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Manatee Mortality in Puerto Rico

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ABSTRACT / The most pressing problem in the effective management of the West Indian manatee (*Trichechus manatus*) in Puerto Rico is mortality due to human activities. We assessed 90 cases of manatee strandings in Puerto Rico based on historical data and a coordinated carcass salvage effort from 1990 through 1995. We determined patterns of mortality, including type of event, condition of carcasses, spatial and temporal distribution, gender, size/age class, and the cause of death. The spatial distribution of stranding events was not uniform, with the north, northeast, and south coasts having the highest numbers. Six clusters representing the highest incidence included the areas of Fajardo and Ceiba, Bahía de Jobos, Toa Baja, Guayanilla, Cabo Rojo, and Rio Grande to Luquillo. The number of reported cases has increased at an average rate of 9.6%/yr since 1990. The seasonality of stranding events showed a bimodal pattern, from February through April and in August and September. Most identified causes of death were due to human interaction, especially captures and watercraft collisions. Natural causes usually involved dependent calves. From 1990 through 1995, most deaths were attributed to watercraft collisions. A reduction in anthropogenic mortality of this endangered species can be accomplished only through education and a proactive management and conservation plan that includes law enforcement, mortality assessment, scientific research, rescue and rehabilitation, and inter- and intraagency cooperation.

The West Indian manatee (*Trichechus manatus*) is the most endangered of the marine mammals of Puerto Rico, with just over 100 animals documented through aerial surveys (J. E. Saliva, Fish and Wildlife Service, personal communication). Although the distribution and relative abundance of manatees has been documented in the past (Erdman 1970, Powell and others 1981, Rathbun and others 1986, Mignucci-Giannoni 1989, Freeman and Quintero 1990), there is a marked absence of data on the basic biology and life history of this species in the Caribbean. Apart from the brief mention of a few mortality cases in Powell and others (1981), Rathbun and others (1986) and Lefebvre and others (1989), manatee mortality in Puerto Rico has not been directly addressed previously, although in the past four decades over 75 individuals have been killed or found dead on shore (Figure 1).

KEY WORDS: Caribbean; Puerto Rico; *Trichechus manatus;* Mortality; Endangered species conservation and management

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The manatee is the marine mammal species most commonly found dead in Puerto Rican waters, accounting for 44% of all marine mammal stranding records in Puerto Rico since 1980 (Mignucci-Giannoni 1996). Its endangered status is probably exacerbated by a suspected recent genetic bottleneck and a low reproductive rate (García-Rodríguez and others 1998). Human interactions, in the form of hunting, accidental net entanglement, and habitat degradation, were reported to be the major cause for manatee mortality in Puerto Rico (Rathbun and others 1986, Rathbun and Possardt 1986), but this assumption was based only on 11 cases examined between 1975 and 1985. The deaths reported since 1975 do not include manatees taken by poachers for meat.

Illegal hunting and the contamination of coastal habitats by industrial discharge also constitute a serious problem (Rathbun and Possardt 1986). In some cases, large-scale global changes may be damaging populations of marine mammals worldwide (Geraci 1989, Harwood and Greenfell 1990, Lavigne and Schmitz

Figure 1. Dead manatee stranded off the south coast of Puerto Rico.

1990), including manatees (O'Shea and others 1991, Bossart and others 1998). If this proves to be the case in Puerto Rico, such losses must be documented and analyzed. Therefore, accurate mortality assessment to prescribe management actions is important and needed for the survival of this species. In this report we document manatee mortality in Puerto Rico using historical data and results from a coordinated salvage effort from 1990 to 1995.

Methods

The Caribbean Stranding Network (CSN, Red Caribeña de Varamientos in Spanish) served as the organizational tool to carry out the objectives of this study. The CSN is part of the Southeastern US Marine Mammal Stranding Network (Odell 1979, Mignucci-Giannoni 1990) and is composed of volunteer participants from private, university, commonwealth and federal agencies.

