Manatee Population Ecology and Management Workshop Proceedings

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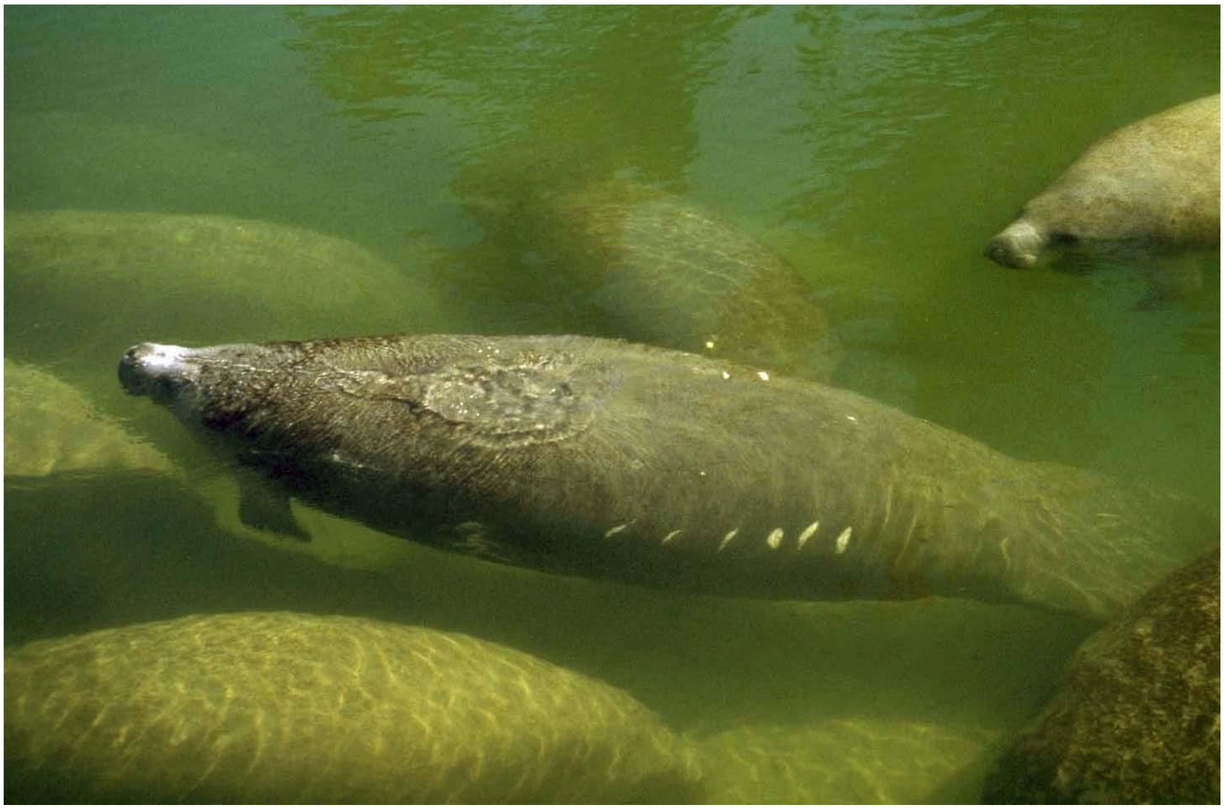

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INTRODUCTION

Information on manatee life history and the development of statistical tools to assess population trends have advanced considerably since 1978, when the first workshop was held to review aspects of manatee population biology. A second workshop was held in February 1992, with the primary goal of synthesizing existing information and integrating key life history parameter estimates into a population model (the 1992 meeting did not include managers). In 2002, the Manatee Population Ecology and Management Workshop was held in Gainesville, Florida. This workshop continued to build on the groundwork established by long-term field research and more recent modeling efforts. It addressed the information needs of managers with respect to manatee population assessment and recovery, and provided managers with tools for making the best management decisions for manatees. The U.S. Fish and Wildlife Service (USFWS), Florida Fish and Wildlife Conservation Commission (FFWCC), and other involved agencies and organizations will use information and recommendations from the workshop in their reassessment of the manatee's status as an endangered species.

In addition to status assessment, managers are confronted with a number of pressing questions for which modeling efforts could inform and assist them in evaluating management options and recovery criteria. How much mortality from boat strikes can the population tolerate and are management actions to control such mortality effective? What will be the effect of power plant shutdowns and what is the best way to manage these shutdowns? What is the manatee carrying capacity in different regions of Florida, and are we nearing it in any areas?

Whereas the last workshop focused on estimation of life history parameters for one provisional model (Eberhardt and O'Shea 1995) to address one recovery criterion (population growth rate), this workshop identified the potential application of population models to a range of biological problems and management concerns.

The workshop was held over a 2.5-day period, from 2-4 April, 2002. There were two major aspects of the workshop: *population ecology*, which focused on estimating population parameters and developing models using those parameters to understand population dynamics; and *population management*, which focused on how to use available data to address manatee management questions and issues of greatest importance at the State and Federal levels.

Following a formal presentation of management needs and research results on the first day of the workshop, four technical and two management forums were held, providing ample opportunity for the eight scientific advisors to provide comments and recommendations on both research and management issues. Managers were polled well before the workshop to determine their priorities and plan the management presentation and discussion sessions.

The goal of the workshop was to better understand and integrate the roles of research and management in achieving recovery of the Florida manatee. The specific workshop objectives were to

- **Review progress in manatee population research, and demonstrate the value of current approaches:**

- **Improve data analyses and population models for future population assessments; for example, the planned status reviews by the U.S. Fish and Wildlife Service and Florida Fish and Wildlife Conservation Commission:**

- **Promote peer review of current population research by a panel of wildlife population experts outside of the manatee research community:**

- **Make recommendations and promote collaborations for future population research:**

- **Synthesize current results in a technical report that will be made available to the public; scientific community, managers, and policy-makers; and**

- **Achieve a balanced approach to manatee conservation.**

Approximately one hundred people participated in the workshop. New data analyses were presented, and a group of scientists with expertise in wildlife population assessment reviewed the current techniques used to assess manatee population status. Participants in the 2002 workshop were a mixture of research and management biologists from agencies, institutions, and private organizations, as well as representatives from environmental and boating groups.

PANEL OF EXPERT ADVISORS

Solange Brault received her undergraduate degree in Biology at the Université de Montréal, and her M.S. degree in Biology at Université Laval, both in Canada. She received her Ph.D. at Imperial College, University of London, U.K. She did postdoctoral work at the Woods Hole Oceanographic Institution, and was then awarded a National Research Council Research Associateship Award to work on population modeling of marine mammals at the National Marine Fisheries Service's (NMFS) laboratory in Woods Hole. She is currently an Associate Professor in the Biology Department at the University of Massachusetts in Boston. She has been a member of the Atlantic Scientific Review Group since 1994, which advises the NMFS on regional issues related to marine mammal assessment. In 1996, she served on the scientific peer-review panel of the marine mammal program at the Southeast Fisheries Science Center (NOAA/NMFS). In 2000-2001, Dr. Brault was a member of the Eminent Panel on Seal Management for the Minister of Fisheries and Oceans, Canada. As a population modeler, she tries to understand the interaction of a species' life history traits (fertility, longevity, age at maturity, etc.) with its environment, including human impacts.

Daniel Goodman received a B.S. degree in Zoology and a Ph.D. in Biology, both from Ohio State University. He is currently a Professor in the Ecology Department at Montana State University in Bozeman, where he studies environmental statistics and risk analysis. His major contributions have been in the subjects of population dynamics, extinction risk analysis, data quality objectives, cost optimization in risk-based remediation, algorithms for Empirical Bayes statistical inference, and regulatory decision frameworks. Prior to his current position, he was a Full and Associate Professor in the Biology Department at Montana State University; Adjunct Professor of Biology at University of California San Diego; Assistant Professor of Population Biology at Scripps Institution of Oceanography; and Research Associate in the program on Science, Technology, and Society and the Division of Biological Sciences at Cornell University. Dr. Goodman currently serves on the Independent Science Advisory Board and the Independent Scientific Review Panel of the Northwest Power Planning Council. Previously, he served on the Scientific Committee of the International Whaling Commission; the Committee of Scientific Advisors of the U.S. Marine Mammal Commission; the Board of Trustees of the Institute of Ecology; and as a consultant to the U.S. Environmental Protection Agency Science Advisory

Board. He is a member of Phi Beta Kappa and recipient of the Woodrow Wilson Fellowship. Daniel Goodman is the author or coauthor of over 70 publications and reports.

Aleta Hohn received her B.S. and M.S. degrees from the Department of Zoology at the University of Maryland in College Park, and a Ph.D. from the Department of Biology at the University of California in Los Angeles. Her primary area of expertise is age estimation and life history of marine mammals. She has worked for the Smithsonian Institution, USFWS, and has been with the NMFS for over 20 years. During that time, she spent 10 years in La Jolla, California, studying dolphins that interact with the tuna fishery in the eastern Pacific and coastal cetaceans, particularly the harbor porpoise. She also spent 5 years in NMFS headquarters, initially helping to improve the processing of applications for scientific research permits, and then serving as Chief Scientist of the permit office. The Chief Scientist role evolved into serving as a primary contact within the National Oceanic and Atmospheric Administration (NOAA) for biodiversity, especially with regard to the Convention on Biological Diversity. Dr. Hohn moved to the NOAA Beaufort Lab in 1996 to return to research, and now leads the cetacean and sea turtle team. She served as Secretary of the Society for Marine Mammalogy for 4 years (1992-1996) and is Chair of the Scientific Program Committee for the 2003 Biennial Marine Mammal Conference. In addition to life-history studies, her current major research includes defining stock structure of bottlenose dolphins along the Atlantic coast of the U.S. applying multiple techniques, including genetics, stable isotope ratios, telemetry, and photo-identification, and evaluating the mortality of bottlenose dolphins from commercial fishing gear using surveys and stranding data.

Fred A. Johnson received a B.S. degree in wildlife resources from West Virginia University in 1978 and a M.S. degree in wildlife and fisheries science from Texas A&M University in 1981. He was hired by the (then) Florida Game & Freshwater Fish Commission in 1981, and served as its waterfowl-management program coordinator from 1985-89. In 1989 he was hired as a management biologist by the U.S. Fish and Wildlife Service and was stationed at the U.S. Geological Survey's Patuxent Wildlife Research Center. During his tenure at Patuxent, he coordinated the development of an adaptive-management program for the regulation of waterfowl harvests in the U.S. He currently is stationed in Gainesville, Florida, where he is part of an interagency effort to develop adaptive-management concepts and tools for application to a variety of wildlife-conservation problems. He has published over 30 articles on various aspects of wildlife ecology and management.

Gil McRae received a B.S. degree in Aquatic Ecology at the University of Michigan, Ann Arbor, and his M.S. degree at the University of Minnesota, St. Paul in Fisheries Science with a Minor in Statistics. He is currently a Research Administrator with the Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute, in the Ecosystem Assessment and Restoration Section. During 2001, he also served as the Interim Administrator for the Endangered and Threatened Species Section. He leads statewide scientific research programs on coral reefs, harmful algal blooms, seagrass, fish health and estuarine monitoring, supervising a staff of 57 with an annual budget of $7.4 million. He is a Special Graduate Faculty Member of the University of South Florida, Department of Marine Science. His research expertise includes statistical design and implementation of environmental monitoring programs in coastal ecosystems, multivariate statistical analysis of ecological communities, fisheries population dynamics and stock assessment, and spatial statistics and the use of Geographic Information Systems (GIS) in ecological research.

