Manatee Population Status Working Group's (MPSWG) Recommendation of Population Benchmarks To Help Measure Recovery

RECOMMENDED POPULATION BENCHMARKS

The Manatee Population Status Working Group developed the following population benchmarks to assist in evaluating the status of the Florida manatee for reclassification to threatened status. In each of the four regions of the Florida manatee population (Northwest, Southwest, Atlantic, and Upper St. Johns River):

1. the average annual estimated rate of adult survival is at least 94%, with statistical confidence that the rate is not less than 90%;
2. the average annual percentage of adult females with calves during winter is at least 40%; and
3. the average annual rate of population growth is at least 4%, with statistical confidence that the rate is not less than 0 (no growth).

The MPSWG recommended that estimates of the benchmark statistics (survival, reproduction, and population growth rate) be determined over a minimum of a 10-year time period, and that no significant downward trend be detectable in these parameters, before FWS considers reclassification of the Florida manatee from endangered to threatened status. The MPSWG did not propose delisting criteria, as specific, quantitative habitat criteria have yet to be developed.

Table 4. Published population benchmark values for each region.

Region	Percent Survival	Proportion of Females with Calves	Percent Growth
Northwest	96.5 (95.1 - 97.5)[a] (1982 -1993)	.431 (1977 - 1991)	7.4 (1978 - 1991)
Southwest	unknown	unknown	unknown
Upper St. Johns River	96.1 (90.0 - 98.5)[a] (1978 - 1993)	.407 (1979 - 1993)	5.7 (3 - 8) (1978 - 1991)
Atlantic	90.7 (88.7 - 92.6)[a] (1985-1993)	.423 (1979 - 1992)	1.0 (1985 - 1991)

[a] 95% Confidence Interval

Data Sources: **Percent Survival** - Langtimm, O'Shea, Pradel, and Beck 1998. **Proportion of Females with Calves** - Rathbun, Reid, Bonde, and Powell, 1995 (Northwest); O'Shea and Hartley, 1995 (St. Johns River); and Reid, Bonde, and O'Shea, 1995 (Atlantic). **Percent Growth** - Eberhardt and O'Shea, 1995.

METHODS FOR DETERMINING THE POPULATION BENCHMARKS

Criterion A: average annual adult survival estimates, is based upon a mark-recapture approach, using resightings of distinctively marked individual manatees (Langtimm et al. 1998; see p. 11 for further details). Using open population models, adult survival probabilities were estimated for manatees in the Northwest, Upper St. Johns River, and Atlantic regions of Florida. After using goodness-of-fit tests in Program RELEASE to search for violations of the assumptions of mark-recapture analysis, survival and sighting probabilities were modeled with Program SURGE. Statistically robust population models with explicit assumptions will continue to be the basis for estimation of this benchmark.

Criterion B: average annual percentage of adult females with calves, is also based upon resightings of distinctively marked individual manatees. Ongoing development of multi-state models that account for misclassification of breeders and non-breeders will improve the accuracy of regional estimates of productivity. Efforts are also being made to develop a statistically valid method for estimation of a confidence interval for this benchmark.

Criterion C: average annual rate of population growth, is based upon a deterministic population model (Eberhardt and O'Shea 1995). Parameters in the model were primarily derived from life history information obtained through resightings of distinctively marked individual manatees in the Northwest, Upper St. Johns River, and Atlantic regions. It is a simple, 2-stage (calves and adults) model that does not incorporate stochasticity (variability in survival and fecundity rates caused by changes in environmental, demographic, and genetic factors). Future models of population growth rates will undoubtedly incorporate more stages (e.g., juvenile and subadult year classes) and stochasticity. New analyses of life history data (obtained through both carcass salvage data and resightings of known individuals), will undoubtedly improve parameter estimates and reduce uncertainty in modeling results.

BASIS FOR THE POPULATION BENCHMARKS

The benchmarks were based on published estimates of survival, reproduction, and population growth rate (Table 1). Adult survival is the most influential factor determining manatee population dynamics (Eberhardt and O'Shea 1995; Marmontel et al. 1997; Langtimm et al. 1998). Since there is currently no method for determining juvenile survival rates, the MPSWG included a reproduction benchmark. Manatee population growth is less sensitive to changes in reproductive rates than adult survival rates (Marmontel et. al. 1997); however, the average proportion of females with calves over long time spans (at least 10 years) is remarkably consistent across regions (O'Shea and Hartley 1995). The MPSWG concluded that changes in reproductive rates could be a useful indicator of manatee population status, but recognized that a relatively high level of variation in reproductive rates among years requires that a period of at least 10 years be used to estimate this parameter.

Survival rates are estimated from resightings of known individuals in the photo-identification catalog, using adults only (at least 5 years of age), resighted between December and February each year (Langtimm *et al.* 1998). Survival rates for three regions (the Northwest, Upper St. Johns, and Atlantic) were estimated using state-of-the-art statistical methods (Langtimm *et al.* 1998). The target is an adult survival rate of at least 94%, that is, at least 94 of each 100 adult manatees survive from one year to the next. This benchmark is less than the estimated survival rates (96%) in two regions (the Northwest, Upper St. Johns), and higher than the lowest estimated survival rate (91%) in the Atlantic region. The lower bound of the 95% confidence interval should be greater than 0.90 (95% certainty that survival rate is actually greater than 0.90).

Similarly, reproductive rates were estimated from resightings of known individuals in the photo-identification catalog, using adult females only (at least 5 years of age), resighted between December and February of each winter (O'Shea and Hartley 1995, Rathbun *et al.* 1995, Reid *et al.* 1995). The target is 40% of known adult females seen with calves in winter each year (1^{st} or 2^{nd} year calves). The target level has been reached in all three regions (the Northwest, Upper St. Johns, and Atlantic) for which adequate data exist to determine reproductive status of adult females (Table 2). The similarity across regions in the average proportion of adult females observed with calves in winter (43%, 41% and 42%, respectively) suggests that Florida manatees may have achieved a maximum level of reproduction (O'Shea and Hartley 1995).

The population growth rates for each region were calculated using a population model that incorporated estimated survival rates for adults, subadults, and calves, and reproductive rates (Eberhardt and O'Shea 1995). The target is a population growing at 4% per year, which is below the estimated growth rate for the Northwest and Upper St. Johns regions (Table 2). There is a one-to-one correspondence between adult survival above 90% and population growth rate (Eberhardt and O'Shea 1995). Thus, an adult survival rate of 94% corresponds to an annual population growth rate of 4%. In addition, 4% is mid-way between 0 and 8% growth, and 8% is likely to be the maximum manatee population growth rate through internal recruitment. Eberhardt and O'Shea (1995) estimated an annual growth rate of 7.4% for the Crystal River. Without any human-related deaths, this population could almost certainly attain a growth rate of 8%.

The proposed benchmark for population growth (4%) is based upon the results of the Eberhardt and O'Shea (1995) deterministic population model. These authors did not attempt to estimate confidence intervals for two of the three regions for which they estimated population growth rates (Northwest and

Atlantic), and used two different methods to estimate (relatively large) confidence intervals for the growth rate of the Upper St. Johns region. There is clearly uncertainty in their model results. Additionally, they did not attempt to account for the effect of environmental variability over time on population trend. It is essential either to be conservative in selecting a minimum growth rate benchmark, as in selecting 4%, or to require a high degree of statistical confidence that the average growth rate is not lower than 0 in all regions. The latter alternative will require development of new models that include statistically robust methods for estimating confidence intervals.

Research Plan to Determine and Monitor the Status of Manatee Populations

The success of efforts to develop and implement measures to minimize manatee injury and mortality depends upon the accuracy and completeness of data on manatee life history and population status. Population data are needed to identify and define problems, make informed judgments on appropriate management alternatives, provide a sound basis for establishing and updating management actions, and to determine whether or not actions taken are achieving management objectives.

MANATEE POPULATION STATUS WORKING GROUP

The interagency Manatee Population Status Working Group (MPSWG) was established in March 1998. The group's primary tasks are to: (1) assess manatee population trends; (2) advise the U.S. Fish and Wildlife Service (FWS) on population criteria to determine when species recovery has been achieved; and (3) provide managers with interpretation of available information on manatee population biology. The group also has formulated strategies to seek peer review of their activities. The working group should continue to hold regular meetings, refine recovery criteria, annually update regional and statewide manatee status statements, and convene a population biology workshop early in 2002, analogous to the one held in 1992.

STATUS REVIEW

Following the Population Status Workshop in 2002, FWS will conduct a status review of the Florida manatee. The review will include: (1) a detailed evaluation of the population status of the species; (2) an evaluation of existing threats to the species and the effectiveness of existing mechanisms to control those threats, particularly with respect to the five listing factors identified under the Endangered Species Act of 1973, as amended (ESA); and (3) recommendations, if any, regarding reclassification and additional and/or revised recovery objectives, criteria and tasks to deal with remaining threats.