The study area included the main island of Puerto Rico and adjacent islands (Figure 2). For the purpose of analysis, the area was divided in nine geographical zones, including Puerto Rico's north, northeast, east, southeast, south, southwest, west, and northwest coasts, and Puerto Rico's offshore islands.

All documented deaths in the study were either historical, where data were collected after the fact, or opportunistic in nature. Historic mortality events were accepted as part of the study after they proved to be reliable in terms of species identification, date, and location. Before 1990, external postmortem examinations were conducted on two animals and necropsies were conducted on 10 carcasses. From 1990 to 1995, external examinations were conducted on five animals and complete necropsies were conducted on 22 carcasses to attempt to document cause of death. We followed the protocol for necropsy and assessing mortality described by Bonde and others (1983).

Trends and associations were studied as in O'Shea and others (1985) and Ackerman and others (1995) and were analyzed to determine patterns of manatee mortality. The variables we analyzed included:

- Type of event: Mortality events were assigned to one of seven categories: (1) single strandings (lone animal); (2) mass stranding (three individuals or more); (3) mother/calf strandings; (4) natural predation; (5) capture (intentional ''take'' or removal of an individual); (6) accidental capture (nonintentional capture); and (7) undetermined event.
- Condition of specimen: Specimens were assigned to one of six categories: (1) live animal; (2) freshly dead; (3) moderately decomposed, organs still distinguishable; (4) advanced decomposition, organs in-

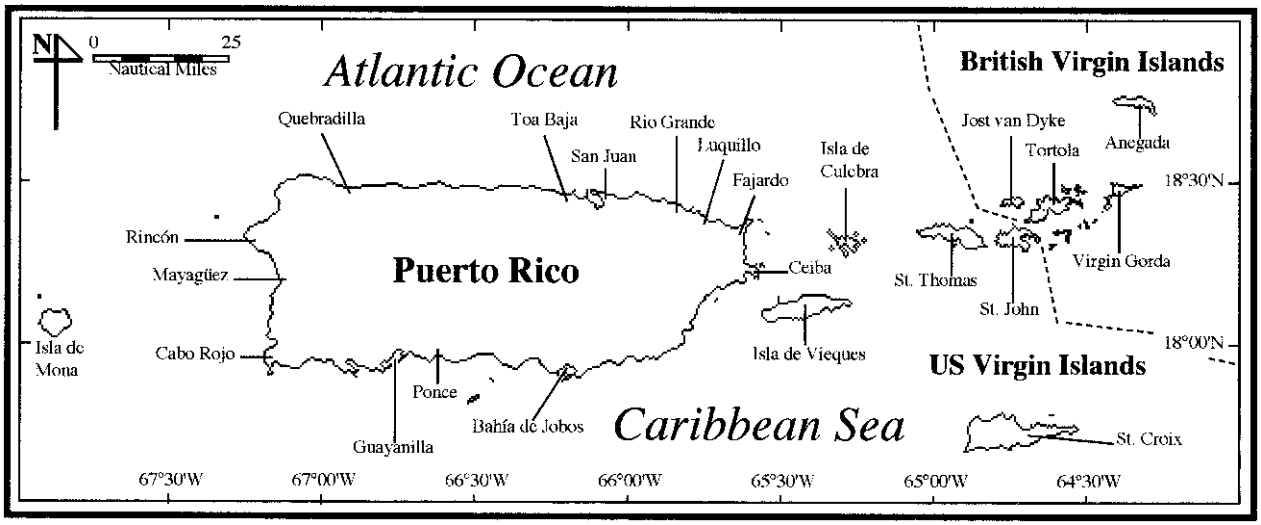

Figure 2. Study area and localities referred to in the text.

side are indistinguishable); (5) mummified carcass or skeletal remains; and (6) unidentified condition. Condition of animals was recorded when the animal first stranded, when it was first found, or upon examination.