Helene Marsh received a B.S. degree at the University of Queensland and a Ph.D. at James Cook University, Australia. She is currently a Professor of Environmental Science at James Cook University. The dugong has been the major focus of her research, funded by grants totaling over

$3 million since 1990. She has published 45 papers in professional journals, 17 chapters in refereed monographs/conference proceedings, 30 papers in conference/workshop proceedings, 19 technical reports and 16 popular articles on dugongs. She also edited the proceedings of the first international dugong workshop and wrote the dugong sections of a book on Australian Marine Mammals. Dr. Marsh has been sponsored to attend international workshops on sirenians in Canada, Japan (7 times), Malaysia (twice), Papua New Guinea, Philippines, Saudi Arabia, the Netherlands, and the United States (3 times). In 1995, she was one of four invited plenary speakers at the international marine mammal conference in Orlando, Florida. More recently, she has been a plenary speaker in the Philippines, Malaysia and Japan (twice). She has been employed as a consultant to assess the status of the dugong in various countries including India, Japan, Malaysia, Palau, Papua New Guinea, and Saudi Arabia, as well as in the Northern Territory, Queensland, and Western Australia. Dr. Marsh's group of postdoctoral fellows and graduate students has studied many aspects of dugong biology including distribution and abundance, life history and reproductive biology, feeding ecology, dugong seagrass interactions, genetics and cultural significance. She was awarded a Pew Fellowship for marine conservation for her dugong research in 1998.

James D. Nichols received his B.S. degree from Wake Forest University, his M.S. degree from Louisiana State University, and his Ph.D. from Michigan State University. As a biologist at the Patuxent Wildlife Research Center, U.S. Geological Survey, he utilizes his expertise in biometrics to conduct research internationally on vertebrate population dynamics, wildlife management, and conservation. He was promoted to Senior Scientist in 1998. He was lead author of a paper published in *Ecology*, titled “Estimating transition probabilities for stage-based population projection matrices using capture-recapture data,” that received the 1993 U.S. Fish and Wildlife Service’s Best Research Paper Award, and co-authored a paper on statistical inference for capture-recapture experiments that received the George W. Snedecor Award of the *American Statistical Association*. Dr. Nichols is currently involved in projects on adaptive management and assessment of habitat changes on migratory birds, development of methods to estimate parameters associated with animal population dynamics, and determination, biological consequences, and modeling of demographic rates in declining, threatened, or endangered metapopulations.

Kenneth H. Pollock was born in Quirindi, a small town in a farming region of Northwestern New South Wales, Australia. He received a B.S. degree in Agriculture from the University of Sydney in 1968, and his Ph.D. in biometry from Cornell University in 1974. He is currently Professor of Statistics, Biomathematics, and Zoology at North Carolina State University. He was lead author on a paper that received the George W. Snedecor Award for the best paper in Biometry during 1991 and is a Fellow of the American Statistical Association. He received a distinguished achievement award from the American Statistical Association Section on Statistics and the Environment in 1994. Dr. Pollock was a member of U.S. Advisory Committee to the International Commission for the Conservation of Atlantic Tunas, 1994-1996. He has served as Associate Editor for the *Journal of Environmental and Ecological Statistics* since 1994, and for *American Statistician and Biometrics* since 2000. He has written four monographs (including one on angler survey methodology) and has published over one hundred articles in the general area of sampling animal populations.

BACKGROUND

Manatee Population Research and its Application to management Strategies and Conservation

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Introduction

Research and conservation efforts for Florida manatees (*Trichechus manatus latirostris*) have gone hand-in-hand for several decades. Hartman (1974, 1979) developed descriptions of manatee behavior, life history, and ecology that were unprecedented in terms of detail and accuracy, and that are still among the best sources of information today; at the same time, his work is also remembered because he correctly predicted that encounters with watercraft and effects of habitat destruction would continue to threaten the existence of manatees well into the future. Even before Hartman conducted his studies of manatee behavioral ecology and distribution in Florida, Moore (1956) examined the use of heated discharges at power plants by manatees in the 1950s, another persistent issue faced by conservationists and biologists in the 21st century.

Building on the efforts and insights of Hartman, Moore, Layne and others, two comprehensive programs were initiated in 1974 to study manatees in Florida (Reynolds 1999). The first was the U.S. Fish and Wildlife Service Sirenia Project, located in Gainesville, Florida. At the University of Miami, Daniel K. Odell initiated complementary studies. These two programs are exceptional, in part because they initiated studies that remain in progress today. The long-term data produced by these studies provide the scientific basis for management decisions. Specifically, scientists over the past three decades have provided long-term perspectives on such factors as survival and mortality of manatees, relative numbers of manatees using specific locations, habitat use patterns and movements of manatees, and life history parameters of recognizable individuals. Analyses of these data provide managers today with insights into a variety of issues or questions, including but not limited to the following: (1) scientific justification to manage the Florida manatee population as four different regional subpopulations (Fig. 1); (2) regional estimates of adult survival (Table 1); (3) insights into critical locations for implementation of regulations; (4) knowledge regarding reproduction and other life history parameters; and (5) models for the assessment of trends in population growth and counts.

Although the Sirenia Project and University of Miami programs were in their infancy in the late 1970s, they provided much of the scientific information used to develop the first recovery plan for manatees in Florida (U.S. Fish and Wildlife Service 1980). That plan, which was sufficiently well prepared to serve as a useful model for recovery plans for other species of marine mammals at the time (Wallace 1994), explicitly stated (page 16) that “data on manatee numbers and population trends are basic to an understanding of manatee biology and a proper assessment of management effectiveness. Accurate knowledge of changes in populations can give early insight into serious declines which may necessitate drastic corrective measures.”

The 1980 recovery plan, therefore, prescribed several types of research that would contribute to a better understanding of manatee biology and more effective conservation; these included (1) determining abundance and distribution of manatees by developing standard survey methods, conducting regular surveys, and developing mark and recapture techniques; and (2) systematic monitoring of manatees at winter refugia to assess age and gender composition, recruitment and foraging. The link between good science and effective management was quite clear in 1980 and that relationship persists to this day (Reynolds 1999; U.S. Fish and Wildlife Service 2001).

Long-term databases

Although many components of research programs to study manatee population biology are relevant to effective management, the long-term programs are especially valuable as they provide a basis for assessing changes over time in population parameters and effectiveness of management efforts. The ability to sustain programs over a period of more than 25 years requires commitment, collaboration, cooperation, and leadership. An overview of efforts to date appears in Reynolds (1999).

The primary agencies and organizations involved in scientific research that focused on population biology and ecology of manatees in Florida are the Sirenia Project (currently part of the U.S. Geological Survey, Department of the Interior), University of Miami, and the Florida Marine Research Institute (currently part of the Florida Fish and Wildlife Conservation Commission). Other organizations have contributed to the collection of important life history data, such as Florida Power & Light Company, Mote Marine Laboratory, and Save the Manatee Club.

Partly as a result of recommendations made at the first workshop on manatee population biology held in 1978 (Brownell and Ralls 1981), several long-term, population related research programs were established (O'Shea and Ackerman 1995). The four largest long-term databases deal with documentation of manatee mortalities and determination of causes of death; assessments of relative abundance through surveys; identification and resighting of individuals through photo-documentation, and telemetry.

The carcass salvage program has recovered and examined carcasses of 4,568 manatees between the time of its inception in 1974 and March, 2002, just prior to the Manatee Population Ecology Workshop. About half of the carcasses have been aged (see Pitchford this volume). This effort, which includes the collection and examination of reproductive tracts and other tissues, along with morphometric data has provided the means to assess age- and gender-specific mortality, as well as regional differences in causes of death (e.g., Ackerman et al. 1995).

Aerial and ground (including boat) surveys have been done since Hartman's efforts in the 1960s. Most of the surveys focus on counts in the winter season, when manatees aggregate at natural and artificial warm-water refugia, making them easier and more cost-effective to count. The Florida Power & Light Company has provided funds to permit regular aerial surveys around eight of their powerplants since 1976. To date, 178 such surveys have been done, providing the basis for some site-specific information on relative numbers and even trends in counts of manatees (see Garrott et al. 1994; Craig et al. 1997; Craig and Reynolds this volume). In addition, since 1991, the State of Florida's Marine Research Institute has coordinated 10 "synoptic aerial surveys" to attempt to generate as high a count as possible each winter (Ackerman 1995; this volume). Aerial surveys have also been conducted discontinuously since 1978 at Crystal River, with weekly surveys conducted in winter. Finally, individuals such as Ranger Wayne Hartley and others have counted manatees from the shoreline at Blue Spring State Park every winter since 1974. Although the unadjusted counts cannot be used to determine changes in population size, they have been useful in determining the distribution of manatees among four regions: the Atlantic Coast, the Southwest, the Northwest, and the Upper St. Johns River (Fig. 1).

Standardized, strip-transect surveys were developed to determine trends in regional manatee abundance in the Banana River lagoon during the warm season (Miller et al. 1998). This approach appears to also hold promise for the Ten Thousand Islands region of southwestern Florida, and may eventually be expanded to include the entire southwestern coast, from Marco Island through Whitewater Bay (Easton et al. 2003).

A telemetry program developed in the late 1970s by the Sirenia Project has facilitated understanding of habitat use, movements, and life histories of manatees (O'Shea and Kochman 1990; Deutsch et al. 1998; Deutsch et al. 2003). Under the direction of T.J. O'Shea and L.W. Lefebvre, Sirenia Project personnel radio-tagged and tracked 78 manatees along the east coast of Florida and Georgia from 1986 to 1998. The research objectives were to determine seasonal movement patterns, migratory behavior, and site fidelity of manatees in this region to assist in the development of effective conservation strategies. Among other important discoveries, the study revealed that manatees were remarkably consistent in their seasonal movement patterns across years and showed strong fidelity to both warm season and winter ranges (Deutsch et al. 2003).

The Florida Marine Research Institute conducted a tracking study of manatees that winter in Tampa Bay, tagging 44 manatees between 1991 and 1996 (Weigle et al. 2001). Sequential point data were transformed into probable travel routes using a GIS-based cost-path analysis. The study concluded that modeling manatee movements using this approach enhanced the ability to characterize high-use areas and travel corridors, but that telemetry data alone would not give a complete picture of the manatee group that uses Tampa Bay. They recommended that telemetry data be used in concert with aerial survey, photo-identification, and mortality information to determine the areas needed for population protection and recovery.

Figure 1. The Florida manatee (*Trichechus manatus latirostris*) population can be divided into four regional subpopulations: Northwest, Southwest, Atlantic Coast, and Upper St. Johns River. The validity of this subdivision is in part dependent upon the manatee's fidelity to specific overwintering sites that provide thermal refuge during cold periods. The major overwintering sites are either natural springs (in the Northwest, Southwest, and St. Johns River regions) or industrial effluents (in the Southwest and Atlantic Coast regions). Before the building of coastal powerplants, the historical limits to the manatee's winter range were believed to be Charlotte Harbor on the Gulf Coast and Sebastian Inlet on the Atlantic Coast.

Table 1. Published estimates of adult manatee survival, adult females with calves, and population growth rate for each region.

Region	Average Annual Percent Adult Survival	Average Proportion of Females with Calves	Average Annual Percent Population 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) [a] (1985- 1991)
Atlantic Coast	90.7 (88.7-92.6)[a] (1985-1993)	.423 (1979-1992)	1.0 (1985-1991)

[a]95% confidence interval

Data Source:

Percent Survival - Langtimm, O'Shea, Pradel and Beck, 1998

Proportion of Females with Calves - Rathbun, Reid, Bonde, Powell, 1995 (Northwest); O'Shea and Hartley 1995 (St. Johns River);

Reid, Bonde and O'Shea 1995 (Atlantic Coast)

Percent Growth – Eberhardt and O'Shea 1995

A computerized, photo-CD based program called the Manatee Individual Photo-identification System (MIPS) stores information and images for almost 2,000 individually distinctive manatees (the earliest sighting records date back to the 1960s). This database, which includes over 25,000 sighting records at the time of the Manatee Population Ecology Workshop, has permitted enhanced understanding of manatee life history parameters, as well as application of mark-recapture models to estimate survival of adults (see Beck and Reid 1995; Langtimm et al. this volume). Annual resighting rates for manatees vary across regions, but stand at 95% for the St. Johns River (thanks to the comprehensive ground survey efforts by Hartley and others noted earlier); 74% along the northwestern coast (including Crystal River); and 51% along the Atlantic coast. The effort to document, catalog, and annually re-identify individual manatees has provided considerable insight into life history parameters and other aspects of the biology of manatees in Florida. In addition, mark and recapture analyses of the photo-identification data have permitted estimates of annual adult survival probability for each "subpopulation" of manatees in Florida (Langtimm et al. 1998; Langtimm et al. this volume). Population models based on survival and reproduction estimates represent the most authoritative approach scientists and managers have to gauge trends in the status of each subpopulation.