LIFE HISTORY PARAMETERS AND POPULATION TREND

Many manatees have unique features, primarily scars caused by boat strikes. When carefully photographed, these features can provide a means of identifying individuals. **Photographs of distinctively-marked manatees** collected by researchers in the field are compiled in a database begun in 1981 by the U.S. Geological Service Sirenia Project (USGS-Sirenia) with support from the Florida Power and Light Company (FPL). Since its inception, the database has been expanded greatly and improved. It is now a photo CD-based computerized system, known as the Manatee Individual Photo-identification System (MIPS), that utilizes digitized images and PC-based search technologies. The Florida Fish and Wildlife Conservation Commission's (FWC) Marine Research Institute (FMRI) and Mote Marine Lab (MML) now assist in maintaining portions of the database.

It is essential to maintain the photography efforts of the USGS-Sirenia, FMRI, and MML to ensure that vital information on manatee sightings, movement patterns, site use and fidelity, reproductive histories, and related databases remain current for further analyses of survival and reproductive rates. Photos routinely should be collected in the field, especially at the winter aggregation sites, according to standardized protocols for data collection and coding by all cooperators. Annual collection of photographs is essential, as the loss of feature information for individuals in one season could result in an inability to recognize the individual in subsequent years, and potentially compromise the value of the database. Efforts to gather photographic documentation of known females should be continued and expanded to the Southwestern region (Naples through Ten Thousand Islands and the Everglades).

One of the most important parameters for estimating trends in population status is age-specific survival. Photographs documenting sightings of individually-identifiable manatees can be used to estimate minimum ages of manatees in the database and **annual survival rates**. Data on manatees overwintering at specific sites (e.g., Crystal River, Blue Spring, and the warm-water discharges on the Atlantic Coast) are extensive. Analyses using mark-resighting modeling procedures to estimate annual survival rates at these sites have been completed through 1993. Analyses to update these estimates and add additional survival estimates for sites in Southwest Florida (Tampa Bay to the Caloosahatchee River) are underway.

Dead manatees previously identified by photographic documentation must be noted in the database before sight-resighting analyses are undertaken. It is crucial that carcasses continue to be photographically documented and those images distributed to managers of the photo-ID databases, to enhance the accuracy and precision of survival estimates.

Concurrently with photography of individual manatees, information on the **reproductive status of each manatee** (e.g., calf associated with female) should continue to be collected whenever possible. Minimum ages of documented manatees and information such as age at first reproduction, calving interval, and litter size can be determined either during photo-documentation or by timely examination of the database. Long-term studies of reproductive traits and life histories of individual females provide data on age-specific birth rates and success in calf-rearing. The relative success of severely- and lightly-scarred females in bearing and rearing calves should be determined.

Information and tissue samples should continue to be collected from all carcasses recovered in the **salvage program** to determine reproductive status. Resulting estimates of reproductive parameters complement information obtained from long-term data on living manatees and will help to determine trends and possible regional differences in reproductive rates.

Paternity cannot be established in wild manatees without the ability to determine family pedigrees. This information is needed to determine if successful reproduction is limited to a small proportion of adult males, which has important implications for the **genetic diversity** of the Florida manatee population. By continuing the development of nuclear DNA markers, pedigree analysis can be applied to the growing collection of manatee tissue samples. Pedigree analysis also would greatly improve our knowledge of matrilineal relationships and female reproductive success. Identification of factors associated with successful breeding by males is important in assessing reproductive potential in the wild and in captivity.

Aerial surveys provide information on the proportion of calves which may provide insights on reproductive trends when a long time-series of surveys have been conducted by one or relatively few individuals in the same geographic regions. Calf counts from such surveys should be continued (particularly the state-wide surveys conducted by FMRI since 1991, the power plant surveys sponsored by FPL since 1977, and the Crystal/Homosassa River surveys conducted by FWS since 1983). The results should be compared to those obtained by photo-ID methods (particularly for the Crystal/Homosassa River wintering group).

Passive Integrated Transponder (PIT) tags should be inserted under the skin of all manatees captured during the course of ongoing research or rescues. All manatees that are recaptured, rescued, or salvaged should be checked for PIT tags, and identification information should be provided to FMRI. By comparing data on manatee size, reproductive status, and general condition between time of tagging and recovery, one can increase the amount of information obtained on life history parameters. This technique is particularly useful in identifying carcasses, which is very important in obtaining accurate survival estimates. Methods for checking for PIT tags reliably on free-swimming manatees should further be developed and tested. When the latter work shows promise, plans should be developed for re-examining the utility of PIT-tagging manatees of certain age classes (juveniles and subadults) or in specific areas where photo-ID is not a feasible way to re-identify individuals. This research should include estimates of sample sizes required to determine population traits, such as survival and reproductive rates.

POPULATION STRUCTURE

Information on population structure can be obtained through the carcass salvage program, the

MIPS database, and telemetry studies. This information is important for the development of realistic population models.

Collection of tissue samples from salvage specimens and from living manatees at winter aggregation sites, captured during research, or rescued for rehabilitation should continue. Continued genetic analysis through collaborations with state and federal genetics laboratories may reveal greater population structure than has been demonstrated thus far (i.e., a significant difference between east and west coasts, but not within coasts). Such research will improve our ability to define regional populations and management units. Stock and individual identity for forensic purposes ultimately will be possible. Analytical techniques recently developed for identifying the structure of other marine stocks also should be investigated.

To aid in characterizing population structure, life history information (e.g., sex and size class) should continue to be collected concurrent with photographs to augment similar information collected from other sources (e.g., carcasses and telemetry). Long-term patterns of fidelity to winter aggregation sites and summer ranges, as well as movement among sites, also can be documented.

Radio-tracking has provided substantial documentation of seasonal migrations, other long-distance movements, and local movements that reveal patterns of site fidelity and habitat use. In Brevard County, for example, a large group of manatees overwinters in the Indian River, using two power plants for thermal refuge, and another group travels south to Palm Beach and Dade counties, using several power plants for refuge along the way. While these two groups are not entirely mutually exclusive, many individuals consistently display the same pattern each year, in timing and distance of moves as well as destinations. Such information is needed from other regions, particularly Southwest Florida, in order to develop management strategies for all significant subgroups within the regional population, however transitory they may be.

The **salvage program** yields important information on the manatee population sex ratio and proportion of age classes (adult, subadult, juvenile, and perinatal) within each cause-of-death category. Annual changes in these proportions may indicate increases or decreases in certain types of mortality, and thus should be considered as part of the weight of evidence that supports (or rejects) a downlisting decision. Ear bone growth-layer-group analysis should be continued to determine more exact ages of dead manatees, particularly those that have a known history through the photo-ID or telemetry studies, or received PIT tags. Although the age structure of the carcass sample is biased toward younger animals, opportunities may occur to document better the natural age structure within specific regions because of age-independent mortality events.

DISTRIBUTION PATTERNS

Shifts in manatee distribution over time may interfere with our ability to assess accurately regional population trends. Changes may occur in response to human activities, such as modifications of warm-water discharges, enforcement of boat speed regulations, or restoration programs, and because of natural events, such as hurricanes or red tides. Efforts to document manatee distribution through aerial surveys, photo-ID, and telemetry should continue, particularly at important wintering sites, areas of high use, and poorly-studied regions. The validity of the four regional subpopulation designations should be periodically re-evaluated, as they may change over time.

As discussed above, **photographs documenting individual manatees** are important to provide information on life history parameters, population trends, and population structure. Such photographs are also important to provide information on fidelity to winter and summer sites, high-use of and seasonal movements among sites. These photos should continue to be taken at aggregation sites primarily in Florida, but also opportunistically at other sites in the Southeastern United States. Photo-ID efforts recently were initiated in the Ten Thousand Islands region, and should be continued and expanded to other sites in Southwestern Florida.

As appropriate and possible, local and regional **aerial surveys** should be undertaken or continued to improve information on habitat use patterns and changes in distribution. Documentation of changes in distribution at power plants will be particularly important when changes in warm water availability occur.

Telemetry research has proceeded as a series of regional studies with tracking efforts concentrated in different areas in different years. Multi-year studies have been completed for the Atlantic coast and Southwest Florida from Tampa Bay through Lee County, and research findings have been summarized in manuscripts currently undergoing peer review. Verified high quality satellite telemetry location information, with descriptive meta data, will be added to the Marine Resources CD-ROM produced by FMRI. Areas not well-studied, such as the Everglades or where anticipated changes are likely to impact manatees, will be targeted for future research.

POPULATION MODELING

Population models are mathematical representations of the underlying biological processes that control population dynamics. In order to be useful in describing the true behavior of population growth, existing models must be evaluated and improved continually. The underlying assumptions of models, the importance of parameters used in the models, the accuracy and uncertainty of the parameter estimates, the relationships of the parameters, and the appropriateness of the mathematics implemented in the models need to be evaluated critically. Comparisons also need to be made between predicted outcomes from the models and estimates or indices of population trend from other modeling efforts or other data sets.

Eberhardt and O'Shea (1995) developed a deterministic population model using estimates of mortality, reproduction, and survivorship to calculate estimates of population growth rates for three subpopulations of manatees. They considered this a provisional model requiring further development and modification. Steps should be taken to continue to improve this model and to develop more complex models incorporating additional life history information and which reflect better our understanding of the processes involved in population dynamics. Examples of additional population parameters that most likely will be needed in future models are stochastic variation in survival and reproduction rates, genetic population structure, and movement of individuals between regional subpopulations.