- Spatial distributions: Events were categorized into one of the nine geographical zones of the study area.
- Seasonal and temporal distribution: Events were categorized by year, season, and month. Seasons were divided into three-month periods: December–February (winter), March–May (spring), June–August (summer), and September–November (fall).
- Gender: Male, female, or undetermined.
- Size/age classes: Animals were categorized into three age classes: calves (<175 cm total length, <2 years old); subadults (176–225 cm total length, 3–7 years old); adults (>225 cm total length, >7 years old). Age was estimated using histological analysis of tympanic bullae (Marmontel 1993), or in the case of adulthood and sexual maturity, by examining the carcasses for pregnancy, lactation, or histological analysis of gonads.
- Cause of death: Determination of natural (i.e., diseases, and orphan/dependent calves), and anthropogenic (i.e., hunting, watercraft collision, accidental entanglement, and shot or speared), causes of death. These were based on criteria for Florida manatees (O'Shea and others 1985, Ackerman and others 1995).

Results and Discussion

Ninety cases were reported between 1864 and 1995 (Table 1). Of these, 35 occurred between 1990 and 1995.

Type of Event and Condition of Specimen

Manatee records in the study area were assigned to three categories: single strandings (63.3%), captures (30.0%), and accidental captures (6.7%). No massive die-offs or antemortem or postmortem shark attacks were reported. Many animals were reported to strand alive (49.4%), but the majority were recovered dead. When carcass condition (excluding live strandings) was assessed, most animals were found in an advanced (19.1%) or moderate (13.5%) state of decomposition. Few were found in a freshly dead condition (4.5%) or as mummified carcass/skeletal remains (1.1%). Animals reported as being in an unidentified condition totaled 12.4%.

Spatial Distribution

Eighty-nine cases occurred in Puerto Rico, and one occurred in the US Virgin Islands (Figure 3). No records exist for the British Virgin Islands. The distribution of manatee strandings resembled the distribution of live sightings of the species based on aerial surveys (Powell and others 1981, Rathbun and others 1986, Mignucci-Giannoni 1989), with the exception of strandings in Culebra, Quebradillas, Rincón, and St. Thomas (US Virgin Islands). The distribution within Puerto Rico was not uniform, with the north, northeast, and south coasts having the highest number of records (between 19.8 and 22.1% each), while the east, southwest, and west had between 9.3 and 11.6% each, and the southeast, northwest, and offshore islands had the fewest records (between 0 and 3.5% each) (Figure 3). The record from St. Thomas may be from a stray animal from Puerto Rico. Six clusters of high incidence were

Table 1. Manatee deaths reported from Puerto Rico and Virgin Islands by year and cause of death categories

	Cause of death[a]							
	Natural		Human related					
Year	IL	DC	CA	EN	WC	SH	Undetermined	Total
No year	—	1	—	—	—	—	—	1
1864	—	—	2	—	—	—	—	2
1866	—	—	1	—	—	—	—	1
1945	—	—	1	—	—	—	—	1
1950	—	—	—	—	—	—	1	1
1954	—	—	1	—	—	—	—	1
1960	—	—	1	—	—	—	—	1
1964	—	—	—	—	—	—	1	1
1969	—	—	2	—	—	—	—	2
1975	—	1	1	—	—	—	—	2
1976	—	—	1	—	—	—	—	1
1977	—	—	—	—	—	1	—	1
1978	—	—	3	—	—	—	—	3
1979	—	—	—	—	—	—	—	0
1980	—	—	—	1	—	—	3	4
1981	—	—	1	—	1	—	2	4
1982	—	—	1	—	1	—	3	5
1983	—	—	1	—	—	—	1	2
1984	—	—	3	—	1	—	2	6
1985	—	2	2	—	—	1	2	7
1986	—	—	—	—	1	—	—	1
1987	—	1	—	—	—	—	1	2
1988	—	—	—	—	1	—	2	3
1989	—	1	1	—	1	—	—	3
1990	—	2	1	—	2	—	1	6
1991	—	2	2	—	4	—	1	9
1992	1	2	1	1	—	—	—	5
1993	1	2	—	—	—	1	3	7
1994	—	1	—	—	2	1	—	4
1995	—	3	1	—	—	—	—	4
Total	2	18	27	2	14	4	23	90

[a]IL = illness, DC = dependent calf, CA = capture, EN = entanglement, WC = watercraft collision, SH = shot or speared.

evident, including (in order of highest first): Fajardo and Ceiba, Bahía de Jobos, Toa Baja, Guayanilla, Cabo Rojo, and Rio Grande to Luquillo (Figure 2).