Collectively, these long-term databases have permitted population viability analyses (Marmontel et al. 1997) and other models (e.g., Eberhardt and O'Shea 1995) to be developed. In addition, the long-term collection and archival of tissues has facilitated genetic analyses that are providing better insights about the relative discreteness of regional manatee subpopulations.

The most comprehensive genetics study conducted to date was by Garcia-Rodriguez et al. (1998) and was based on the doctoral study by the first author. She identified eight polymorphic DNA microsatellite loci for her analyses of 223 samples from manatees throughout Florida. Although there are significant genetic differences between manatees from the east and west coasts, the study detected no significant differences among manatees along either coast. The small number of alleles identified (23 in all for the 8 loci) suggested a bottleneck or founder effect, followed by breeding among related individuals. Altogether Garcia-Rodriguez et al. (1998) considered the Florida manatee population to be a single evolutionary unit, consisting of two well-defined management units on the east and west coasts of the State. Unfortunately, and despite a growing archive of tissues, little additional genetic work has been done to help address interesting biological questions or pressing management needs (U.S. Fish and Wildlife Service 2001).

Impacts of Population Parameter Studies on the Florida Manatee Recovery Plan

The cumulative contribution of the various long-term databases has helped to shape management approaches for Florida manatees and has provided a fundamental underpinning for recent recovery planning.

The goal of the most recent revision of the manatee recovery plan (U.S. Fish and Wildlife Service 2001, p. 40) is "to assure the long term viability of the Florida manatee in the wild…" To assess the extent to which that goal is being reached, the U.S. Fish and Wildlife Service wished to have "objective and measurable recovery criteria" which, if met, could trigger downlisting of manatees from "endangered" to "threatened" or actual removal of Florida manatees from the Endangered Species List. An interagency Manatee Population Status Working Group was established to assess manatee population trends, advise the Service and the Manatee Recovery Team on quantitative population recovery criteria, and provide managers with interpretation of available information on manatee population biology. The group, which held its first meeting in March 1998, had representatives from the U.S. Geological Survey, the USFWS, and the FFWCC.

The Manatee Population Status Working Group considered a variety of databases, most notably the MIPS database and resultant adult survival, reproduction, and population growth rate estimates (Table 1; Langtimm et al. 1998; Eberhardt and O'Shea 1995), as well as aerial and ground survey databases and analyses and cause of death determinations (e.g., Garrott et al. 1995; Craig et al. 1997; Deutsch et al. this volume). A statement from the Group appears as Appendix D in the latest recovery plan (U.S. Fish and Wildlife Service 2001).

The USFWS fundamentally adopted what the Working Group recommended, namely that Florida manatees could be reclassified as threatened if the following benchmarks were met at the 95% confidence level for the most recent 10-year period in each regional subpopulation (U.S. Fish and Wildlife Service 2001):

- **The average annual rate of survival of adult manatees is at least 90%.**

- **The average annual percentage of adult female manatees accompanied by first or second year calves in winter is at least 40%.**

- **The average annual rate of population growth is at least zero.**

The Service proposed these same three benchmarks be used as criteria for delisting manatees, when all are achieved for an additional 10 years after reclassification. In addition, 5 criteria related to habitat protection must be met before manatees can be delisted (Table 2) (U.S. Fish and Wildlife Service 2001).

As the Service develops a recovery plan, it must weigh scientific information, as well as other information and perspectives. As noted earlier and in different ways (e.g., Meffe et al. 1999), good science should inform management decisions, but science alone should not dictate the decisions. In this case, a number of stakeholders (not all) were very pleased that the recovery plan reflected the best available scientific information and analysis.

Ongoing and future needs

In the 1970s, many publications regarding manatees included an apology about the status of biological information on the species. As of 2003, the Florida manatee is among the best-studied marine mammals in the world, and lack of scientific data is not a significant impediment to conservation and management efforts (Reynolds 1999; Reynolds 2003). This situation does not imply there is nothing left to learn; in fact, we have much to learn as we ask new questions, or apply new techniques that allow us to ask old questions again at a higher level of resolution.

Nonetheless, scientists, managers, and laypersons must all acknowledge the limitations of science. For example, we are never likely to know exactly how many manatees exist. People must acknowledge, accept, and incorporate uncertainty into both research and management plans. In addition, application of the precautionary principle, which provides a measure of safety for living resources, should be standard practice when the best available science is applied to management decisions in the face of uncertainty (e.g., Mangel et al. 1996; Meffe et al. 1999).

In summary, we have noted the utility of population ecology research for the effective management and conservation of manatees. The creation of the Manatee Population Status Working Group facilitated the translation of scientific data into clear, objective, and measurable recovery goals. Conversely, major deficiencies exist in terms of understanding manatee habitat selection and habitat needs, as well as threats that exist to habitat (see Ragen et al. this volume). A Manatee Habitat Working Group, long recommended and overdue, was created recently by the U.S. Fish and Wildlife Service to promote coordination of scientific research on the latter topics. Information on manatee feeding, reproduction, and thermal ecology will permit optimal decision making by managers to protect and conserve habitat for manatees. Until this is done, the demographic criteria described above will provide only a partial measure of what it will take to allow Florida manatees to recover.

Table 2. Habitat tasks to reduce or remove the present or threatened destruction, modification, or curtailment of the manatee's habitat or range (Listing/Recovery Factor A). This criterion, in addition to demographic criteria, must be met in order to consider reclassification of the Florida manatee from endangered to threatened status (U.S. Fish and Wildlife Service 2001).

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Reduce or remove threats to manatee habitat or range through Federal, State or local regulations that:
• **Adopt and maintain** minimum spring flows • **Protect** a network of warm-water refuge sites • **Protect** feeding habitat associated with selected warm-water refuge sites • **Protect** other important manatee areas, such as migratory corridors, feeding areas, calving and nursing areas

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ABSTRACTS OF PRESENTED PAPERS

(Abstracts represent the status of research findings at the time of the workshop. Author affiliation information has been updated if agency name has changed).

Management

Manatee Population Research and its Application to Management Strategies and Conservation

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Since the pioneering research of D.S. Hartman at Crystal River in the mid-1960s, efforts to understand aspects of the manatee's population biology have been linked to conservation and management efforts and addressed formally in recovery plans. In addition to Hartman's work, multifaceted, long-term research programs were initiated in 1974 by the Sirenia Project, U.S. Department of the Interior, and by D.K. Odell at the University of Miami. Scientists over the past three decades have provided long-term perspectives on mortality (through a comprehensive carcass salvage network), relative numbers of manatees based on counts or estimates made at specific locations (through aerial and ground surveys), habitat use patterns and movements (via telemetry studies), and life history parameters of recognizable individual manatees (through the Manatee Individual Photo-Identification System, or MIPS). Analyses of these data have provided managers with: (1) scientific justification to manage the Florida manatee population as four different regional subpopulations; (2) regional estimates of adult survival; (3) insights into critical locations for implementation of regulations; (4) knowledge regarding reproduction and other life history parameters; (5) assessments of trends in counts; and other information. Additional valuable insights have come about through recent genetic studies and efforts to develop calibration indices for aerial survey counts at particular locations. In the most recent revision of the Florida Manatee Recovery Plan, such scientific insights provided specific quantitative recovery criteria that, if achieved, could promote reclassification of the Florida manatee from its current endangered status. However, scientists and managers must: (1) continue to extend knowledge about manatee population parameters and integrate the best science into recovery planning; (2) acknowledge, accept and incorporate uncertainty into research and management plans; and (3) develop and incorporate better knowledge of habitat issues into management efforts and recovery planning.

Assessment of Marine Mammal Population Status: A Comparison of the Mandates of Federal Laws and the Requirements of Good Management

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The answer to the question "What is the status of the Florida manatee?" depends on how one defines the term "status." The Marine Mammal Protection Act defines status of a species (or stock) as either depleted or not depleted on the basis of its current abundance relative to its optimum sustainable population range. Under this Act, status is defined on the basis of the number of individuals presently comprising the species or stock, irrespective of the condition of those individuals, their habitat, or factors that may affect the species and its habitat in the foreseeable future. In contrast, the Endangered Species Act uses multiple criteria to define status as endangered, threatened, or neither on the basis of the species' risk of extinction. An "endangered" species is one that is in danger of extinction (or in danger of becoming extinct), and a "threatened" species is one that is likely to become endangered within the foreseeable future. Thus, under this Act, status is best viewed as a projection over time, taking into account all factors that may have bearing on the species' future trends (e.g., a population viability analysis). The differing standards under the two Acts reflect, at least in part, their different management approaches--under the Endangered Species Act, species are afforded no protection until listed as endangered or threatened; under the Marine Mammal Protection Act, certain provisions, including the taking provision, apply to all marine mammals, albeit heightened protection is accorded to depleted species and stocks.

The reliability of a projection to describe status under the Endangered Species Act depends on whether the projection model incorporates the factors that will affect the species within the period of the projection, accurately describes the effects of those factors, and accurately predicts how those factors and their effects might change over the course of the projection. Examples of such factors include the age/sex structure of the population, vital parameters, availability of habitat, measures of the health and condition of animals in the population, and anthropogenic and environmental threats to the species. A projection that assumes no change from current conditions constitutes a "null hypothesis" approach to predicting future status. This approach is highly questionable for many species, but particularly for the Florida manatee as, for example, expected growth of the human population in Florida and resulting coastal development can reasonably be expected to degrade or destroy manatee habitat in the future. A more realistic "alternative hypothesis" approach would incorporate all factors that may affect the species status in the future and best possible predictions of how those factors might change over time (e.g., expected changes in manatee habitat). The utility of such status projections for conservation and management purposes depends heavily on the ability of modelers to make them as realistic and reliable as possible.

"How are the Manatees Doing?" and Other Tough Questions for Managers

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"How are the manatees doing?" is one of the most frequently asked questions by the public of managers responsible for the recovery of the Florida manatee. Although the answer may depend on which part of Florida you are considering, most people who ask the question appear interested in the short-term picture: at the end of the year, are there more or fewer manatees in Florida? Managers should recognize that this type of question is much more engaging and relevant to the public than long-term assessments more typically used in science, such as the probability of extinction in one hundred years. Many managers struggle to effectively deal with this fundamental quest for annual assessment, especially in recognition of the long-term nature of endangered species recovery. Because of difficulties in obtaining accurate estimates of manatee population size, managers have tended to use the annual death count as a proxy for an annual assessment. In the past, agencies have issued press releases that declared that certain years were "bad" for manatees, based primarily on a perception that the body count was too high. This approach is not sound science nor sound resource management. The terms "high" and "bad" have no standard of measurement. Furthermore, these terms are no longer readily accepted by an increasingly knowledgeable public. Managers need to focus on determining actual mortality, (the percentage of the population that dies annually), birth, and population growth rates.