To construct valid models, accurate **estimates of population parameters** are required. Where estimates of model parameters need to be developed or improved, other relevant tasks should be modified or strengthened. Because parameters can vary over space and time and such variation affects population growth rates, emphasis should be placed on **estimating variance** and 95% confidence intervals along with developing best estimates of particular population parameters.

It is important for those **developing manatee population models** to coordinate their activities and to interact directly with research biologists who have collected manatee life history data or who are very familiar with manatee ecology. Biologists will understand better how models were derived, and the modelers will obtain feedback on the reasonableness of their assumptions and interpretation of their results. Interaction with management also is needed to help focus the questions addressed by present and future modeling efforts. For example, FWS wants to know if modelers can estimate the number of manatee deaths that can be sustained per region, while still allowing population stability or growth to be achieved. The coordination and interaction of all players will lead to the adaptive development of newer and better models that meet the needs of manatee biologists, policy makers, and managers. The multi-agency MPSWG is best positioned to track research developments, link important players, and provide one level of peer review and evaluation. Peer review from internal and external sources is essential to such evaluations.

Uncorrected aerial survey data do not permit statistically valid population estimation or trend analyses. However, models to correct for some of the inherent bias and uncertainty have been developed, and these efforts should be continued. Methods to correct for various types of visibility bias in surveys should be developed. Standard procedures for survey teams involved in annual statewide surveys need to be developed and implemented. Use of strip transect aerial surveys make it possible to use survey data to detect regional population trends, e.g., in the Banana River and perhaps in Southwest Florida between the Ten Thousand Islands and Whitewater Bay. Strip transect surveys should be continued on an annual basis in the Banana River, and their feasibility should be investigated in remote coastal areas of Southwest Florida. To the extent possible, surveys should be designed to estimate accurately a minimum population number.

As manatee habitat requirements are documented and recovery criteria are identified (based on habitat needs), it will become possible to **link regional population and habitat models and estimate optimum sustainable populations for regions and subregions**. Integration of population and habitat information is essential to understand the implications of habitat change before negative impacts on manatee population trends can occur. The Population Status and Geographic Information System (GIS) working groups should meet jointly on an annual basis to coordinate their activities and progress. Reports of these meetings should be distributed to all agencies and interested parties involved in manatee recovery efforts.

The manatee salvage/necropsy program is fundamental to **identifying causes of manatee mortality and injury**. The program is responsible for collecting and examining virtually all manatee carcasses reported in the Southeastern United States, determining the causes of death, monitoring mortality trends, and disseminating mortality information. Program data help to identify, direct, and support essential management actions (e.g., promulgating watercraft speed rules, establishing sanctuaries, and reviewing permits for construction in manatee habitat). The program was started by FWS and the University of Miami in 1974 and was transferred to the State of Florida in 1985.

The current manatee salvage and necropsy program is administered through FWC 's FMRI. The major program components are: (1) receiving manatee carcass reports from the field; (2) coordinating the retrieval and transport of manatee carcasses and conducting gross and histological examinations to determine cause of death; (3) maintaining accurate mortality records (including out-of-Florida records); and (4) carrying out special studies to improve understanding of mortality causes, rates, and trends. The carcass salvage program also has permitted scientists to: (1) describe functional morphology of manatees; (2) assess certain life history parameters of the population; and (3) collect data on survival of known individuals. Program staff also coordinate rescues of injured or distressed manatees. To implement the salvage program, FWC maintains a central necropsy facility called the Marine Mammal Pathobiology Laboratory (MMPL), located on the Eckerd College campus in St. Petersburg. FWC also has three field stations on the east coast situated in Jacksonville, Melbourne, and Tequesta, and one field station on the west coast at Port Charlotte.

To improve the program, FWC is hosting a series of manatee mortality workshops to review critically its salvage and necropsy procedures and methods. These workshops: (1) establish and improve "state-of-the-art" forensic techniques, specimen/data collection, and analyses; (2) identify and create projects focusing on unresolved death categories; (3) prepare for and assist with epizootics; (4) generate reference data on manatee health; and (5) generate suggestions for attainment of a "healthy" manatee population. In addition, FMRI personnel are urged to move forward with models based on life history and mortality data, and process improvement is being implemented to expedite data dissemination.

Georgia Department of Natural Resources, South Carolina Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, Texas Marine Mammal Stranding Network, University of North Carolina at Wilmington, and others help to coordinate carcass salvages and rescues in other Atlantic and Gulf coast states. Mortality information collected from these efforts needs to be centralized and should be kept in the mortality database maintained by FWC. FWS and FWC should provide assistance to these manatee salvage and rescue programs through workshops, providing equipment and assistance when possible.

While it is believed that most dead manatees are found and reported to the salvage program, an unknown proportion are unreported. Annual manatee carcass totals, therefore, under-represent the actual number of deaths, indicating the need to **improve carcass detection, retrieval, and analysis**. Decomposition, increased in part by delayed carcass retrieval, reduces the ability to assign cause of death in some cases. To estimate the number of unreported manatee carcasses, studies should be done on carcass detection and reporting rates. Studies focusing on carcass drift, rate of decomposition, and how decomposition affects necropsy results should be conducted. Periodic peer reviews should take place on necropsy methods, data recording and analysis, and documentation of tissues collected. Representative samples should be archived with appropriate national tissue banks. Workshops such as the FWC Manatee Mortality Workshop should continue to be conducted to strengthen collaborative research and information sharing. Partnerships with other agencies and process analysis of carcass retrieval protocols should be ongoing in order to improve efficiency.

Collisions between manatees and boats is the largest known cause of manatee mortality, both human and non-human related; in the late 1990s, watercraft-related deaths constituted at least 25% of the total known annual mortality. Therefore, it is essential to **improve the assessment and understanding of manatee injuries and deaths caused by watercraft**. Under-reporting of watercraft mortality may occur because individuals may not die immediately but rather may develop complications resulting from injuries sustained by boats; such deaths are difficult to attribute to watercraft.

Benchmarks have been established for survival, reproduction, and population growth.

Longitudinal studies should be established to examine the effect of boats and boating activity on these parameters. Investigations of the characteristics of lethal compared to non-lethal injuries and causes should be developed using data from carcasses, photo-ID records, and characterizing healing in rescued injured animals. Investigations on lethal and non-lethal injuries also should attempt to characterize size of vessels, relative direction of movement of vessel, and propeller vs. blunt trauma statistics. Research on mechanical characteristics of skin and bones should be developed to obtain a better understanding of the effects of watercraft-related impacts. Regional studies are needed to characterize boating intensity, types of boats, boating behavior, and boating hot spots in relation to manatee watercraft-related mortality.

Increasing numbers of manatees in the Northwest region of Florida may lead to increasing numbers of animals killed by watercraft. However, such population increases would not explain the recent increase in the percent of mortalities related to watercraft. In addition, this explanation cannot be used for areas where the number of manatees is stable or decreasing. The available data suggest that on average in 2000, collisions with watercraft killed a manatee every 4.6 days. However, these data may underestimate the number of manatee mortalities. More effective diagnosis of watercraft-related injuries and mortalities is important for describing the extent and nature of the threat posed by watercraft. Mortality workshops are intended to improve our ability to diagnose watercraft-related mortalities more effectively on both fresh and decomposed carcasses.

Prevention of such injuries and mortalities is the goal. **Research is needed to address the causes of watercraft mortality and the effectiveness of management actions**. Importantly, such research also should investigate the effects of sublethal injuries and stress occurring as a result of boating activity. Injuries and stress may: (1) lead to reductions in animal condition and reproductive success; (2) cause animals to abandon habitat important for foraging, reproduction, or thermal regulation; or (3) impair immune system function thereby increasing the vulnerability of animals to disease, pollutants, or toxins. Thus, indirect or secondary effects of boating activity also may impede population recovery in ways that have not yet been assessed.

Studies are underway to **identify and evaluate adherence to manatee speed zone restrictions through statewide boater compliance studies**. The following should be continued and assessed: (1) the frequency of boater compliance with posted manatee speed zone restrictions; (2) the degree of boater compliance with posted manatee speed zone restrictions; (3) the levels of compliance among boat classes, seasonally, and temporally; (4) changes in compliance resulting from different enforcement regimes; and (5) changes in compliance resulting from different signage. Underlying sociological factors that affect compliance also should be investigated.

MML recently completed a **study that characterizes the intensity and types of boating**

activities in Southwest Florida. Similar studies should be conducted at selected locations around the state, with emphasis on areas where boat-related mortality of manatees is highest.

MML, FWC, and others are **investigating reactions of manatees to boats**. Preliminary information indicates that manatees perceive boats, but may, under certain circumstances, react in ways that place the animals in the path of, rather than away from, the boats. Additional studies of manatee responses to boats and vessel acoustics are needed. Indirect deleterious effects of shallow-draft or jet boats that can disturb manatees and cause them to move to boating channels or interrupt normal behaviors need to be studied. An evaluation of spatial and temporal factors associated with risk to manatees (i.e., proportion of time manatees are exposed to vessels relative to depth, habitat, and manatee activity) should be conducted.