Seasonal and Temporal Distribution

The first case recorded was in March 1864, and the last record studied was on 15 July 1995. This does not include early accounts by settlers of the use of manatees as food (Fernández de Oviedo y Valdéz 1526, de Acosta 1590, Fewkes 1907, Cabanillas 1972). The three historical records from the 1860s were of animals caught by fishermen to be exported for captivity by the Austrian Counsel to Puerto Rico (Mignucci-Giannoni 1998).

There has been a general increase in the number of cases reported each year, with a steep increase during the past 20 years. Over 79.8% of all records occurred in the past two decades (Figure 4). The proportion of cases reported between 1975 and 1995 assigned to five-year blocks was not even, with 9.0% of the cases occurring between 1975 and 1979, 26.9% occurring between 1980 and 1984, 19.2% occurring between 1985 and 1989, and 44.9% occurring between 1990 and 1995. Overall, reported mortality cases increased an average of 9.6% a year (SD = 16.9%), but from 1990 to 1995, the increase averaged 8.3% each year (SD = 3.5%). A lower rate of increase was observed in 1994 and 1995 with 4.9% and 4.7% increase, respectively.

The long-term trend of increased reporting of events in the study area does not necessarily relate to an increase in the death rate of manatees, but may be an artifact of increased interest, knowledge, and dedication of the public and government agencies to report stranding events in the study area. Furthermore, the increase observed from 1990 to 1995 corresponds to the interest and commitment of scientific institutions and universities to the study of these events, in cooperation with government agencies and parallel to a proactive education campaign to inform the public of the status,

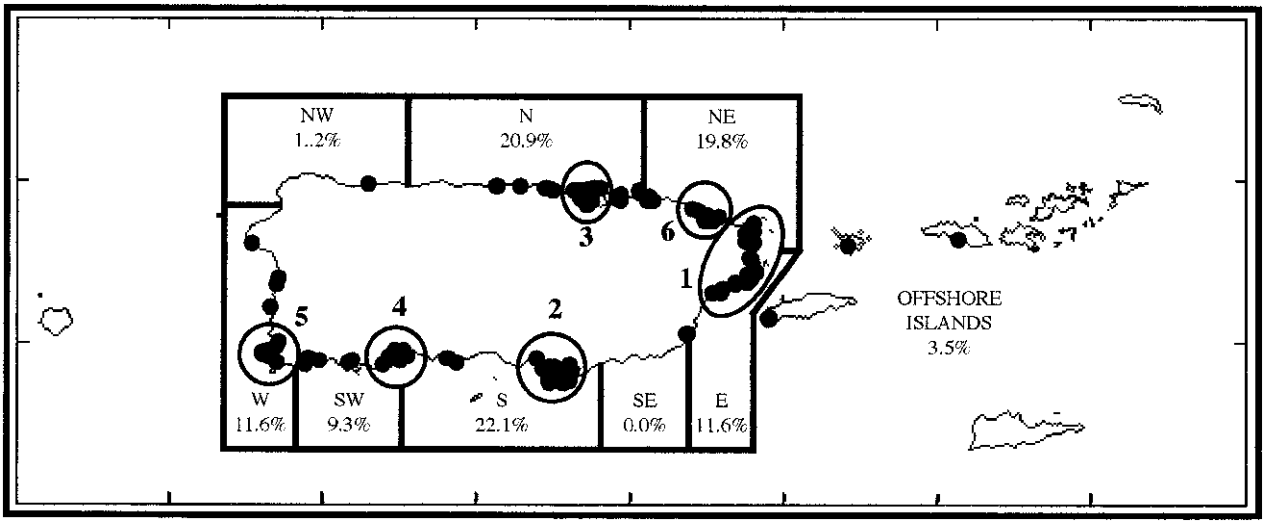

Figure 3. Distribution of documented manatee mortality in Puerto Rico. Dots represent death records, large circles represent clusters of high incidence of mortality.