Related to the question of how the manatee population is doing each year is another tough question facing managers: "Are manatees truly endangered?" The public is asking both Federal and State managers to reassess the official status of the manatee. The FFWCC is presently undertaking a status re-evaluation for the Florida manatee using the procedures prescribed in State Rule (68A-27.0012 F.A.C.). FFWCC staff will be preparing a preliminary biological status report and will invite public comment on that report. In addition, the commission will appoint a biological review panel with a minimum of three scientists with demonstrated knowledge and expertise pertaining to species conservation and management. We expect that the status report will be brought before the commissioners no later than the January 2003 meeting. Although the State has specific criteria to determine the level of imperilment, ultimately species status becomes a policy question in addition to a biological one. It will be difficult for scientists, policy-makers, and the public to reach consensus on how the biological information should be translated into the appropriate status classification of manatees.

Scientists need to be aware that the heightened level of public involvement in manatee issues is a direct result of management activities such as boat speed limits and permit recommendations that have had significant individual and societal impacts. Public acceptance of management strategies has become strained, in part because of the inability of scientists and managers to provide answers to seemingly fundamental questions regarding annual population change and level of endangerment. If managers are going to pursue additional regulations, they must define the current status of the population in terms that are both scientifically valid and meaningful to the public. They must also provide a clear picture of long-range goals and measurable biological criteria for recovery.

Managing Warm-water Sites for Manatees: An Adaptive Framework

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Over the last 50 years, many Florida manatees (*Trichechus manatus latirostris*) have come to rely on artificial sources of warm water, notably once-through-cooling powerplants, to meet their habitat needs in the winter. Market forces, changes in government regulation, and improvements in technology will result in significant changes in the operation and ultimately, closure, of these plants over the next three decades. Two central questions challenge managers of manatees and powerplants alike: (1) how will manatees respond to changes in the network of warm-water sites, and (2) what actions might be taken to mitigate the negative consequences of these changes? We have used the principles of adaptive management to develop a conceptual framework for this problem of management under uncertainty. Two core elements of this approach are: *a predictive model* for manatee winter distribution and use of warm-water sites that captures scientific uncertainty about manatee behavior in relation to management actions; and *a monitoring system* that provides feedback to improve the predictive model. Ideally, these elements will be used to evaluate proposed management actions, and assess their effects once implemented. Model development is currently underway, and a prototype monitoring system was initiated in winter 2001-02.

The use of Aerial Survey Based Methods and Population Models in Dugong Conservation

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Aerial surveys have been widely used to estimate the population size and density of dugongs since the mid-1980s. Aerial surveys have been conducted at large spatial scales (~30,000 km^2), typically at 5-year intervals. Even at these spatial scales, the use of aerial surveys to determine trends in abundance is confounded by the dugong's tendency to undertake large-scale movements in response to seagrass dieback events. Attention is shifting from trend estimation to techniques to estimate sustainable mortality levels. Such techniques require estimates of absolute abundance. However, there are many difficulties in obtaining defensible population estimates from aerial surveys because not all animals are detected. The probability of detecting a dugong consists of three components: the probability of sampling a particular area (transect); the probability of the dugong being available for detection (availability); and the probability of its being detected conditional upon its being available for detection (perception). We are refining the aerial survey methodology using a combination of empirical and mathematical techniques. The availability process is being improved through experiments to determine zones of detectability for dugongs in water of a range of turbidities and sea states using fiberglass model dugongs and dive profiles obtained from time-depth recorders on 15 wild dugongs. The use of a tandem team of two observers on either side of the aircraft permits the fitting of generalized Lincoln-Petersen models with the program MARK. These models allow for detection probability conditional upon availability to potentially vary by seat (mid or rear), side (port or starboard), and location of the survey as well as possible individual group covariates such as size of group, sea state, glare, distance class etc. The Akaike model selection criterion is used to pick the simplest model that explains the data adequately. We then use the generalized Horvitz-Thompson estimator based on the overall detection probability of each individual group to generate population estimates. This approach was used to estimate dugong abundance in the Torres Strait region between Australia and New Guinea, and the Potential Biological Removal Method was then used to estimate a sustainable harvest for dugongs in this region. The results indicate that the indigenous dugong harvest in Torres Strait exceeds the sustainable harvest by an order of magnitude.

Population Ecology

Trends in Manatee Mortality in Florida

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Quantitative information on causes of death is critical for identifying the key factors suppressing population growth of endangered species, and the analysis of these data is necessary for the development of effective management actions that will promote population recovery. A total of 4439 carcasses of the endangered Florida manatee (*Trichechus manatus latirostris*) have been reported from coastal and riverine waters of the southeastern United States over a period of 28 years (1974-2001). Nearly all carcasses (98.4%) were found in the State of Florida and results reported here are based on these data. The manatee carcass salvage and necropsy program was initiated by U.S. Fish and Wildlife Service researchers in 1974, in collaboration with the University of Miami, and then turned over to the State research agency (Florida Marine Research Institute) in 1986. Carcasses are reported by the public on a toll-free phone line, recovered by biologists located at field stations throughout the State, transported to the Marine Mammal Pathobiology Laboratory in St. Petersburg, and then necropsied to determine cause of death and to collect information on life history (e.g., age, reproductive status), anatomy, genetics, and histology, and to bank tissues for future analyses. Our goal has been to recover and necropsy every manatee carcass that is reported in the State of Florida; since 1974, 97.3% of verified carcasses have been salvaged. The mortality database has 109 variables for each carcass, including the following information: date, location (State, county, waterway, latitude and longitude), carcass condition, sex, estimated age, morphometrics (e.g., standard length, girth), and cause of death.

The number of reported carcasses statewide increased at an average of 5.8% per year, from 62 in 1976 to 325 in 2001; this rate has averaged 8.0% per year over the past decade (1992-2001). Deaths were attributed to the following causes between 1986-2001: collision with watercraft (25.2%), perinatal (i.e., death of newborn ≤150 cm total length not attributed to human causes) (22.6%), cold-related (i.e., from acute hypothermia or chronic cold stress) (5.2%), other natural causes (13.2%), crushing in water control structure (3.4%), other human causes (e.g., entanglement in fishing line, entrapment in culvert, ingestion of fish hook) (2.4%), and undetermined (of which there are 3 subcategories) (28.0%). Natural mortality events due to extreme cold and red tide were episodic and regional. The highest annual number of manatee carcasses on record occurred in 1996 (415) as a result of catastrophic mortality (estimated 149 deaths) from a nearshore red tide bloom in southwestern Florida. Since 1986, 31% of all deaths and 49% of adult deaths (i.e., animals >275 cm total length) were attributed to human causes, and 81% and 77% of those, respectively, were due to watercraft collisions. The number of deaths due to watercraft collisions rose at 10.3% per year from 1976-91, dropped by 28% from 1991 (53) to 1992 (38), and then resumed a 10.3% rate of increase over the most recent decade (to 81 in 2001). There was no trend over time, however, in the proportion of total deaths caused by watercraft (annual range = 14.5-34.2% since 1986). Watercraft-related deaths varied seasonally, peaking in spring and declining in autumn. The number of perinatal deaths increased at a high rate (12.0%/year) from 1976-91 and then appeared to level out in the late 1990s. As a percentage of the total, perinatal deaths declined steadily from 30% in 1991 to 19% in 2001. The total number of reported carcasses has increased in all subpopulation regions (5.1-7.9% per year, 1976-2001) except the upper St. Johns River; the rate of increase in carcasses has been highest in the southwest region.

Given that the annual number of carcasses reflects manatee population size, age-specific mortality rates, and carcass-detection rate, it is important to interpret the mortality data in the context of other types of population data. The current rates of increase in carcasses in the Atlantic (6.9% per year) and southwest (9.1% per year) regions exceed probable rates of population growth and are cause for concern. The remarkable decline in the rate of increase of perinatal deaths from the 1980s to the 1990s requires further investigation.

Life in the Breakdown Lane: Age and Life History Analyses of the Florida Manatee

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Age determination and age-related analyses are critical to understanding the population biology of a species. State, Federal, and private groups are focusing their research efforts on understanding the biology of the Florida manatee in order to develop the most appropriate and effective management and conservation measures for the species. Since the development of the technique of absolute-age determination of manatees using growth-layer-groups (GLGs) in the earbone, ages have been determined for over 2,000 manatees. Methods for using GLGs as a forensic tool to reconstruct life history events are being developed.

Analyses of aged carcasses (n = 2,026) indicate that 21% of the manatees were at least 10 years old and 1% were at least 30 years old. The average age at death was 5.6 per year; if the zero-year age class is excluded, the average age at death was 7.7 per year. This finding is surprising because it is believed that manatees have the potential to live much longer; the oldest age found was 59 per year. However, if the manatees examined are representative of the population, most are not reaching the older ages. Examination of age structure by cause of death indicates that natural deaths occur more to younger manatees (2.5-6.7 per year, n = 386, excluding perinatals) and deaths from human-related causes occur more to older animals (7.7-8.6 per year, n = 684). Analyses of age structure by geographic subpopulation show no significant difference in average age at death. The youngest ages at death were found in northwest Florida (≥1 per year, average age at death is 7.4 per year; ≥ 5 per year, average age is 11.3 per year) and the oldest in the Upper St. Johns region (≥1 per year, average age at death is 7.8 per year; ≥5 per year, average age at death is 13.5 per year). It is important to note that the northwest and Upper St. Johns also had the fewest number of animals aged, n = 71 and n = 35, respectively.

Using GLGs as a forensic tool involves measuring the distance between adhesion lines to assess annual growth in individuals. Changes in annual growth may indicate life history events. Examination of GLGs from animals with well-known histories (n = 11) showed the following: (1) growth rates vary during an animal’s life, (2) the first distinct change in growth is associated with known reproductive events, and (3) the first distinct change in growth occurs during the published age of sexual maturity (generally age 3-5 years). Neither the appearance nor timing of the first change in growth is consistent between individuals.

Seventy-eight manatees separated into four groups, one for each recovery region, were examined using GLGs as a potential tool for assessing the age of sexual maturity. The results indicate no regionally specific growth type or consistency in timing of the first change in growth. Although there were no regional differences, there were three apparent growth types that are distinct based on the appearance of the first change in growth. Within these types, there are subgroups that vary by the age the first change occurs. A frequency distribution of the data resulted in a bell curve, with the majority of manatees becoming sexually mature at age 4-5 years (minimum age = 2 years, maximum age = 8 years). Approximately 86% of the manatees were sexually mature by age 5. Age at sexual maturity is a plastic life-history trait that can change in response to biological and ecological factors. Thus data on the age at maturity of manatees can be useful for tracking such factors.

The manatee age database provides useful information about Florida manatees and new techniques using GLGs allow for assessments of the timing of sexual maturity of both individuals and the population. These data can be incorporated into population models to better assess both the past and present status of the Florida manatee.

Calibrating Aerial Manatee Counts at Tampa Bay Powerplants Using A Numeric Correction Factor

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To evaluate site-specific bias in aerial-survey counts of manatees, an intensive study is being conducted during winters 1999-2000 through 2002-03. The preliminary results presented here represent the first 3 years of this 4-year study. A total of 206 flights were flown over the Tampa Electric Company's (TECO) Big Bend powerplant discharge canal in Tampa Bay, Florida. Aerial surveys of manatees during seven flight series (morning and afternoon flights flown on 4 to 10 consecutive days) and 13 tandem flights (one plane following another) were conducted to assess visibility bias under various weather conditions. Data collected will be used to estimate the percentage of manatees missed during the surveys. This estimate will then allow us to develop a numeric correction factor to adjust counts. The following were employed to help identify factors affecting counts: (1) multiple regression models to assess the influence of environmental factors; (2) mark-resight analysis to estimate counts; (3) time, depth, and temperature data to estimate manatee dive depth and duration; and (4) tandem surveys to compare observer counts. Results indicated that an observer's ability to accurately count manatees is strongly affected by environmental conditions. We recorded the highest number of manatees 3-6 days following a cold front, on warm days with sunny conditions and light winds; these also were the periods when discharge- and intake-temperature differentials were lowest. A multiple regression model showed that when weather conditions were cloudy, manatees were more likely to be missed. During 71% of the flight series surveys, more manatees were counted in the afternoons than in the mornings. Counts of manatees increased by a maximum of 212% from one day to the next (from 102% to 318%) and increased by as much as 181% from morning until afternoon (73% during the morning flight and 205% during the afternoon flight) in one day. For all flights flown (November to March), 59% of counts were higher in the afternoon than in the morning. We monitored manatees between the hours of 8 a.m. and 4 p.m., and at least 50% of the time the manatees were at depths of at least 1 meter. A paired *t*-test showed that there was no significant difference between the counts made from the first and second planes. A regression analysis used to compare the coefficient of variation to the mean of the counts on a given day indicated that variability in counts decreased as the number of manatees counted increased. Future work on this project includes applying mark-resighting analysis using maximum-likelihood methods to our counts of marked animals to estimate manatee aggregation size. We will continue to analyze the data and proceed with developing a means of correcting aerial survey counts by taking into account the number of manatees missed by observers due to biases during the surveys.