In the 1970s, Odell and Reynolds described the extent to that flood control structures killed manatees in southeastern Florida. In response, the South Florida Water Management District modified the way that the structures operate, to determine if this change would mitigate the problem. The problem, however, continues to exist, and it involves flood control structures and navigational locks located throughout the state. The U.S. Army Corps of Engineers and various flood control agencies (among others) have devoted considerable time and money to possible solutions, but mortality in the structures was the second highest ever in 1999 (15 manatees died, accounting for approximately 5% of the total deaths during this year). **Research is needed to continue to assess manatee behavior leading to vulnerability around these structures**, as well as operational or structural changes that can prevent serious injury or death of manatees.

Presently, pressure-sensitive strips are being installed on vertical lift structures, and acoustic arrays are being installed on navigational locks. Efforts continue to understand better how and why manatees are killed by structures. The MMPL will associate forensic observations obtained at necropsy with specific characteristics of the structure that caused the death. Continued testing and improvement of manatee protection technology is encouraged.

Commercial fishing is not a major culprit involved in manatee mortality, unlike the case with most other marine mammals. Commercial fishing accounts for far fewer manatee deaths than do either collisions with boats or entrapment in water control structures. Nonetheless, manatees are killed by shrimp trawls, hoop nets, monofilament entanglement, hook and line ingestion, and crab pot/rope entanglement, indicating the need to **improve the evaluation and understanding of injuries and deaths of manatees caused by commercial and recreational fishing**.

Since the introduction of Florida's ban on the use of commercial nets in inshore waters in July

1995, manatees have been exposed to fewer opportunities to become entangled in nets. Because of the net ban, however, some former commercial net fishermen switched to crabbing using crab pots. Probably as a result of this increased number of crab pots, rescues of manatees entangled in crab pot lines have more than tripled since 1995. To reduce the increasing numbers of fishing gear entanglements by manatees, a multi-agency Manatee Entanglement Task Force has been established, focusing on creating changes in data collection protocols, potential technique/gear modifications, innovative tag designs, entanglement research, gear recovery/clean-up, and education/outreach efforts. Research on rates of entanglement, types of gear involved, and geographical and temporal changes in rates and types of entanglements should be developed. Studies on behavioral characteristics of manatees contributing to entanglement should be pursued. Hubbs-Sea World Research Institute currently is studying how manatees become entangled. Research on the amount of marine debris in inshore waters should be conducted, particularly where there are high levels of manatee entanglement. Programs to remove marine debris and recycle monofilament line also should be encouraged and continued.

Tests for several types of man-made compounds and elements have been conducted on manatee tissues. Although no known death or pathology has been associated with toxicants, some concentrations of contaminants have caused concern. Over time, concentrations of chemicals found in manatees from early studies have changed, possibly as a result of the regulation of chemical use. Such changes highlight the need to monitor tissues for chemical residues. In addition, survey studies provide insight into the presence of different or new compounds in the environment. While a broad range of tests have been conducted, there needs to be a greater focus on endocrine disruptor compounds. These compounds can alter reproductive success and have a dramatic effect on population growth.

By definition, **natural causes of mortality** are not directly anthropogenic and thus not easily targeted by management strategies. However, some aspects of natural mortality may be influenced by human activities. These activities include but are not limited to: (1) sources of artificial warm water; (2) nutrient loading; and (3) habitat modification.

Cold stress- and cold-related death are both factors contributing to manatee deaths. Acute cold-related mortality is related to hypothermia and metabolic changes which occur as a consequence to exposure to cold. Cold stress is related to the amount of cold exposure, nutritional debt, age and size of the animals, and time; cold stress can last as long as several months before the individual dies. The syndrome was originally described based upon the gross internal appearance of carcasses, combined with age of the animal (e.g., recently-weaned) and time of year (late winter to early spring). More recently, the appearance of skin lesions, not unlike frostbite, have been associated with cold stress, although the presence of these lesions is not considered to be a definitive indicator. Research continues to focus on critical cold air and water temperatures that affect manatee physiology (particularly as it pertains to acute cold- and cold stress-related mortality). To provide important clues as to how manatees deal with cold temperature, future research should study behavioral adjustments to cold (e.g., directed movement to warm-water refuges, time budget during cold periods, and surface resting intervals during warm spells). Research identifying the manatee's anatomical and physiological mechanisms for heat exchange are important to understanding the biological limitation of the species. Ancillary research should include identification of natural warm-water sites, because a growing population of manatees may be seasonally-limited by overcrowding at the larger well-known warm-water refuges.

In Florida, there are many species (approximately 20) of marine alga that can produce harmful **naturally-occurring biotoxins**. These toxins have the potential to cause massive deaths of fish, fish-eating predators (e.g., birds and dolphins), some species of sea turtles, and manatees. Many of the toxins also affect humans after they consume contaminated fish or shell fish (although human deaths are rare). One biotoxin (brevetoxin) has been the suggested cause of deaths of manatees. Brevetoxin is produced by the marine dinoflagellate, *Gymnodinium breve*, and is responsible for the red tides that occur along coastal Florida. The most recent epizootic of manatees in 1996 was attributed to brevetoxin and underscores the catastrophic effect such events can have on the population; in just 8 weeks, 145 manatees died in Southwestern Florida, representing a substantial loss to the population. Research is needed to improve our ability to detect brevetoxin in manatee tissues, stomach contents, urine, and blood. At the same time, environmental detection of red tides, their strengths, and the development of retardants are necessary. More advanced immunological research utilizing manatee cell cultures may result in the development of better treatment of manatees exposed to brevetoxin as well as the development of prophylactic vaccine.

Perinatal mortality has averaged approximately 24% of the total annual mortality for the last ten years; ranging from 11% in 1981 to 30% in 1991. The category termed "perinatal" is based on a size classification and is not a true cause of death; all manatees measuring 150 cm or less are grouped into this category regardless of developmental stage. Since the developmental stage of a young manatee may have important implications in the analysis of overall deaths, the MMPL initiated the generation of a protocol to identify characteristics of specific stages within this category. The protocol includes the documentation of changes in the circulatory system which occur around the time of birth. Improved methods are needed to subdivide the perinatal category into categories of: (1) clearly fetal; (2) at or near the time of birth; and (3) clearly born. Once these categories are well-defined, analysis can ascertain the life stage subject to the greatest impact, thus allowing for the future development of appropriate management policies. Field research focusing on factors affecting calf survival should be conducted (e.g., age of mother at reproduction, behavior, characteristics of calving areas, and human disturbance).

Periodically, **unusual mortality events** occur in which large numbers of manatees die or become moribund. In 1982 and again in 1996, manatees died or became ill from inhalation and ingestion of brevetoxin (see discussion above). Spikes in mortality also occur during periods of extreme or prolonged cold. Such events represent: (1) the potential for disastrous reductions in numbers of manatees occupying certain regions of the state; (2) the opportunity to learn about manatee response to disease agents or about manatee life history; and (3) a logistic ordeal if proper steps for coordination and communication have not been taken ahead of time. Consequently, FWS and FWC have created complementary manatee die-off contingency plans (Geraci and Lounsbury 1997; FWS 1998) that have been merged into one comprehensive document (FDEP *et al*. 1998). The document contains information and guidance from the two plans together with advice and provisions outlined in the executive summary from Wilkinson (1996). Research and investigations should follow the protocols and recommendations found in the Contingency Plans. In addition, there should be ongoing collection and storage of tissues and samples from healthy and non-mortality event manatees to establish a baseline and to aid interpretation of test results obtained during a catastrophic event and for retrospective studies. Investigators should contact and work closely with other research projects monitoring and evaluating harmful algal blooms. FWC mortality workshops should continue to facilitate and develop cooperative arrangements among investigators and institutions.

FACTORS AFFECTING MANATEE HEALTH, WELL-BEING, PHYSIOLOGY AND ECOLOGY

Relatively little attention has been paid to the health and well-being of individual manatees, although factors affecting individuals ultimately influence the overall status of the population. A variety of factors go into the making of a healthy individual, and health is defined by ranges of values rather than specific ones. Scientists discuss these ranges of values in terms of biological limits. Assessment of what is outside the range of normal values is important, and to make such assessments, baseline data are needed. This generally requires multiple samples from individuals representing a range of ages, different sexes, and a variety of reproductive stages.

There is a need to determine the relatively constant internal state in which factors such as temperature and chemical conditions remain stable and therefore within a range of values that permit the body to function well, despite changing environmental conditions. Stress is part of existence, and not all stress is bad for an individual. However, a stressor can affect homeostasis and health, and thereby precipitate a chain of events that can compromise the survival of an individual. There is also a need to understand the factors underlying large-scale trends. For example, individual manatees compromised by severe injury or disease may not be able to reproduce successfully. Similarly, sublethal effects of toxicants and even the effects of nutritional, noise-related, and disturbance-related stresses can impair immune function and potentially reduce the ability of individuals to reproduce. Study plans and protocols should be developed, collaborators identified, and results published.