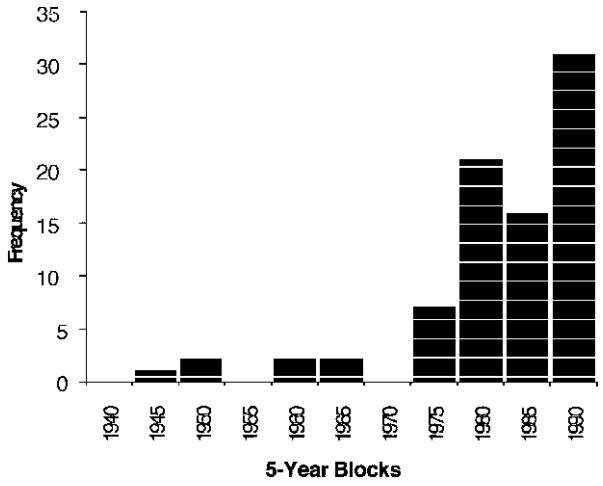

Figure 4. Increase of documented manatee mortality in Puerto Rico by five-year blocks.

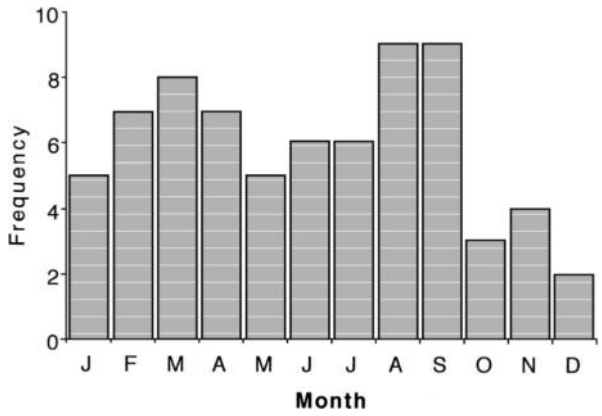

Figure 5. Temporal distribution for documented manatee mortality in Puerto Rico.

conservation efforts, and need to report sightings and strandings of this endangered species.

Thirty percent of the reported cases occurred during the summer, while 26% occurred during the spring, 25% during the fall, and 19% during the winter. This contrasts with the seasonal pattern of manatee deaths in Florida, with higher numbers in the winter (39%), and relatively even numbers in the spring (23%), summer (20%), and fall months (18%) (Ackerman and others 1995). The monthly temporal distribution showed a slight bimodal pattern, with peaks from February through April and in August and September (Figure 5). The seasonality for natural-caused mortality cases was even. Captures of manatees were more common in March and October, but also occurred throughout the year. The seasonality of deaths caused by collisions with watercraft was evenly distributed throughout the year.

Gender and Age/Size Class

Sex was not determined for 53.3% of the cases. When sex was determined, males constituted 51.2% and females 48.8% ($N = 43$), which was consistent with the sex ratio found in Florida manatees (52.9% males: 47.1% females) (Ackerman and others 1995). This slight variance from parity may be because gender is easier to confirm in males, especially in moderately decomposed animals in which the penis is often distended and exposed. Experience in determining the sex of manatees also may have an effect, as undeter-

mined gender reports declined from 66.7% (1864–1989) to 31.4% from 1990 to 1995, when a coordinated effort by trained prosectors was established. During the latter period, parity was observed in males and females.