Survival Estimates for Florida Manatees from the Photo-identification of Marked Individuals

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Adult survival is the most important single factor influencing population growth rates of the four subpopulations of the Florida manatee. Unbiased estimates of survival probabilities are crucial to managers and population modelers to assess population status and to determine the impact of environment factors and management actions on survival and population dynamics. We used mark-resighting statistical models to estimate annual adult survival probabilities from the sighting histories of known manatees in the Manatee Individual Photo-identification System. Survival was estimated for manatees in four geographic subpopulations of Florida: northwest, upper St. Johns River, Atlantic coast, and southwest.

Annual sighting probabilities were good for all of the subpopulations, ranging from a low mean of 0.48 for the Atlantic coast to a high of 0.88 for the upper St. Johns River. Goodness-of-Fit (GOF) tests calculated with the program RELEASE identified significant heterogeneity among individuals in sighting probabilities on the Atlantic Coast and in the southwest and upper St. Johns River, which may bias the estimates. This heterogeneity was most likely due to some individuals not frequenting the aggregation sites during warmer winters and hence temporarily not being available for photography. For the southwest population, the GOF tests also identified a significant proportion of individuals that were seen only 1 year and have not yet been resighted. Some of these individuals may be dead, some may be moving through the area never to be seen again, and some may have home ranges that include areas not currently being monitored, thus limiting availability for sighting. The GOF tests showed the lack of fit was not severe, and we calculated a variance inflation factor for each subpopulation to reflect the degree of uncertainty of the estimates due to the lack of fit. We used the program MARK to model and estimate survival probabilities. For the northwest subpopulation, modeling identified significantly lower survival probabilities during years in which Category 3 or greater hurricanes and winter storms hit the region. Survival during years without major storms was estimated at 0.97. In 1985 with Hurricanes Elena and Kate, survival was 0.94, in 1993 with the March Storm of the Century survival was estimated at 0.92, and in 1996 with Hurricane Opal survival dropped to 0.876. For the upper St. Johns River, using data from manatees with known year of birth we estimated survival probabilities for 1st-year calves, 2nd-year calves, subadults, and adults at 0.81, 0.92, 0.96, and 0.97, respectively. For the Atlantic coast, mean annual adult survival was 0.94, with evidence of a possible decline in survival estimates in later years. For the southwest, where many individuals have been sighted once, we estimated survival of 0.90 when these animals were included in the analysis and 0.95 when they were excluded (using program TMSURVIV). Both estimates are biased and the true value probably lies somewhere in-between. More advanced estimation models are available to deal with the kinds of heterogeneity identified in the southwest, Atlantic Coast and Upper St. Johns regions, and at the recommendation of the review panel will be used to provide revised estimates in the published final report.

Mark-Recapture Analysis for Estimating Manatee Reproductive Rates

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Unbiased estimation of reproductive rate is an important component of understanding the dynamics of manatee populations. Previous approaches to this estimation employed photo-identification data to estimate the proportion of all adult females that were accompanied by a first-year calf in a given winter. We extended this approach using sight-resighting statistical methods. We modeled annual probabilities of survival, sighting, and transitions between breeder and non-breeder states as dependent on current breeding state. We also used multiple sightings of the same adult female within a season to estimate the sighting probability for her calf, thereby avoiding biases due to misclassifying a breeder as a non-breeder. We analyzed sighting data from aggregation sites in Crystal River for 1982-83 to 2000-01, considering two sampling sessions per winter season. The best fitting model indicated the probability that an adult female non-breeder would produce a calf in the following year that would survive to the winter was 0.51 (std. error = 0.06). This, combined with other parameter estimates, implies an overall proportion of adult females with first-year calf to be 0.34, and an expected inter-birth interval of 2.56. The same analysis indicated that sighting probability for females with first-year calf was slightly higher, on average. These state-specific estimates are easily incorporated into a population projection model.

Use of Aerial Survey and Carcass Data to Model Manatee Population Growth

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Recent analyses of data on the endangered Florida manatee (*Trichechus manatus latirostris*) yield controversial information on their population dynamics. Field data are ambiguous about the population trends. Several independent models have been developed to integrate data about manatee life histories in Florida. These models describe the dynamics of the population in the past. A recently developed model is described here.

A discrete-equation population model was developed for data collected statewide from 1975 to March 2002, on all four subpopulations of Florida manatees (Atlantic Coast, Upper St. Johns River, Northwest, and Southwest [includes Tampa Bay] subpopulations). The model used regional numbers of carcass recoveries, reproductive rates estimated from necropsies of carcasses, and aerial counts of living manatees. Projections from the model were validated by comparison with trends in aerial survey data.

The annual number of carcasses recovered and the number of living manatees observed through aerial survey counts have both increased. The statewide aerial count of 3,276 manatees in January 2001 exceeded all previous counts. Long-term studies using aerial surveys have suggested annual increases in counts of 3-10% in all areas studied. However, carcass numbers in 1996 were also extremely high (n = 416 deaths) following catastrophic mortality from a cold winter (47 deaths) and from red tide (149 deaths).

Reconciling the divergent data has been difficult. Crude mortality rates were calculated from carcass and aerial survey counts, and patterns were compared to estimates of adult survival rates (Langtimm et al. 1998). The model indicates that manatee populations have increased slowly at annual rates between 1.8% and 7.4%, from 1975 to 1995 in all four subpopulations of Florida, and in two subpopulations through the spring of 2002. However, due to the high mortality in 1996, and increasing numbers of deaths since 1997, the Atlantic Coast and Southwest subpopulations may have declined slightly since 1996-97. Manatee numbers in those two subpopulations may have declined as much as 1.1% per year between 1996 and 2002. The population increases projected by this model from 1975 to 2002 are compatible with long-term increases seen in all available aerial survey trend data. The increases also agree qualitatively with results of earlier models by Packard (1985) and Eberhardt and O'Shea (1995).

The current model can help reconcile apparent differences in field data, assess current population dynamics, help predict future trends in the manatee population with increasing human impacts, and improve conservation strategies in critical areas. Additional research needs to be conducted to refine data on rates of reproduction, survival, and carcass recovery, to expand the model, and to extend its projections into the future.

A Stage-based Model of Manatee Population Dynamics

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A stochastic, stage-structured model for Florida manatee (*Trichechus manatus latirostris*) population dynamics was developed, and parameters were estimated for each of the four subpopulations (Northwest, Southwest, Upper St. John's River, and Atlantic). The model incorporates stage-specific female life-history parameters, physiological constraints on reproduction, and temporal variance in survival and reproductive rates. The Northwest subpopulation has a stochastic growth rate of λ_s = 1.050 and a 50% quasi-extinction probability of 0 (i.e., the probability that the population will decline to 50% of its current size is 0, provided environmental conditions stay the same). The Upper St. John's River subpopulation has a stochastic growth rate of 1.073 and a 50% quasi-extinction probability of 0. Conclusions about the other two subpopulations are equivocal because of uncertainty about the life-history parameters. For the Atlantic subpopulation, optimistic and pessimistic scenarios result in stochastic growth rates of 1.029 and 0.992, and 50% quasi-extinction probabilities of <0.001 and 1.0, respectively. For the Southwest subpopulation, the current data are too sparse to warrant quantitative analysis. Because these latter two subpopulations are the most numerous, conclusions about the current status of the Florida manatee are impeded by our scientific uncertainty. The model is used to identify key research priorities for future status assessment.

TECHNICAL DISCUSSIONS

I. Survival Estimation with Photo-identification Data

Edited by Dr. Catherine Langtimm, U.S. Geological Survey

Facilitator: Dr. H. Franklin Percival

Advisory Panel: Mr. Fred A. Johnson, Dr. Helene Marsh, Dr. James D. Nichols, Dr. Kenneth H. Pollock

Primary Researchers: Dr. Catherine A. Langtimm, Dr. Holly H. Edwards

Database Managers: Ms. Cathy A. Beck, Ms. Kristin J. Fick

The discussion on the application of photo-identification studies to survival estimation focused on five basic questions posed by Dr. Percival:

1. What information are we going to need in 10 years?

2. How do we get there from here?

3. Are the current methods adequate to take us there?

4. How will we use the results to direct management?

5. At what spatial and temporal scales can these methods be applied?

Management Needs and Research

During the session, management stated that their current actions center around two primary issues, both related to human-causes of manatee death:

What is the status of the population? Is it in good shape? Where are manatees in regard to complete recovery?

What is it that we need to do to control boats and reduce manatee mortality? Most management actions today involve controlling boats.

Managers have already identified a need for annual survival estimates to address these issues and requested more photo-identification studies in areas where we currently lack data. Providing estimates, however, is only half the story. The major question is, "how do we use survival estimates in a way that is most helpful to management"? Do we use spatial and time scales that are appropriate to address their needs? Are data and analytical approaches appropriate to detect a sufficient magnitude of change in survival probabilities that is useful to management? What can research do to meet present and future needs? To address these issues, researchers need to know and understand the nature of the decisions that managers have to make and how they will apply survival information in a decision-making context—this is a difficult task. Managers are affected by legislation that changes every year, and a lot of management practices are affected by lawsuits and administrative hearings. In these cases managers need data to support their decisions and rulemaking to defend them adequately in court. Consequently, management must be responsive in the short term, and this affects research.

A discussion followed concerning perceptions and needs with regard to survival estimates and management actions:

Using adult survival estimates for management purposes is difficult. Rates vary among regions and within regions from year to year. If adult survival varies in response to both natural and watercraft-related causes, then there is a problem in using adult survival estimates to guide management of human activities. We need to know whether the analysis can tell us how boat-strike deaths affect the adult survival estimates, and consequently the population, relative to natural mortality. Boaters need an understanding of how their actions and the new regulations affect manatee recovery, and no plan will be successful without public understanding. The boating industry is frustrated with the scientific community because, from their perspective, there is not enough coordination to assess the success of management regulations. Are we putting all of the pieces together to accomplish what really needs to be done? The public has seen the number of manatees increase over the last 20 years, but boat regulations continue and they do not understand why. Environmental groups maintain that the human population and boat registrations keep increasing and therefore the regulations are necessary. Consequently, the environmental groups have challenged the boating industry to make boats less of a risk to manatees.

The timeframe for providing estimates to management also was a concern. The reality is that the public affected by the regulations wants to have the information immediately, but it is not possible for scientists to provide a robust answer at this time. Managers are equally concerned with the longer-term time frame consistent with the Manatee Recovery Plan (20 years). The courts seem insensitive or ignorant about the limitations of the best available data and analytical methods, as well as the constraints associated with logistical problems and limited institutional resources.