Blood serum is the watery portion of the blood remaining after cells and fibrin are removed. Analysis of serum permits assessment of electrolyte levels, hormones, antibodies indicative of exposure to certain pathogens, and other factors important to the health of individual manatees. Serum can be banked for retrospective analyses. Efforts should be made to develop and publish a synthesis of: (1) current knowledge of **manatee serology**; (2) ranges of values associated with manatees in various demographic groups; (3) anomalies identified in manatees via serum analyses; and (4) any remaining unanswered questions.

Major organs and organ systems have been examined by a variety of scientists over the years. The compilation of anatomical observations by Bonde *et al*. (1983) reflects the fact that early in the evolution of manatee programs, efforts were made to understand **anatomy of manatees**. Such assessments have assisted scientists performing necropsies of dead manatees to determine morphologies and pathologies. Some systems or organs have been ignored but are important to assessing manatee health; these include: (1) the lymphatic system; (2) most parts of the endocrine system; and (3) non-cerebral parts of the brain. In addition, potential changes in reproductive tracts routinely should be assessed as part of ongoing life history assessments.

Manatee histology (microscopic anatomy) has been relatively unstudied, compared to gross anatomy. However, it is of no less importance in understanding normal organ or tissue functions, as well as abnormalities thereof. Responsible agencies should respond to this important deficiency.

Although work has been ongoing to assess effects of environmental temperatures on metabolism of manatees, the relationship among temperature change, metabolic stress, onset of chronic or acute disease symptoms, and even mortality of manatees is not perfectly understood. As noted above, the relationships among manatee reproductive status, body condition, thermal stress levels, and metabolic responses to such stress remain unclear. Answers to these **thermoregulation** questions are needed urgently as the specter of decreased availability of both natural and artificial warm-water sources looms. The research should focus not only on lower critical temperatures (the cold temperatures where metabolic stress occurs), but also on the upper critical temperature.

It is unclear whether or not manatees physiologically require fresh water to drink, and it is unknown what stresses may be created when fresh water is not available. Anatomical and experimental studies have indicated that manatees **osmoregulate** well in either fresh or salt water. The extent to which manatees seek fresh water suggests that the animals prefer it to drink, and they may be healthiest when they have at least occasional access to fresh water. Managers attempting to protect resources sought by, if not required by, manatees should bear in mind that fresh water is a desirable and possibly necessary resource for healthy manatees.

Stirling *et al*. (1999) provided an important assessment of polar bear **body condition indices** and related those values to changes in the environment and in consequent availability of polar bear food. They also related changes in reproductive performance and survival of offspring with changes in female body condition. This study exemplifies the importance of long-term data regarding animal health (as assessed by body condition), reproduction, and environmental quality. In Florida, where environmental quality varies considerably over time and space, the value of such a study is enormous. Body indices research at FMRI has initiated certain measurements documenting body condition of manatees. Maintenance of this work and refinements/extensions thereof, should be continued to gain a better understanding of physiology and health of individuals and the population.

Continuous long-term monitoring of the **health histories of individual manatees** allows for documentation of an animal's health. Information should be gathered on: (1) the acquisition and severity of new wounds to facilitate research on the length of time required for injuries to heal; and (2) any effects of injuries on behavior or reproduction. Natural factors affecting the health of the population also should be monitored during the course of photo-ID studies on wild individuals (e.g., cold-related skin damage, scars caused by fungal infections, and papilloma lesions).

As discussed earlier, brevetoxin, a **naturally-occurring toxin**, has been implicated or suspected in major and minor mortality events for manatees for decades. Tests now exist to allow pathologists to assess, even retrospectively, manatee tissues for signs of brevetoxicosis. The important questions include: (1) how many manatee deaths can be truly attributed to exposure to brevetoxin over the years; (2) if red tides are a natural occurrence, how can effects of red tides on manatees be reduced or mitigated; (3) would changes in human activities (i.e., creation of warm-water refuges which lead to aggregations of manatees) appreciably change vulnerability of the animals; and (4) have human activities contributed to increased prevalence and virulence of red tides.

Inasmuch as a single epizootic event can cause 2 to3 times as many manatee deaths as watercraft causes annually, gaining a better understanding of the issue is vital and urgent. Development of cell lines and testing of manatee tissues would represent an extremely useful approach. In particular, preliminary results indicate that exposure to brevetoxin reduces manatee immune system function. Further study of the immune system will define levels of concern and will help to identify when rehabilitated manatees are ready for release into the wild.

Other natural toxins have affected marine mammals (e.g., saxitoxin) and may represent another potential problem for manatees. Exposure of cultured cells of manatees to saxitoxin and assessment of the responses of those cells, would be useful.

To date, the only efforts to assess levels of **toxicants** in manatees have involved some organochlorines and a few metals. This situation is typical of toxicological work for marine mammals in general (O'Shea 1999; Marine Mammal Commission 1999). These studies demonstrate that a few metals occur in high concentrations in manatee tissues. Testing for toxicants can be extremely expensive; thus, a carefully-constructed study plan should be developed first to address the most critical uncertainties and to make the assessments as cost-effective as possible. Some important habitats in Dade County (e.g., Miami River and Black Creek) contain sediments contaminated with trace metals and/or synthetic organic chemicals to the extent that the sediments are considered to be toxic. Sediment chemistry/toxicity testing could be used as an indicator to direct toxicant studies in these types of areas.

A **disease** involves an illness, sickness, an interruption, cessation, or disorder of body functions, systems, and organs. In other words, disease represents the antithesis of homeostasis. As previously noted, scientists need to learn the boundaries of normal structure and function before they can diagnose what is normal or diseased. This process has occurred to some degree through the necropsy program, but it needs considerable refinement. Over the years, cause of death for about 1/3 of all manatee carcasses has been undetermined; this percentage probably would drop considerably with better information about and diagnosis of manatee disease states. Planned workshops by FMRI will attempt to bring scientists conducting necropsies on manatees together with pathologists and forensic scientists working with humans and other species. This effort should be very useful as a first step in an ongoing process of refinement.

Nutritional characteristics of manatee food plants and the importance of different food sources for different manatee age and sex classes in various regions are understood poorly. Such information is needed to help assure that adequate food resources are protected in different areas of the population's range. Ongoing studies should be completed to identify manatee food habits and the nutritional value of different aquatic plants important to manatees. In addition, seasonal patterns of food availability in areas of high manatee use need to be documented. Research also should address **manatee foraging behavior**, emphasizing ways that manatees are able to locate and utilize optimal food resources.

Catalogs of **manatee parasites** were prepared two decades ago (Forrester *et al*. 1979). A recent description of parasites for cetaceans (including manatees) in Puerto Rico also was published (Mignucci-Giannoni *et al*. 1998). Since degrees of parasitic infestation may be associated with the changes in the health of manatees, assessments of changes in prevalence of parasites over time should be undertaken. Inasmuch as parasite loads are assessed, at least qualitatively, during necropsies, this should be easy to accomplish, relatively speaking.

Vision in manatees has been well studied relatively. Tactile ability and acoustics also have been assessed. Conclusions reached as a result of acoustic studies are somewhat inconsistent and controversial, especially in terms of the extent that manatees may hear approaching watercraft. Since the auditory sense of manatees appears to be vital to their ability to communicate and to avoid injury, further studies are warranted. In addition, although chemoreception has been suggested as a mechanism by which male manatees locate estrous females, chemosensory ability of manatees is virtually unknown. Studies should continue on these topics to **develop a better understanding of manatee sensory systems**.

It is clear from various lines of evidence that manatees show site fidelity, especially in terms of their seasonal use of warm-water refuges, but also in their use of summer habitat. To some extent, calves learn locations of resources from their mothers. However, the way that manatees perceive their environment, cues they use to navigate, and the hierarchy of factors they use to select a particular spot or travel corridor are all unknown. As humans continue to modify coastal environments (physically, acoustically, visually, and chemically), it would be useful to understand better how such changes may interfere with the manatee's ability to **orient and to locate or select optimal habitat**.

Relatively few studies have been directed at **manatee behavior** since Hartman's work in the late 1970s. Rathbun (1999) summarized existing information on activity and diving, foraging, thermoregulation and movements, resource aggregations, mating, social organization, and communication. He concluded that, although the manatee's herbivorous diet is perhaps the most important factor in understanding their life history and behavior, it is the least studied aspect of manatee behavioral ecology. Both field studies and controlled experiments at captive facilities are needed to document basic behaviors. This documentation will allow detection and understanding of changes in behavior that occur through changes in allocation of essential resources, such as vegetation and warm water. To date, telemetry, photo-ID, and aerial videography have been useful tools for behavioral research. New innovative approaches are needed, particularly in habitats where visibility is poor.

