize the effects of another red tide event.

Other threats to the manatee include natural catastrophic events such as low temperatures, and hurricanes (Ackerman *et al.* 1995). Most catastrophic mortality, however, is due to low temperatures (O'Shea *et al.* 1985). Lethal temperatures and lethal exposure times are not well known, but manatees cannot survive indefinitely in water colder than 16 degrees C (Ackerman *et al.*1995). Although deaths from natural weather events cannot be prevented by humans, these mortalities must be considered because they play an important factor in the overall status of the manatee.

Marmontel's (1993) population viability analysis (PVA) model discussed previously suggest that a 10 percent mortality rate is probably a critical threshold for the survival and recovery of manatees. Although the minimum population estimate reached a record high in 1996 with approximately 2,639 manatees, the number of manatees killed in the first quarter of 1996 almost equals 10 percent of that minimum population estimate. According to FDEP, 415 manatees died in 1996.

Although Marmontel's (1993) PVA had limitations resulting from the lack of specific life history information on the manatee, her simulations represent the best information available regarding the consequences of human activities on the manatee. First, she noted that the small population size of the manatee lessens their probability of persistence and increases the chances that the populations will be adversely affected by environmental variation or additional mortalities. Second, her simulations projected that a 10 percent increase in overall manatee mortality would reduce the manatee below the critical threshold of 500 animals in about 100 years. Finally, her simulations projected that reducing the mortality of adult manatees by watercraft would be the most productive mechanism to increase the probability of manatee survival and recovery.

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