Discussions and Recommendations of the Review Panel

Overall assessment of the current mark-resighting statistical approach:

The mark-recapture analysis presented at the workshop is state-of-the-art. The long life span of manatees, strong fidelity of individuals to specific overwintering sites, and consistent and dedicated collection of data, result in the impressive high annual sighting probabilities, which explain why confidence intervals for the survival probabilities are typically small. Compared to studies of other marine mammals and terrestrial species, the database and estimates presented at the workshop are very good.

The lack of fit of the data to the initial models identified for three of the four subpopulations is not bad, and the estimates are reasonable. This lack of fit may be due to differences among individuals of the region in terms of their probabilities of being sighted. Three scenarios are likely. First, the home ranges of individuals during winter are large and the photography sites are few, thus some individuals may only infrequently visit these sites compared to others. Staffing is inadequate to monitor all the sites where individuals may be present. Second, during warmer winters, some individuals may habitually return to the photography sites, whereas others choose not to because cold is not driving them to these warm-water sites. Both situations can result in non-random temporary emigration of individuals out of the study area. Third, if individuals are seen in one winter with very little chance of ever returning to the area of initial sighting for environmental or other reasons, then such individuals can be viewed as transients. All three situations can result in poor model fit as identified with Goodness-Of-Fit tests (GOF). There are two options to address these problems. Expand the number of sites visited for photography and/or use modeling approaches, such as the robust design and transient modeling, to model these specific types of heterogeneity in sighting probabilities and provide unbiased estimates.

Recommendations for future analysis:

Several developments in the field of mark-recapture statistical modeling would be appropriate for application to the manatee sightings database. These modeling approaches use additional data and could reduce the bias from the identified GOF problems as well as address new questions concerning manatee survival probabilities and movement probabilities among aggregation sites.

Pollock's robust design models—This approach entails partitioning the data within each winter season into two or more sessions. Such data can be used to estimate probabilities of temporary emigration. One can then incorporate these probabilities when estimating survival and movement, as well as to model heterogeneity in sighting probabilities. Using this approach, it is important to visit all photography sites at least once during each of the sessions in order to estimate within-season sighting probabilities. The robust design should be used in the future, as both heterogeneity among individuals in sighting probabilities and non-random temporary emigration appear to be routine situations in monitoring manatees at the winter aggregation sites.

Modeling multiple groups—Often mark-resighting data can be grouped into cohorts that share common survival or sighting probabilities (i.e., males and females). Procedures are available to construct a series of models in which parameters are estimated separately or shared between the cohorts, and model selection criteria are used to detect differences in parameters between cohorts. These methods would be useful for modeling and estimating survival probabilities in the southwest when data may be appropriately grouped; for example, between Tampa Bay and Ft. Myers sightings.

Joint likelihood models with carcass recovery data—With the effort now underway to match dead animals with animals in the MIPS database, it is possible to model survival probabilities using both live sightings and dead recoveries. The sample size of identified dead individuals is small, but may be sufficient for this approach either now or in the near future. The potential advantages of this approach are that it can provide (1) estimates of mortality that do not include permanent emigration, and (2) estimates of cause-specific (e.g., boat-related) mortality.

Multistate models—In regions such as the Atlantic coast and southwest, movement of individuals among widely spaced aggregation sites may result in different mortality risks and movement probabilities. This modeling approach allows for the estimation of movement probabilities and associated survival probabilities among aggregation sites.

Joint likelihood models with radio-telemetry data—New modeling approaches are also available to combine multi-state models with radio-telemetry, which would improve estimates of movement probabilities among aggregation sites.

Recommendations to improve sampling design and data collection:

The manatee research community recognized that there are areas where manatees occur in winter, which are not sampled due to logistical constraints or poor photography conditions. The largest area is in southern Florida, and includes the Everglades and Florida Keys. Portions of the southwest region south of Marco Island also are not monitored. Participants at the session discussed various methods to improve data collection, ranging from infrared photography to a video camera mounted on a stationary blimp. Various methods have been tried or considered, but no new technology appears to be forthcoming, and funding to increase staffing at new sites seems unlikely. Despite these limitations, new sites and new methods should be brought on line whenever possible to increase coverage and provide additional insights into the populations in these areas. The problems with the GOF tests for the southwest and Atlantic coast also could be improved if more sites where manatees occur are monitored.

Even if it is impossible to add more monitoring sites to the southwest and Atlantic coast regions, the lack of fit can most likely be accommodated with robust design models. Under this design, the winter season should be divided into two contiguous sessions and surveys conducted at all sites in each region during each session. Three contiguous sessions ideally would provide the best means of modeling heterogeneity, but practical difficulties may prevent this.

Because of limited resources, it may be possible to reduce the number of days spent monitoring the sites and to target data collection for the most effective time periods. A retrospective assessment of the data should be undertaken to determine the best sample interval for future monitoring and analysis.

Data collection thus far primarily focuses on the winter months when animals amass at the warm-water winter refuges. Sampling at other times of the year in the regions, although difficult, would allow for estimation of survival probabilities across seasons. This could provide important information on the most vulnerable times of the year for manatees.

Recommendations to address management needs:

The review panel was asked to assess two aspects of the mark-resighting approach to answer management questions. First, how good are the data and the analysis; specifically, are estimates good assessments of survival in the population? Second, do we have the capability with this approach to monitor the success or failure of management actions to reduce boat deaths by monitoring for changes in survival probabilities?

The consensus was that the data are sound, and the models and analyses well done. The manatee photo-identification resighting program is very effective, especially when considered in the context of other large-scale animal sampling programs. The ability to detect changes in total annual survival associated with human-related mortality will be limited by the amount of that mortality. If changes in human-related mortality resulting from changes in boat regulations, for example, are large, then the current program may have a reasonable chance of estimating this change with reasonable precision. However, if there are no major changes in boat-related mortality over time or space, then it would be unreasonable to expect the photo-identification program and associated analyses to estimate small changes well.

Analysis thus far has centered on retrospective analysis of annual monitoring data, which has demonstrated the value of the mark-resighting approach to provide regional estimates and to identify patterns in adult survival. At this juncture, however, researchers now need to move forward and in addition to the current monitoring and analysis, focus on explaining the underlying processes affecting survival and the identified patterns. In this regard, retrospective analysis with methods to model survival probabilities in association with possible covariates (such as past hurricane strikes or past implementations of new regulations) are valuable for generating hypotheses, which then can be tested in targeted field studies. This should be a high priority. Once hypotheses are identified, researchers can consider how the monitoring design might be changed to answer specific management questions, such as understanding the effectiveness of management actions. The spatial scale and time scale will be critical issues for managers and researchers to address in the design of these proactive studies. Ideally, there should always be a retrospective ongoing monitoring program, along with a proactive field research program with an increasing focus on questions generated by managers. This combined approach is taking place to some extent in the research directed by the Warm Water Task Force.

Data on sightings of juveniles and subadults are limited, primarily because few animals acquire unique scars and features from non-fatal boat strikes at such an early age. Often, only after several strikes, does an individual meet the strict criteria for inclusion in the MIPS dataset. Efforts are underway at Blue Spring and Crystal River to notch the tails of calves to provide definitive identification of individuals or to determine their birth year. This technique is not easily used at other sites. The population at Blue Spring provides the best information to estimate survival probabilities for calves and subadults. Efforts to develop new methods, such as genetics, to identify and resight young manatees should continue. Parameter estimates for these young age-classes will be important for any models developed to address management needs.

The group discussed a potential new approach to directly estimate the mortality rate associated with boating using carcass recovery data and photo-identification data. Band-recovery models can be used to estimate recovery rates, reflecting the probability that an identified manatee alive one winter will die and be encountered and reported during the subsequent year. If such reported deaths are partitioned into different causes of death, or at least if boat-related deaths can be detected, then it would be possible to estimate a recovery rate or encounter rate associated with boat mortality. However, this recovery rate will not estimate cause-specific mortality rate, because some deaths are not encountered and reported. An *ad hoc* means of trying to estimate the actual number of manatees identified in one winter that die of boat-related mortality the subsequent year but that are not encountered and reported is to record the number of reports received before each carcass is "picked up." This frequency distribution of reports per carcass (number of carcasses reported once, twice, etc.) can be used with the limiting jackknife estimator of capture-recapture model *M(h)* developed by Burnham and Overton (1979) to estimate the number of carcasses not reported, and hence the total number of deaths. This approach has some potential to be useful in estimating mortality rate associated with boating (or any identifiable cause), and might be especially useful in evaluating the effectiveness of boating regulations and similar management activities.

II. Manatee Population Status based on Mortality Database and Age Distribution

Edited by Dr. Timothy J. Ragen, Marine Mammal Commission

Facilitator: Mr. Ken Haddad

Advisory Panel: Dr. Solange Brault, Dr. Daniel Goodman, Dr. Aleta Hohn, Dr. James D. Nichols

This working session focused on the utility of the manatee mortality database and age-structure information in assessing manatee population status. The session began with a description of a preceding workshop that reviewed the efforts of the Florida Wildlife Research Institute's Marine Mammal Pathobiology Laboratory to assess the causes and incidence of manatee mortality. The laboratory's database on manatee mortality contains records on over 4,000 manatee carcasses and is probably the most thorough database of its kind in the world. The laboratory uses the most up-to-date tools to diagnose causes of death and associated circumstances (e.g., age, condition) and has developed a sophisticated computer database for recording the data collected. The review workshop concluded that the laboratory's efforts were excellent and that needed improvements are best characterized as "fine tuning." The review workshop also established stronger connections with other researchers and organizations with similar responsibilities, increased opportunities for supplemental funding, and provided a feedback mechanism that will be useful as efforts to understand the causes of manatee mortality continue in the future.

Mortality

The session then focused on the realized and potential utility of the manatee mortality database. The database is recognized as a useful general measure of mortality and indicator of mortality trends. The session first addressed the following question:

How can the mortality database be used to facilitate assessment of manatee population status?

Discussion pertaining to this question focused initially on the biases inherent in the mortality database. When a manatee dies, its death and the surrounding circumstances are included in the database only if the carcass is observed and reported, and the appropriate data are collected and recorded. The probability that a carcass and associated data are observed, reported, collected, and recorded may vary by, among other things, year, season, location, age, cause of death, and nearshore current patterns. Due to potential sources of bias, conclusions about population status based on the mortality database must be derived with caution. One of the more significant questions regarding the database is whether the age structure of the examined carcasses is the same as that of the living population. The session participants concluded that it is likely not the same due, for example, to incomplete representation of juveniles in the mortality database.

In view of the apparent limitations of the mortality database, the discussion then shifted to consider alternative methods for characterizing mortality (or survival) rates and for incorporation of such information into the assessment of manatee population status. Participants considered investigation methods that had been used with other species, as well as modification of current methods that might be free of, or less affected by, the biases inherent in the mortality database. Although several studies were mentioned that involved the successful characterization of mortality rates for other species, no conclusion was reached regarding their application to the manatee. Additional comments emphasized the need to consider how the existing manatee database might be improved to provide both a better understanding of real mortality rates and more opportunity to use those data in a population assessment model (as done in Marmontel et al. 1998).

Discussion of this first question concluded with a general consensus that the most robust and reliable approach may not result from a search for alternative methods that are free of biases, but rather from an approach that integrates all the available data, identifies the biases associated with those data, and then uses additional research to quantitatively characterize those biases.

The session then addressed a second question regarding the mortality database and the issue of human-related manatee mortality:

Is human-related manatee mortality excessive or an important determinant of population status?

Discussion on this question began by emphasizing the significant effect that reports of human-related manatee mortality have on the public. In view of the public's concern, it is particularly important that reporting of individual events or of annual summaries be accurate and be accompanied by sufficient additional information to put those numbers in perspective.