Captive dolphins have developed ulcers and died when subjected to excessive human activity or excessive noise (i.e., from pumps) around their enclosures. Chronic levels of **disturbance** may create stresses to manatees; certainly, manatees change their behavior or actually leave certain areas to avoid disturbance. The stress involved would be difficult to document, but if manatees move away from critically important resources (e.g., warm water in winter) to avoid being disturbed, this movement could place the animals in immediate and acute jeopardy. Buckingham *et al*. (1999) provide an interesting case study for manatees, and data exist to support problems created by disturbance for a variety of marine mammals, including animals sympatric with Florida manatees (i.e., dolphins). Sources and level of activities eliciting disturbance responses need to be characterized further.

Manatees, particularly mothers and calves, communicate vocally. Often, while vessels are still outside of visual range, manatees initiate movements as boats approach, suggesting that they respond on the basis of hearing the boats. Noise from boats or other sources may interfere with communications or provide a source of stress. Hearing capabilities have been examined through studies involving two individuals in captivity (Gerstein 1995, 1999). There is a need for further research on hearing capabilities and the **effects of noise on manatees**. In particular, it is important to determine: (1) the sensitivity of manatee hearing to the different kinds of vessels to which they are exposed; (2) the range of frequencies of importance to manatee communication; (3) the abilities of manatees to localize sound sources; and (4) the role that habitat features may play in altering sound characteristics. The levels and characteristics of vessel sounds leading to behavioral changes, including potentially vacating an area, need to be determined.

Manatee distributions have been found to be **affected by boat traffic** in at least one study, with manatees moving into established sanctuary areas during periods of heavy boat traffic (Buckingham *et al*. 1999). Factors to be investigated include types and frequency of approaches, numbers of boats, distance of nearest approach, individual variations in manatee responses to boats, influences on diurnal activity patterns and habitat use, and effects on mothers and young.

Human swimming (and to a lesser extent diving) with manatees occurs in many parts of the species' range. In a few warm-water refuges, sanctuary areas have been established for manatees to escape from contact with human swimmers, but few data from systematic studies are available to evaluate the potential **impacts of human swimmers** or the effectiveness of the sanctuaries. The specific circumstances or characteristics of human swimming, snorkeling, or SCUBA-diving that may result in changes in manatee behavior, including vacating an area, remain to be determined. Factors to be investigated include types and frequency of approaches, numbers of swimmers, distance of nearest acceptable approach, occurrence of contact, individual variations in manatee responses to humans, influences on diurnal activity patterns and habitat use, and effects on mothers and young.

Public viewing of manatees has become increasingly popular in recent years and now occurs in many parts of the species' range. Commercial operations as well as private individuals are bringing increasing numbers of people to view manatees in areas where the animals can be found predictably. The opportunity for the public to move into close proximity to the animals typically is associated with other potentially disturbing activities such as swimming, diving, boating, or provisioning. The relative benefits of burgeoning human attention as compared to potential adverse impacts on the animals have not been evaluated properly to determine the desirability of increasing or decreasing control over manatee viewing activities. Studies relating marketing and overall levels of human viewing activities to changes in manatee behavior, including vacating an area, need to be conducted. Conversely, benefits accrued to the manatees from increased viewing by the public also should be evaluated for comparison.

In many parts of the species' range, people provide food or water to manatees, in spite of regulations prohibiting such activities. A systematic evaluation should be conducted to determine if these **provisioning** activities potentially adversely affect manatees in terms of changing their behavior, placing them at greater risk from other human activities, or encouraging them to use inappropriate habitat.

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FLORIDA MANATEE CAUSE OF DEATH BY REGION (1991-2000)
ATLANTIC, UPPER ST. JOHNS RIVER, NORTHWEST AND SOUTHWEST

Manatee carcasses reported in Florida from 1991 to 2000 (FWC, unpublished data) were assigned to four regions of the state: (1) Atlantic Coast (St. Johns River and tributaries downstream (north) of Palatka); (2) Upper St. Johns River (St. Johns River upstream (south) of Palatka); (3) Northwest (Homosassa/Crystal River and north); and (4) Southwest (Tampa Bay area). The percentage of carcasses by each cause of death was calculated for each region (Tables 5-6 and Figures 17-21).

Two regions contained most of the 2,306 carcasses located state-wide (Atlantic 50%, Upper St. Johns River 2%, Northwest 5%, Southwest 43%); however, the Atlantic and Southwest regions also have the highest numbers of living manatees. Therefore, results should be viewed cautiously because percentages among causes of death can seem contradictory. Large numbers of deaths in one region in one category can make another category seem less important. A mortality event in one region can make all the other causes seem less important (smaller percentages), when actually all of the causes take on even greater importance due to the high number of deaths in a short time period.

Carcasses (n=145) from the 1996 red tide epizootic in southwest Florida were omitted from the following analysis, because this was considered to be a non-typical situation; their inclusion here would make other human-related and natural causes of death seem less important.

Causes of death varied among regions. The percentage of watercraft-related deaths was highest in the St. Johns River region (15 carcasses, 34%) and lowest in the Atlantic (264 carcasses, 24%) region. The highest number of watercraft deaths occurred in the Atlantic and in the Southwest regions (252 carcasses, 27%).

The highest percentage of flood gate and lock deaths occurred in the Atlantic (69 carcasses, 6%) and St. Johns River regions (4 carcasses, 8%), and lowest percentage occurred in the Northwest region (1 carcasses, 1%). The highest number of gate/lock deaths occurred in the Atlantic and Southwest (19 carcasses, 2%) regions. Only a few water control structures and navigational locks are present on the west coast, and percentages were lower there.

All other human-related causes of deaths combined accounted for the highest percentage of deaths in the Atlantic (40 carcasses, 4%) and Northwest regions (4 carcasses, 4%), and accounted for the lowest in the St. Johns River (0 carcasses, 0%). The highest number of other human-related deaths occurred in the Atlantic and Southwest (14 carcasses, 2%) regions.

Perinatal deaths accounted for the highest percentage of deaths in the Northwest region (32 carcasses, 33%). The highest number of perinatal deaths occurred in the Atlantic (296 carcasses, 27%) and Southwest (190 carcasses, 20%) regions.

Cold-related deaths accounted for the highest percentage of deaths in the Atlantic region (29 carcasses, 3%). The only recent large cold mortality event primarily in Brevard County during the winter of 1989-1990. Cold-related deaths were lowest in the two regions with major natural springs, the St. Johns River (0 carcasses, 0%) and Northwest (3 carcasses, 3%) regions.

Other natural causes of death combined accounted for the highest percentage of deaths in the Southwest Region (154 carcasses, 17%), and accounted for the lowest percentage in the St. Johns River (2 carcasses, 5%). The highest number of other-natural deaths occurred in the Southwest and Atlantic (112 carcasses, 10%) regions. The high number of deaths from natural causes in the Southwest region may partly reflect occasional small red tide events.

Undetermined deaths (including verified but not recovered carcasses) accounted for the highest percentage in the Southwest Region (277 carcasses, 30%), and accounted for the lowest percentage in the Northwest (20 carcasses, 20%). The highest number of undetermined deaths occurred in the Southwest and Atlantic (279 carcasses, 26%) regions. The high number of undetermined deaths in the Southwest region may be related to the high levels of carcass decomposition because of the warm temperatures and remoteness of large parts of the region (i.e., few observers to find carcasses and long travel times required to retrieve carcasses). The high percentage of undetermined causes in the Southwest makes all the other categories proportionately smaller in that region.

Deaths of adult-sized animals (276 to 411 cm total length) were summarized separately. Analysis using only deaths of adult-sized animals eliminates all of the perinatal carcasses and most of the cold-related deaths, which are mostly sub-adult manatees. Percentages of deaths, by causes, were similar among the four regions. Regions with high percentages of perinatal and cold-related deaths showed the greatest differences when adults were considered separately.

Statewide, watercraft-related deaths accounted for 39% of adult deaths, and all human-related deaths combined comprised 53% of deaths. All human-related causes combined constituted the highest percentage of deaths in the St. Johns region (14 carcasses, 64%) and in the Atlantic region (181 carcasses, 58%). The Atlantic region has the largest coastal human population of the four regions. The health of a regional population is closely tied to the adult survival rate. Therefore, it is very important that the percentages of human-related deaths be kept as low as possible.

Table 5. Manatee deaths in Florida, 1991-2000, by 4 regions and statewide. **All size classes** (FWC, unpublished data).

CAUSE OF DEATH	ATLANTIC		ST. JOHNS		NORTHWEST		SOUTHWEST		STATEWIDE	
	Number	%	Number	%	Number	%	Number	%	Number	%
Watercraft	264	24.2	15	34.1	26	26.5	252	27.1	557	25.8
Gate/Lock	69	6.3	4	9.1	1	1.0	19	2.0	93	4.3
Other Human	40	3.7	0	0.0	4	4.1	14	1.5	58	2.7
Perinatal	296	27.2	11	25.0	32	32.7	190	20.4	529	24.5
Cold-Related	29	2.7	0	0.0	3	3.1	24	2.6	56	2.6
Other Natural	112	10.3	2	4.5	12	12.2	154*	16.6	280*	12.9
Undetermined	279	25.6	12	27.3	20	20.4	277*	29.8	588*	27.2
TOTAL	1089	100.0	44	100.0	98	100.0	930*	100.0	2161*	100.0

* Omit n=145 Red Tide deaths in Southwest Florida, 1996

Table 6. Manatee deaths in Florida, 1991-2000, by 4 regions and statewide. **Adult-only size class** (>275 cm total length). FWC unpublished data.