Overall, age/size class was not determined for 36.3% of the cases. Of those in which a class was assigned ($N = 58$), 44.8% were adults, 5.2% were subadults, and 50.0% were calves. The latter differs from age/size class ratios for Florida manatee carcasses (33.2% adults, 40.3% subadults, 26.5% calves) (Ackerman and others 1995). When analyzing gender and age/size classes, it is of interest to note that more of the dead calves were females (52.4%) than males (47.6%). In contrast, in both subadults and adults, males were more numerous than females, contrary to what Ackerman and others (1995) found in Florida manatees, in which more females were found than males for the adult and subadult categories. Most of the subadult deaths in Florida relate to winter weather (O'Shea and others 1985), something that does not occur in the tropical island of Puerto Rico.

Three age groups were evident from 22 animals aged by histology of the tympanic bullae: dependent calves and juveniles (0–3 years old, $N = 7$), adults (9–17 years old, $N = 8$), and older animals (22–28 years old, $N = 7$). One female, 25–26 years of age, was observed to be pregnant, which supports Marmontel's (1995) conclusion that manatees reproduce into old age. The oldest manatee ever recorded was a 59-year-old, 362-cm female from Florida (Marmontel 1995).

The smallest animal measured was a 100-cm male from Guánica, which was killed in a boat collision. The next smallest was a 102-cm, 16.8-kg female, which, based on the clinical history of the animal, most probably was born prematurely. A calf measuring 80 cm was determined to be an aborted fetus. The average size of calves in the 0-age category was 118.4 cm ($N = 16$, range 100–152 cm). Weights of calves ranged from 16.8 kg in one of the smallest animals (102 cm, female), to 31.8 kg in a 129-cm male. Total body lengths of 1-year-old animals averaged 208.0 cm ($N = 3$, range 206–210 cm). Of interest is the case of a 2 to 3-year-old, 174-cm female, indicating the possibilities of dwarfism, as has been reported for two manatees in Colombia (Millán-Sánchez and others 1995). Two orphaned calves rescued and raised in captivity since they were approximately 1–2 weeks of age (Mignucci-Giannoni 1998) reached their expected first birthday at 171 and 198 cm in length, respectively. One reached its second birthday at about 230 cm in length, and at about 2.8 years of age, measured 238 cm. These two manatees grew at an average rate of 0.14 cm/day and 0.28 kg/day until the age of 2. Growth in both calves occurred in spurts, similar to that of human children and other animals.

Adults ranged between 253 and 366 cm, with an average of 302.3 cm ($N = 21$). Females appear to attain larger sizes at an earlier age (9–16 years of age) than males, but old males (22–27 years of age) were on average larger than females of the same age. A 12-year-old, 300-cm female was found to be carrying a 72-cm male fetus before dying from a collision with a boat. Another female, 25 years old, 300 cm in length, also killed by a boat, was pregnant with a 1.5-cm embryo. Embryonic developmental abnormalities were found in a calf which exhibited ectodactyly in both flippers, a congenital malformation previously reported for manatees in Florida by Watson and Bonde (1986).

Causes of Death

It was possible to assign predominant cause of stranding categories in 67 of 90 of the cases (74.4%). The majority of the identifiable cases were due to human interaction (52.2%), while 22.2% were due to natural causes. Natural-caused mortalities were assigned mostly to the dependent calf category (90.0%), with the remaining 10.0% due to illness. One manatee death was diagnosed as cardiac failure. Human-related mortalities were due to direct captures (57.5%), watercraft collisions (29.8%), animals being shot or speared (8.5%), and accidental entanglement (4.2%).