The remainder of the discussion on this question addressed whether several reference points defined under the Marine Mammal Protection Act might serve as indicators of the tolerance of the manatee population for human-related mortality. The first reference point discussed was the potential biological removal (PBR) level, which is defined to mean "the maximum number of animals, not including natural mortalities, which may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population." The PBR is calculated as the product of the minimum population estimate of the stock, one-half the maximum theoretical or estimated net productivity rate of the stock at a small population size, and a recovery factor of between 0.1 and 1.0. If, for example, the minimum population estimate for the current population is 3,276, the estimated maximum growth rate is 8% per year, and the recovery factor is set at 0.1 (for an endangered species), then the resulting PBR would be 3,276 x (0.5 x 0.08) x 0.1 = 13 animals. Unfortunately, human-related manatee mortality is known to exceed this or similar estimates by a considerable amount.

A second potential reference point mentioned in the discussion was the zero mortality and serious injury rate goal, often referred to as "ZMRG." This potential standard was developed under the

Marine Mammal Protection Act, which states that with respect to marine mammals taken in commercial fisheries, "it shall be the immediate goal that the incidental kill or incidental serious injury of marine mammals permitted in the course of commercial fishing operations be reduced to insignificant levels approaching a zero mortality and serious injury rate." Manatees do interact with commercial fisheries, but such interactions are not the primary type of human-manatee interaction leading to manatee mortality. The zero mortality and serious injury rate goal has not been officially defined by the National Marine Fisheries Service, but has been used in stock assessments to mean a rate that would lead to a mortality level less than or equal to 10% of the potential biological removal level.

The participants debated the utility of the PBR and ZMRG standards as indicators of whether human-related manatee mortality was "excessive." Although these standards were not derived specifically for the manatee case, they are expressive of social values that seek to minimize such mortality and provide a reasonable assurance of population recovery. However, it was noted that the data from synoptic counts are consistent with population growth in spite of the fact that the number of human-related mortalities has exceeded the PBR. This apparent contradiction can be explained by the fact that PBR is not intended as an exact, deterministic limit on tolerance, but rather, as a limit that seeks to provide 95% assurance of recovery to a maximum net productivity level with no more than a 10% delay in the recovery time expected in the absence of human-related mortality. Thus, the observation that the population may have grown despite human-related mortality exceeding PBR is not necessarily inconsistent in view of the probabilistic nature of PBR.

Finally, with regard to this question, it was noted that the formula used to calculate PBR was developed as a default formula that can be applied in the absence of more complete information about a species. The underlying concept behind PBR was to identify the level of human-related take that would result in 95% certainty that:

- Populations at or above their maximum net productivity level remained so after 20 years of human-related mortality at PBR;

- Populations at 30% of their maximum net productivity level recovered to at least their maximum net productivity level after 100 years experiencing human-related mortality at PBR; and

- Populations below their maximum net productivity would not experience more than a 10% delay in recovering to their maximum net productivity level.

It was then suggested that for species for which scientists have sufficient information, the probability of satisfying these criteria might be evaluated by modeling that information rather than relying on the default approach. That is, one approach to estimating excessive levels of human-related mortality would be to incorporate all the known information about manatees and factors affecting their status into a stochastic population model that both represents the best available information about the species and those factors affecting their status, and provides a probabilistic assessment of the potential effects of different levels of human-related mortality. This approach is similar to that taken in a comprehensive population viability analysis.

Age Distribution

The status of the Florida manatee is best characterized and projected into the near future by a suite of information pertaining to abundance and trends, survival and reproductive rates, age/sex class distribution, health and condition of the population, and the status and trends of important habitat. Due to insufficient or uncertain information about birth rates and juvenile survival in recent years, the age distribution of the existing manatee population (or the four subpopulations) is not well understood. The determination of ages for a large number of the manatees in the manatee mortality database has provided information on the age structure of dead animals and additional important age-specific information (e.g., age of sexual maturity, size at age), but the best manner in which to translate such information into an estimate of age structure for the living population is not yet clear.

In this portion of the working session, the discussion focused on the questions about how the existing age structure of the living population might be estimated and what the significance of that structure is with respect to determining population status. A number of important points were made:

- The existing age structure of the population cannot yet be determined on the basis of the best available information, including the manatee mortality database.

- Nevertheless, the development of aging techniques and the application of those techniques to a large number of carcasses in the mortality database have provided important insights into the life history of manatees and age-specific information such as age of maturity and first reproduction, and reproductive rates for mature animals.

- Most of the gaps in our understanding of age structure result from insufficient information on birth rates and, especially survival rates of young animals.

- Many of the factors resulting in mortality or sublethal effects on manatee health and condition are, or may be, age- or stage-specific (e.g., vulnerability to cold). Factors that increase mortality of manatees near the peak of their reproductive potential may have the most significant impact on population growth and recovery.

- The lack of information on age structure and age-specific vital rates (reproduction and survival) confounds efforts to assess the status of the existing population or project the status of the population in the near future.

- Depending on the purpose at hand, stage-based rather than age-based modeling can be used to project population status and trends. Stage-based modeling reduces the number of parameters that need to be estimated for modeling, although the requirement for accuracy and precision in parameter estimates remains the same. At present, additional information is needed to increase reliability of both age- and stage-based modeling efforts.

- Ultimately, age distribution or structure is a direct consequence of reproduction and survival patterns over time. More reliable information on vital rates is essential to better understand the age structure of the manatee population, as one element or determinant of manatee population status.

The primary conclusion from this session was that additional age-specific information on vital rates and population structure is needed to enhance our understanding of the status of the manatee and to project that status into the future.

III. Estimation of Reproductive Parameters Based on Resightings of Living Manatees and Recovery and Examination of Carcasses

Edited by Dr. John E. Reynolds, III, Mote Marine Laboratory

Facilitator: Dr. Aleta Hohn

Advisory Panel: Dr. Solange Brault, Dr. Daniel Goodman, Dr. James D. Nichols

This session had two primary goals: (1) to assess the extent to which ongoing programs provided useful insights into reproductive biology of manatees; and (2) to recommend fruitful avenues for expansion of studies to better assess key aspects of reproduction. Facilitator Aleta Hohn suggested five guiding questions for the group:

1. What information would scientists and managers like to have in 10 years?

2. How do we get that information?

3. Is current research pointed in the proper directions?

4. How can results of such research direct management?

5. What is the proper scale for research on manatee reproduction?

Four long-term sources of information exist concerning Florida manatee reproduction. Photo-identification of recognizable individuals has provided age-specific data and longitudinal data on reproductive performance of females. Examination of carcasses provides insight into reproductive status of individuals through examination of gonads and earbones (for age); in addition, it appears that certain life history events, such as onset of sexual maturity, can be assessed by examining growth layer groups. Aerial surveys provide some measure of the numbers of calves in particular areas, although definition of what constitutes a “calf” is subjective. Additionally, studies of captive manatees have provided some information regarding reproductive physiology (including some data on endocrinology) and behavior. Key information gaps identified early in the discussion concerned (1) the effects of factors such as exposure to red tide or cold, disturbance, serious injuries, or habitat alterations on reproduction rates, and (2)knowledge about the overall health of manatees and how changes in health status might affect reproduction.

Manatee photo-identification and its utility for understanding reproduction was discussed at length. Although data exist regarding reproductive performance of certain female manatees in certain parts of the State, data on male reproductive success are lacking. Anatomical and behavioral studies suggest that males are sperm competitors. In females, inter-calf intervals vary, and traumatic events may play a major role in extending such intervals. Participants agreed that data on reproductive performance from female manatees in one location should be applied with great caution to animals at other locations; in other words, there are likely to be significant inter-regional differences. In this regard, the participants noted that there are enormous differences in the amount and quality of data on reproductive performance and other aspects of life history for Florida manatees found in different management regions. **A recommendation was made to attempt to obtain equal levels of information regarding manatee life history from each of the four management areas (southwestern Florida represents a notable "black hole").** As a related issue, the participants noted that most photo-identification effort occurred at warm-water refugia in winter (an exception being work done in Sarasota in summer); thus, a related **recommendation was made to expand photo-identification efforts to include more manatees outside the winter season.**

As a more general approach to identifying individual manatees, PIT tagging and genetic research were discussed and it was suggested that both approaches could be usefully expanded. Concerning genetics research, few questions have been addressed despite the development of a large tissue bank. **The participants therefore recommended that greater effort be put into PIT tagging and population genetics research.**

The issue of stressors on inter-calf intervals and other aspects of reproduction also were discussed. In Belize, food availability may affect reproduction in manatees. The same holds true for dugongs, for which stochastic events such as cyclones appear to be important determinants of food availability. In addition, it is known that spermatogenesis, metabolically inexpensive as it may be relative to oogenesis, lactation, and gestation, essentially ceases in Florida manatees during cold winter weather. As noted above, serious injuries, habitat changes, disturbance (e.g., by human activities) and exposure to red tides or cold may also affect inter-calf intervals. The participants noted that tools exist to assess manatee health status, and they **recommended that photo-identification studies should be complimented by telemetry, endocrinology (through examinations, for example, of fecal hormone levels) and thorough health assessments.** Of particular interest are the following testable questions: (1) endocrine disruption associated with presence of particular toxicants; (2) the effects of particular management actions to mitigate stressors and optimize reproductive performance; and (3) the relationship between nutritional status and effects on birth rates, inter-calf intervals, and survival of immature animals**. The development and use of suites of chemical, histological, and metabolic biomarkers** (currently being facilitated by Rommel/Reynolds) **should be encouraged.**

The utility of telemetry as a tool was discussed. Participants agreed that photo-identification is more useful for assessing reproductive parameters, but that telemetry could provide insights into movements, calving and mating locations, and the relative success of primiparous females versus older females.

The participants discussed that the available data provide adequate information to develop a model that would permit scientists and managers to judge whether specific management actions are effective in terms of promoting reproduction at the level mandated in the latest recovery plan for reclassification to occur. Managers are anxious to know whether current knowledge is adequate for making informed decisions. One manager specifically asked when he needs to start worrying about reproductive success in making his decisions.

It was suggested that conservation is sometimes paralyzed by a lack of data. Even though all the answers may not exist, there are good data available on which to base justifiable decisions. It is extremely important, however, to keep the precautionary principle in mind and to adapt management approaches as new data become available.

Therefore, although a model would necessarily involve certain assumptions, the participants **recommended that one be developed to incorporate existing data on age-specific**

reproduction rates and success; calf survival of primiparous vs. multiparous females; calf survival outside of warm-water aggregation sites; and effects of certain stressors on survival. There is enough information available to develop research approaches to test specific hypotheses and examine cause and effect relationships.

Modeler Jim Nichols provided a specific example of a hypothesis that could be tested. Managers and scientists could consider a group of manatees using an important warm-water source will cease to exist. With an *a priori* hypothesis based on the probability of a female having a calf, and with adequate photo-identification effort, one could test the extent to which females changed their breeding behavior (e.g., became non-breeders following the stress).

The participants concluded that ongoing efforts have been successful in providing some baseline data on manatee reproduction. They also recognized that existing staff are fully tasked and that expansion of ongoing programs would be difficult without either some expansion of funding or a reallocation of staff. The participants did, however, generate a list of recommended actions that would prove useful over the next 10 years. Among the unprioritized recommendations of the participants (besides those identified above) were:

1. Utilize captive animals better than has been done in the past to assess the effects of reproductive physiology and nutrition on reproduction and other parameters;

2. Explicitly address questions about how differences in nutrition and energetic demands of manatees affect manatee reproduction;

3. Develop a metapopulation model;

4. Consider carefully what the questions are and apply the best research approach to address the question. In other words, recognize that certain approaches will not provide all of the answers;

5. Maintain ongoing strong programs to assess age-specific reproductive parameters and changes in life history attributes;

6. Attempt to relate changes in life history features to documented changes in manatee environments

7. Continue to examine the gross anatomy of female reproductive tracts and greatly enhance histological examinations, even though uterine scars do not persist and ovarian anatomy is very unusual;

8. Consider appropriate temporal and spatial scales as hypotheses are developed and tested;

9. Enhance the extent to which management and research groups interact;

10. Examine the utility of developing comparative studies of manatees outside Florida;

11. Certain aspects of manatee biology (e.g., sensory biology and habitat selection) have not been well addressed, but should be due to their implications for understanding reproductive biology; and

12. Develop management questions and solutions that consider anticipated growth of the human

population and expansion of human activities that affect manatee habitat.