CAUSE OF DEATH	ATLANTIC		ST. JOHNS		NORTHWEST		SOUTHWEST		STATEWIDE	
	Number	%	Number	%	Number	%	Number	%	Number	%
Watercraft	122	39.0	11	50.0	8	33.3	103	39.3	244	39.3
Gate/Lock	37	11.8	3	13.6	0	0.0	13	4.9	53	8.5
Other Human	22	7.0	0	0.0	2	8.3	6	2.3	30	4.8
Perinatal	—	—	—	—	—	—	—	—	—	—
Cold-Related	1	0.3	0	0.0	2	8.3	0	00.0	3	0.5
Other Natural	35	11.2	1	4.6	5	20.9	51*	19.5	92*	14.8
Undetermined	96	30.7	7	31.8	7	29.2	89*	34.0	199*	32.1
TOTAL	313	100.0	22	100.0	24	100.0	262*	100.0	621*	100.0

* Omit n=145 Red Tide deaths in Southwest Florida, 1996

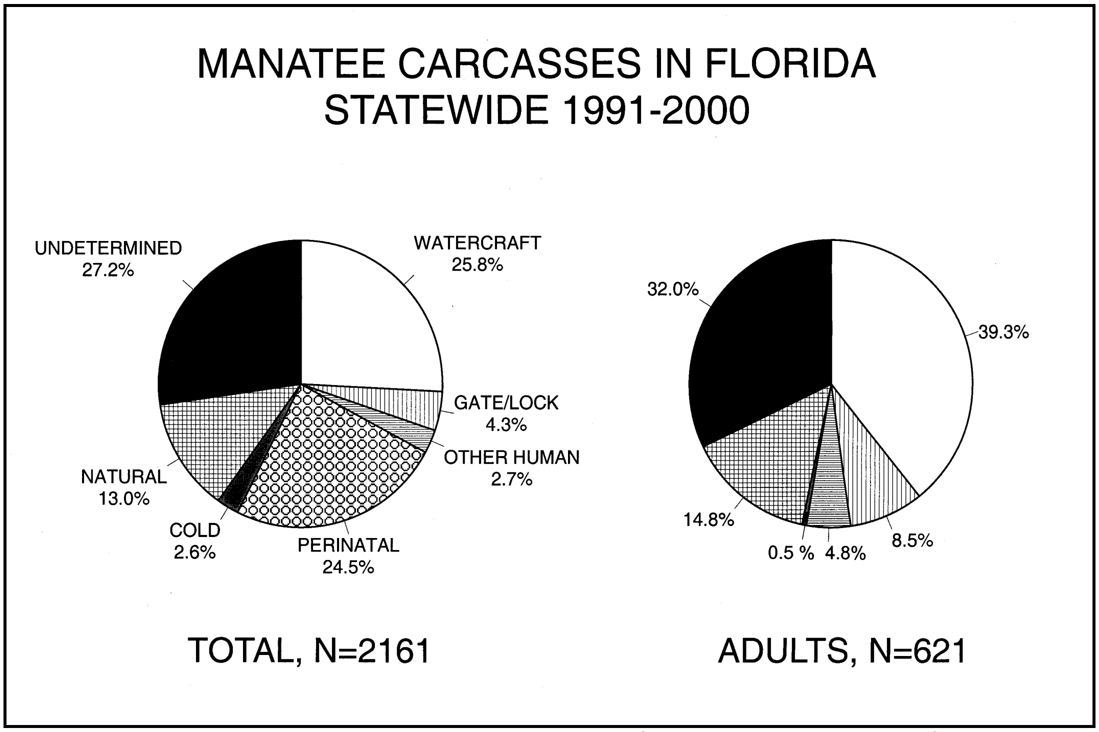

Figure 17. Manatee deaths in Florida by cause of death, 1991-2001. FWC unpublished data.

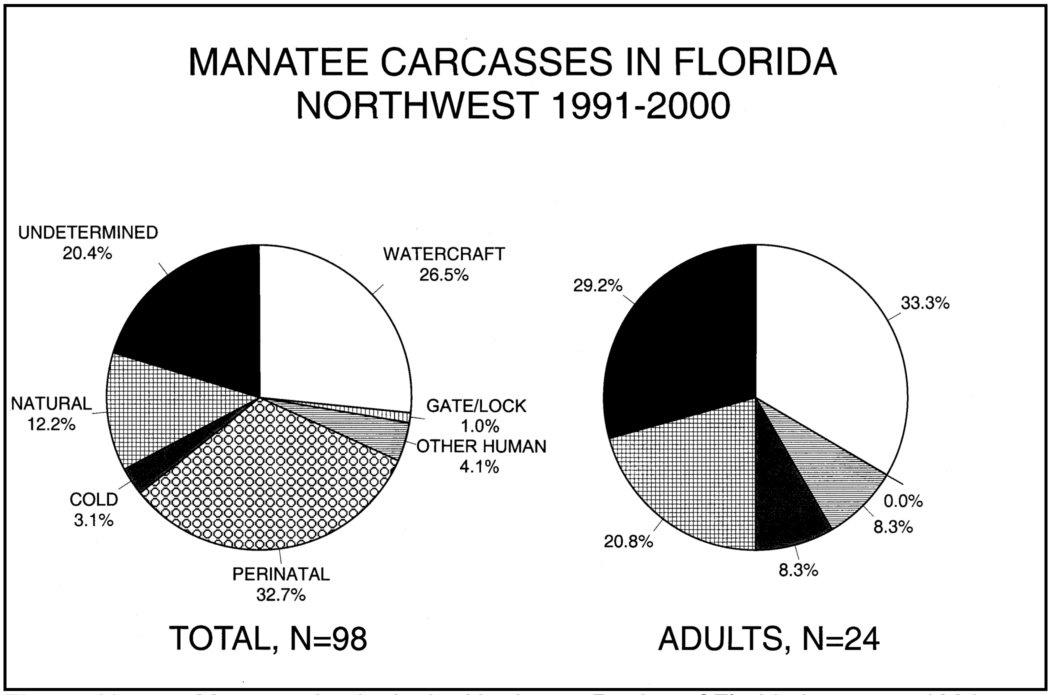

Figure 18. Manatee deaths in the Northwest Region of Florida by cause, 1991-2000. FWC unpublished data.

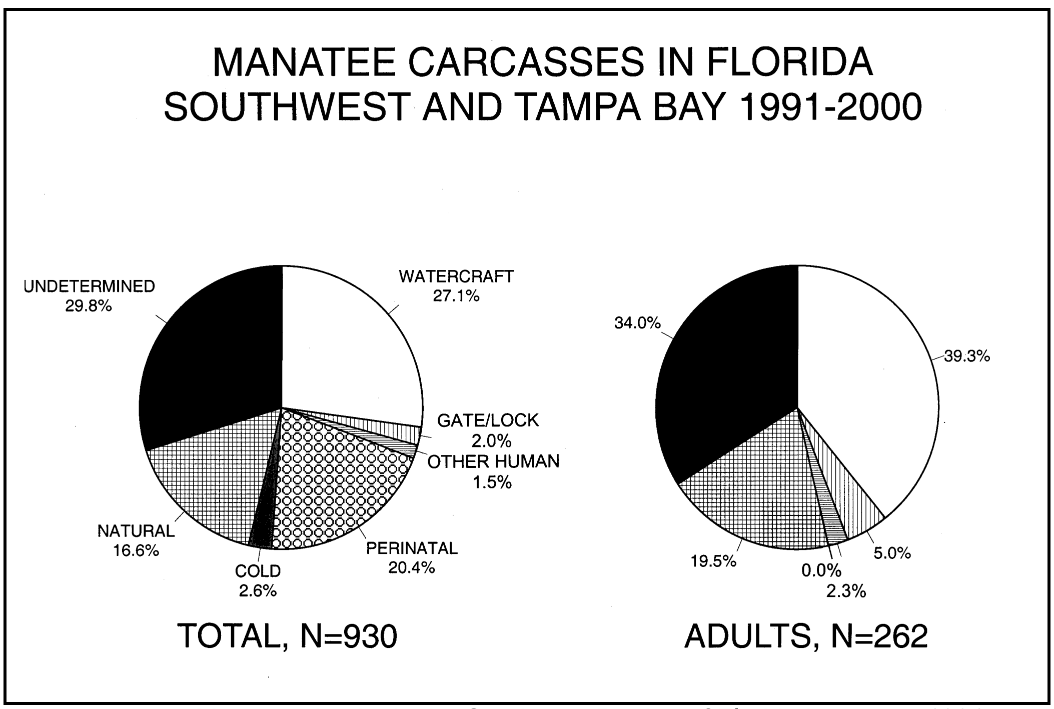

Figure 19. Manatee deaths in the Southwest Region of Florida by cause, 1991-2000. FWC unpublished data.