Between 1990 and 1995, cause of death categories were different from the historical causes. The majority of the cases were due to human interaction (45.8%), 39.9% were due to natural causes, and in 14.3% of the cases the cause of death could not be determined. During these years, natural-caused events were assigned to the dependent calf category (85.7%) or to the illness category (14.3%). Human-related deaths were due to watercraft collisions (50.0%), direct captures (31.3%), animals being shot or speared (12.5%), and accidental entanglement (6.2%). Watercraft collisions included both power boats and jet-skis. Jet-ski-caused mortalities were determined by a combination of examining the head trauma, the history of the case, and circumstancial evidence. In all of the deaths due to watercraft collision, the animals died from the impact, not from propeller cuts. While we have observed in Puerto Rico both live and dead manatees scarred by propeller cuts, no dead manatees were observed with fresh, open cuts, as has been documented for Florida. In the watercraft collision category between 1981 and 1995, 57.1% of the animals were calves. This percentage increased to 62.5% between 1990 and 1995. Excessive speed, not propellers, seems to be the underlying death-causing factor in watercraft collision for manatees in Puerto Rico, affecting especially calves that have probably not learned how to avoid vessels. Although ingestion of debris was not

Table 2. Comparisons between Florida[a] and Puerto Rico in manatee cause of death

Cause of death category	Florida, 1974–1995		Puerto Rico 1974–1995		Puerto Rico 1990–1995	
	N	%	*N*	%	*N*	%
Natural	952	36.7	19	24.1	14	39.9
Dependent calf	557	21.5	17	21.5	12	34.2
Other natural	395	15.2	2	2.6	2	5.7
Human related	839	32.4	39	49.3	16	45.8
Watercraft collision	644	24.8	14	17.7	8	22.9
Flood gate	118	4.6	0	0.0	0	0.0
Other human related	77	3.0	25	31.6	8	22.9
Undetermined	802	30.9	21	26.6	5	14.3
Total	2593		79		35	

[a]Florida data provided by Florida Department of Environmental Protection and USGS Sirenia Project.

found as a cause of death in manatees, one orphaned calf rescued by the CSN expelled pieces of green plastic bags in its feces. Its mother was reportedly killed by fishermen.

Comparisons of mortality data from Puerto Rico and Florida (provided by the Florida Department of Environmental Protection and USGS Sirenia Project) are shown in Table 2. Similarities were found in proportions of natural causes categories between 1990 and 1995. Proportions of dependent calf deaths were equal in Puerto Rico and Florida between 1974 and 1995, but during the 1990–1995 period they were higher in Puerto Rico.

Overall, human-related categories differed, with Puerto Rico having a higher proportion. The latter is due to hunting in Puerto Rico. Watercraft mortalities were overall slightly higher in Florida than in Puerto Rico, although recently, Puerto Rico's proportions are reaching similar proportions as in Florida. Other human-related causes (i.e., capture, gunshot, accidental capture), were proportionally higher in Puerto Rico than in Florida, and although they have decreased, still constitute 22.9% of all deaths in Puerto Rico. Flood gate mortalities were not reported for Puerto Rico. Proportions of the undetermined category were similar since 1974, but they have recently decreased with time in Puerto Rico.

Management and Conservation Implications

Carcass Salvage and Mortality Studies

Evaluation and recommendations to improve the carcass salvage program and mortality research fall into three areas: identification of organizational and logistical problems, long-term recommendations on basic responses to future events, and short-term recommendations on immediate actions.

Logistical problems were encountered when dealing with manatee mortality events in Puerto Rico. For example, in some cases, it took too long to process and close a case. In others, there was a lack of coordination, were participants at times responded immediately, but at others were lagging. In a number of instances, loss of valuable and needed data was evident because of several factors. These included delays in reporting and responding, the animal was in an advanced state of decomposition, the case was not of interest to a particular participant, improper equipment or poor working conditions precluded conducting a thorough *postmortem* examination; or a lack of training or availability of an easy-to-follow protocol. Lack of funds to finance *postmortem* exams, laboratory analysis, coordination, and time for curating parasites, histopathology specimens, and osteological collections were also a problem. Lack of a feedback process to inform participants of the results of mortalities in their area also caused difficulties in the development of the research.

Long-term recommendations can be summarized as follows: (1) continue the mortality and stranding monitoring program; (2) continue associated education and public awareness campaigns; (3) find financial support to cover basic costs of equipment, supplies, salaries, maintenance of facilities, and laboratory analysis; (4) develop parallel scientific studies taking advantage of the availability of carcasses to study and document basic biology and life-history parameters of the species; and (5) meet at least once a year with program participants and government officials to review and evaluate program achievements and problems.

Short-term recommendations on immediate actions that should be taken in order to continue the program in a more efficient and effective manner, and thus aid in reducing human-related mortality can be outlined as follows: (1) train participants regularly, through seminars and written material, especially participants who will be in the first-line of action (i.e., rangers and wildlife refuge managers); (2) increase effort in areas of poor coverage (i.e., southeastern and northwestern Puerto Rico); (3) offer feedback from the program's center to regional participants; (4) improve the computerized database by processing cases faster and completing all data fields in old and new cases; (5) standardize a protocol for salvage and necropsy, especially in the collection of parasites, tissue, samples, stomach contents, genetics, hematology, organ weights, morphometrics and total body weight, age analysis, osteological collection, and assessment of physical and sexual matu-

rity; and (6) establish and initiate collection protocols for bacteriology, virology, and toxicology.

Manatee Conservation and Management in Puerto Rico

If manatees are to survive in Puerto Rico, the development of a strategic plan to significantly reduce human-related mortalities and obtain baseline data on the biology and life history of the manatees in this area is crucial to their conservation and proper management. This plan should incorporate strategies that will help to facilitate the following actions:

1. Address manatee hunting and conduct law enforcement operatives to reduce hunting substantially. Law enforcement should also assess and control boat and jet-ski speed in designated manatee areas, as well as establish guidelines for manatee watching in Puerto Rico.

2. Continue to monitor human-induced and natural mortalities, and prepare for catastrophic mortality events (oil spill, red tide, etc.).

3. Establish and run media campaigns, addressing public involvement in the conservation of manatees. The campaigns should also address specific conflict-use groups (fishermen, boaters, jet-skiers) as well as government officials, school children and the general public through a lecture program in specific areas. These campaigns should include production and distribution of educational materials for the use of school children, fishermen, boaters, and the general public, including the development of an Internet web site.

4. Continue or commence research activities in the following areas: inventory of sighting data and stranding/mortality data; assessment of population abundance through continued aerial surveys and boat surveys; assessment of genetic diversity; assessment of habitat use, through the use of sighting data, radiotelemetry and photoidentification techniques; assessment of human and nonhuman user conflicts in certain areas of shared use; assessment of migration and movement patterns, using radiotelemetry and photo-identification techniques; and inventory of opportunistically collected life-history parameters, including food habits (as in Mignucci-Giannoni and Beck 1998), age determination, reproduction status, parasitology (as in Mignucci-Giannoni and others 1999a,b), and biomedical parameters (blood chemistry, hematology, immunology, etc., as in Montoya-Ospina 1994, Jiménez-Marrero and others 1998).

5. Continue paraveterinary assistance, treatment, and care of stranded, ill, injured, or orphaned manatees. Establish and carry-out reintroductions of rehabilitated animals, following established protocols, especially for orphaned calves and injured manatees.

6. Establish in Puerto Rico an intergovernmental office for manatee management that will coordinate involved agencies with the following activities: review and update the above-mentioned strategies and programs; update, further develop, and implement cooperatively the Puerto Rico Manatee Recovery Plan (Rathbun and Possardt 1986); establish cooperative agreements to conduct the strategies and programs outlined herein; and search for funding opportunities to support programs.

The development of a unified, strategic and cooperative recovery plan for manatees in Puerto Rico would not only facilitate appropriate assessment of mortality and strandings, but would also begin to aid in the reduction of mortalities due to human activities. The first step is to assess what is happening to the population in terms of mortality and their present status through continued research and scientific documentation, but decreasing the rate of human-related mortality for the species only can be done through education and a proactive, not reactive, management and conservation plan. This recovery plan should include law enforcement, mortality assessment, scientific research, rescue, and rehabilitation and cooperative inter- and intra-agency agreements.

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