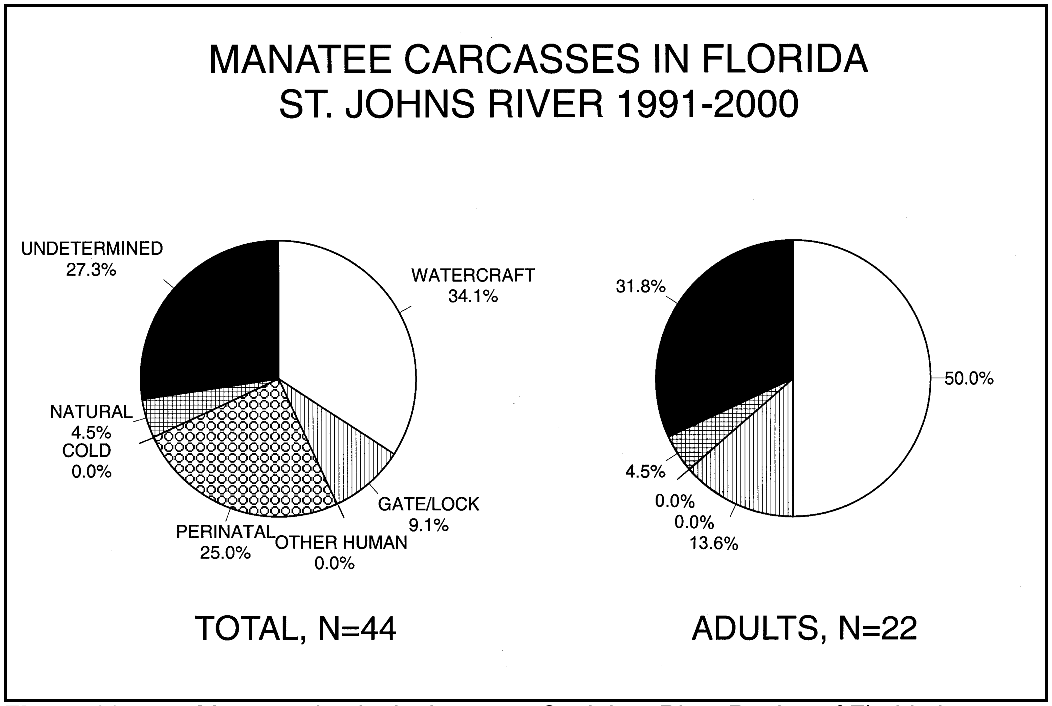

Figure 20. Manatee deaths in the upper St. Johns River Region of Florida by cause, 1991-2000. FWC unpublished data.

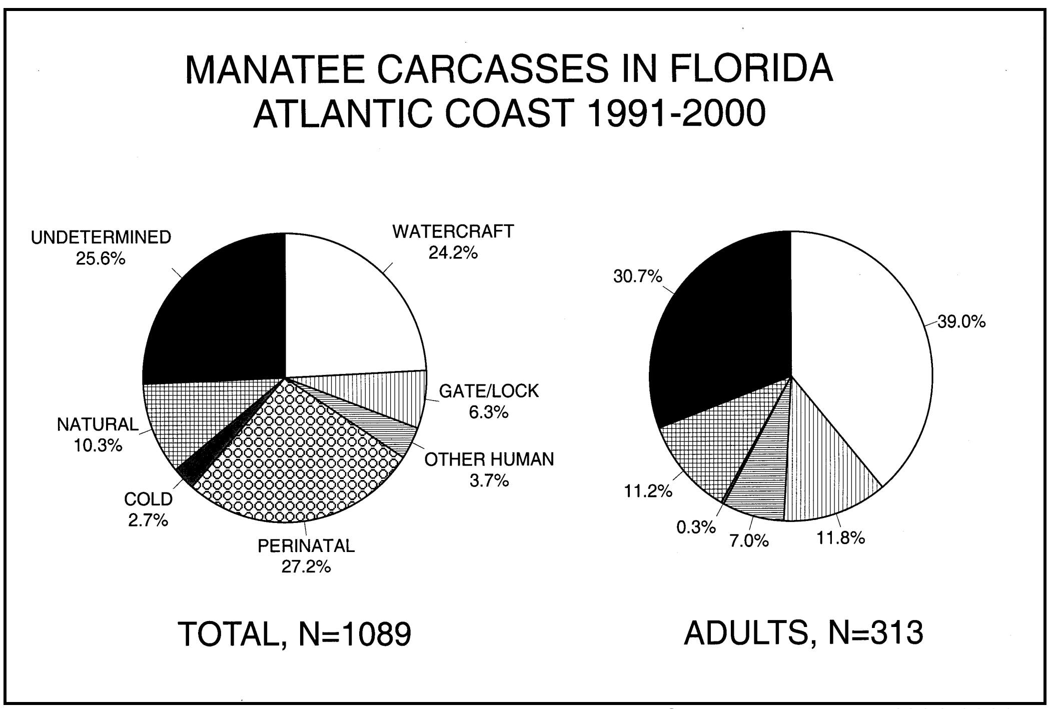

Figure 21. Manatee deaths in the Atlantic Region of Florida by cause, 1991-2000. FWC unpublished data.

FLORIDA MANATEE STATUS STATEMENT

Manatee Population Status Working Group

9 March 2001

Years of scientific study of the Florida manatee have revealed both good news and some cause for concern regarding the status of this endangered aquatic mammal, according to the interagency Manatee Population Status Working Group. The Manatee Population Status Working Group comprises biologists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, Florida Fish and Wildlife Conservation Commission, Chicago Zoological Society, and Wildlife Trust. The group's primary tasks are to assess manatee population trends, to advise the U.S. Fish and Wildlife Service on population criteria to determine when species recovery has been achieved, and to provide managers with interpretation of available information on manatee population biology.

Long-term studies suggest four relatively distinct regional populations of the Florida manatee: Northwest, Southwest, Atlantic (including the St. Johns River north of Palatka), and St. Johns River (south of Palatka). These divisions are based primarily on documented manatee use of wintering sites and from radio-tracking studies of individuals' movements. Although some movement occurs among regional populations, researchers found that analysis of manatee status on a regional level provided insights into important factors related to manatee recovery.

The exact number of manatees in Florida is unknown. Manatees are difficult to count because they are often in areas with poor water clarity, and their behavior, such as resting on the bottom of a deep canal, may make them difficult to see. A coordinated series of aerial surveys and ground counts, known as the statewide synoptic survey, has been conducted in most years since 1991. The synoptic survey in January 2001 resulted in a count of 3,276, the highest count to date. The highest previous count was 2,639 in 1996. Survey results are highly variable, and do not reflect actual population trend. For example, statewide counts on 16 and 27 January 2000 differed by 36% (1,629 and 2,222, respectively). Excellent survey conditions and an unusually cold winter undoubtedly contributed to the high count in 2001.

Evidence indicates that the Northwest and Upper St. Johns River subpopulations have steadily increased over the last 25 years. This population growth is consistent with the lower number of human-related deaths, high estimates of adult survival, and good manatee habitat in these regions. Unfortunately, this good news is tempered by the fact that the manatees in these two regions probably account for less than 20% of the state's manatee population.

The picture is less optimistic for the Atlantic coast subpopulation. Scientists are concerned that the adult survival rate (the percentage of adults that survives from one year to the next) is lower than what is needed for sustained population growth. The population on this coast appears to have been growing slowly in the 1980s but now may have leveled off, or could even be declining. In other words, it's too close to call. This finding is consistent with the high level of human-related and, in some years, cold-related mortality in the region. Since 1978, management efforts to reduce human-related manatee deaths have included strategies focused on reducing manatee collisions with boats, reducing hazards such as entrapment in water control structures and entanglement in fishing gear, and protecting manatee winter aggregation sites to reduce cold-related mortality. Managers are continually challenged to develop innovative protection strategies, given the rapidly growing human population along Florida's coasts.

Estimates of survival and population growth rates are currently underway for the Southwest region. Preliminary estimates of adult survival are similar to those for the Atlantic region, i.e., substantially lower than those for the Northwest and Upper St. Johns River regions. This area has had high levels of watercraft-related deaths and injuries, as well as periodic natural mortality events caused by red tide and severe cold. However, pending further data collection and analysis, scientists are unable to provide an assessment of how manatees are doing in this part of the state.

Over the past ten years, approximately 30% of manatee deaths have been directly attributable to human-related causes, including watercraft collisions, accidental crushing and drowning in water control structures, and entanglements in fishing gear. In 2000, 34% (94 of 273) of manatee deaths were human-related. The continued high level of manatee deaths raises concern about the ability of the overall population to grow or at least remain stable. The Manatee Population Status Working Group is also concerned about the negative impacts of factors that are difficult to quantify, such as habitat loss and chronic effects of severe injuries.

The group agrees that the results of the analyses underscore an important fact: Adult survival is critical to the manatee's recovery. In the regions where adult survival rates are high, the population has grown at a healthy rate. In order to assure high adult survival the group emphasizes the urgent need to make significant headway in reducing the number of human-related manatee deaths.