Clear themes that emerged from the discussion were that (1) health and reproduction in manatees are vitally linked to habitat quality, and (2) examination of habitat issues has lagged far behind the assessment of life history and population parameters.

IV. Population Trend Estimation Based on Aerial Surveys

Edited by Dr. Lynn W. Lefebvre, U.S. Geological Survey and Dr. Timothy J. Ragen, Marine Mammal Commission

Facilitator: Dr. Helene Marsh

Advisory Panel: Mr. Fred A. Johnson, Mr. Gil McRae, Dr. Kenneth H. Pollock.

The working group facilitator, Helene Marsh, provided a list of six questions that managers seek to answer about the manatee population:

1. What are the status and trends of the population?

2. What are the most important actions to reduce anthropogenic mortality?

3. Are management actions working?

4. How can future population trends be predicted?

5. What is the Optimum Sustainable Population?

6. What is the sustainable anthropogenic mortality?

The group planned to discuss the utility of three types of surveys for addressing the preceding management questions: synoptic winter surveys, long-term power-plant surveys, and broad-scale distribution surveys. However, only the synoptic survey was discussed in depth.

Long-term Powerplant Surveys

<u>OBJECTIVE</u>: *Determine long-term trends in manatee use of selected powerplant effluents during winter cold periods*. These surveys, which are sponsored by the Florida Power & Light Company, cover 8 plants, 7 of which are located along Florida's east coast. These surveys do not aim to determine overall population size.

<u>CHALLENGES</u>: The proportion of the population visiting the plants during a given cold period and variation in use among cold periods are unknown. Assessments are confounded by potential visibility bias, which results from animal behavior (e.g., presence/absence of manatees at the powerplants, whether or not manatees are resting on the bottom) and physical conditions (e.g., turbidity).

RESPONSE TO CHALLENGES: Correction factors for visibility bias have not been used in the past; however, biologists at the Florida Marine Research Institute are currently developing a correction factor for the Tampa Electric Company's plant on the eastern shore of Tampa Bay (see Edwards et al., this volume).

PRIORITY: The surveys are of high priority because waters warmed by powerplant effluent provide important habitat for manatees, and the future availability of the effluent is uncertain because of the limited operational lifetime of the powerplants.

Broad-Scale Distribution Surveys

OBJECTIVE: *Map manatee distribution and habitat use.* These aerial surveys typically cover one county at a time, and are flown every other week for 2 years. Like the powerplant surveys, they are generally not intended to determine population sizes or trends, but rather to determine the relative abundance and distribution of manatees in the survey area. The resulting manatee location data are included in Geographic Information System databases and used, for example, to identify important manatee habitat and manage human activities in that habitat in a manner that does not adversely modify its value to manatees.

CHALLENGES: Conservation of the manatee will depend largely on conservation of its habitat. Surveys of manatee distribution and identification of key habitat areas is critical, especially in reviewing permits and establishing manatee sanctuaries and refuges.

RESPONSE TO CHALLENGES: Distribution surveys should be repeated in specific areas to provide essential information on habitat use. Strip-transect surveys, a type of broad scale survey, have been used successfully in two regions—the Banana River in Brevard County and the Ten Thousand Islands in Collier County. These are the only surveys designed to provide information on manatee distribution, relative abundance, and population trends.

PRIORITY: These surveys are of high priority because they provide essential information on manatee distribution, habitat use and in the case of strip-transect surveys, population trends.

Synoptic Surveys

OBJECTIVE: *Obtain a statewide count to provide a minimum estimate of and assess trends in manatee population size*. A single survey requires 20 or more aircraft, each covering a different area. These surveys are typically flown one to two days after the passage of a cold front, and one to two synoptic surveys have been flown per year since 1991 (except in 1993 and 1994). The surveys focus on important manatee wintering habitat, and all State waters are not covered.

RATIONALE: Synoptic surveys were conducted in response to a requirement by the Florida legislature to conduct a "statewide survey" as an "impartial benchmark" of the statewide manatee population and its trends.

CHALLENGES: Survey results are subject to certain biases, which differ throughout the State depending on site, and may change over time. For example, many areas on the west coast have murky water and counts are likely to underestimate actual numbers present. East coast waters tend to be clearer and, therefore, the counts are probably more accurate.

At least three types of bias (absence, availability, and detection) may confound estimations of manatee abundance and assessments of population trends. **Absence bias** occurs when a portion of the population being counted is not present in the area where the count occurs, such as at a winter aggregation site. **Availability bias** occurs when manatees in the survey area are invisible because they are submerged or hidden by vegetation, other objects, or turbid water. **Detection bias**, which is also referred to as perception or observer bias, occurs when manatees are in the survey area and visible, but are not seen and recorded by the observer. Availability and detection bias are collectively known as visibility bias. These types of bias were noted in the 1992 workshop, and Ken Pollock indicated that researchers have not yet addressed them adequately. Characterization of these bias types is important for estimating total abundance and assessing population trends. Related research has been conducted primarily in Tampa Bay, but biases may vary spatially and temporally, and additional research will be required before the types of bias and associated variability can be estimated and used to characterize population abundance and trends. Until that work is completed, inferences from these surveys are considered questionable.

Confusion has also arisen because of the failure to distinguish between the approaches required to estimate population abundance and assess the population trend. The distinction is important because it affects the way the surveys are designed and conducted. If the primary objective is to obtain a reliable estimate of abundance, then it is important to minimize or at least correct for bias. If the primary objective is to obtain trend information, then it is important to conduct surveys in a manner that results in constant biases and minimal error. For example, counting at all sites on the same day following a cold front is a method for minimizing bias (obtaining a count as close to the true number as possible), but does not provide useful trend information because the bias will vary markedly from one year to the next; thus, this method may exaggerate the variability in yearly counts, which confounds trend information. A better way to obtain trend information might be to conduct multiple counts each season and then use some measure of central tendency such as the mean count from each year to examine trends.

The nature and importance of such biases also must be explained to politicians, managers, and the public, each of whom do not necessarily understand their significance. However, communicating science is a separate issue from acquiring reliable estimates, and ease of communication should not be viewed as a rationale for using simple, but inappropriate, survey methods.

RESPONSE TO CHALLENGES:

- FWRI is conducting a 3-year calibration study at the Tampa Electric powerplant to estimate visibility bias. Fifteen manatees were captured, marked with flags, and equipped with satellite-monitored radio tags and time/depth recorders. These animals are used as a "subpopulation" at the plant to determine how many flagged animals are observed during a flyover in relation to the total number of flagged animals at the plant during the flights. Time/depth recorders provide information on manatee diving behavior and how it may influence counts. Temperature and turbidity data are also collected.

- The calibration study addresses the probabilities of availability and detection given availability. The resulting data will be used to develop correction factors for surveys conducted at this powerplant. Dive-pattern data do not provide direct information about availability bias, but do give some indication of detection probability when animals are known to be present.

- A negative bias can occur when a flagged manatee is sighted, but the flag is not. To date, researchers have not developed a means for reliably estimating this bias. However, flags are sometimes observed on submerged manatees, resulting in a positive bias that may offset (to some unknown degree) the aforementioned negative bias.

- The number of synoptic surveys should not necessarily be increased because more of the same type of survey will not address the biases addressed here. It is important to clarify and prioritize survey objectives.

- It is probably not reasonable to draw inferences about the population trend from synoptic survey data, given the enormous variation in the counts and availability bias, in addition to other confounding factors.

- Studies of dive patterns may provide useful estimates of the percentage of time that animals are visible at the surface under varying conditions and during different types of behavior. Such studies may help determine corrections for visibility biases.

- The questions that researchers are asking need to be reassessed. State researchers are mandated to conduct a statewide census, not a synoptic survey. If a true census cannot be conducted, then population assessment efforts may need to focus on different objectives to achieve the same goal. Bruce Craig's approach, for example, combined absence and visibility biases, and used temperature to calculate a likelihood of a manatee visiting a warm-water refuge. The resulting projection of population trend was not precise, but showed a pattern of change over time that was similar to projections from other modeling approaches.

- From a management perspective, little information is available on an annual basis to assess population status. The two numbers that receive the most attention are (1) the number counted in the synoptic survey and (2) the number that died the preceding year. We need to reevaluate the use of these numbers in assessing the status of the population and communicating the results to policy makers, managers, and the public.

- Panel members and the reviewers recommended that manatee researchers review the questions being asked and the methods being used to determine if their methods are appropriate for those questions.

PRIORITY: High. New survey methods and statistical approaches for correcting survey bias need to be developed.

Conclusions

- The broad-scale distribution surveys have provided important information for management on the distribution and habitat use of manatees in Florida at a range of scales. Strip-transect surveys have only been used in two regions, but show promise as a tool to determine regional population trends.

- The objectives of providing a census of the manatee population of Florida and of detecting trends in numbers cannot, in general, be met by the surveys as conducted. The current design for synoptic surveys is confounded by a number of variables that, collectively, result in potentially significant biases (absence, availability, and detection). Until these biases can be assessed, this particular approach to assessment of manatee trends will remain unreliable.

- Some interesting work is in progress that attempts to address the problem of visibility bias at the Tampa Electric powerplant. This work should be reviewed in consultation with a statistician before continuing.

Recommendations

- o In conjunction with the managers and other stakeholders, the researchers should re-examine and prioritize the objectives of each major survey type (synoptic, long-term, broad-scale) including the issues of scale. The survey effort should then be redesigned in the context of these revised and prioritized objectives, noting that it may be necessary to conduct additional research external to the surveys to address the various types of bias.

- o Managers' questions regarding status and trends of the Florida manatee population should be addressed using a range of methods and the weight of evidence.

MANAGEMENT DISCUSSIONS

Determination of Negligible Impact for Incidental Take

Summary by Mr. Peter M. Benjamin, U.S. Fish & Wildlife Service, Jacksonville, FL

The Marine Mammal Protection Act (MMPA) states that, "It is the sense of the Congress that [Marine Mammals] should be protected and encouraged to develop to the greatest extent feasible commensurate with sound principles of resource management and that the primary objective of their management should be to maintain the health and stability of the marine ecosystem."

The passage of the MMPA established a moratorium on the taking of marine mammals, and prohibited all taking, including incidental taking of marine mammals.

"Take" is defined under MMPA regulations as to "harass, hunt, capture, collect, kill, or attempt to harass, hunt, capture, collect, or kill any marine mammal, including, without limitation, any of the following: collection of dead animals or parts thereof; the restraint or detention of a marine mammal, no matter how temporary; tagging a marine mammal; or the negligent or intentional operation of an aircraft or vessel, or the doing of any other negligent or intentional act which results in the disturbing or molesting of a marine mammal."

Under the regulations implementing the MMPA, incidental take is defined as "an unintentional taking that is infrequent, unavoidable, or accidental, but not necessarily unexpected." The incidental taking of marine mammals may be allowed under section 101(a)(5)(A) of the MMPA only if the Director of the Service finds, based on the best scientific evidence available, that the total taking during the specified time period will have a negligible impact on the species or stock and will not have an immitigable adverse impact on the availability of the species or stock for subsistence uses.

The term "negligible impact" is defined under MMPA regulations as "an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival."

The manatee is protected under the MMPA and is also listed as an endangered species under the Endangered Species Act. The largest known human-related cause of manatee deaths is collisions with watercraft. Between 1976 and 1999, watercraft-related deaths increased at an average rate of 7.2% per year. From 1996 to 2001, annual watercraft-related deaths were the highest on record, ranging from 54 to 82 per year. Minimizing the amount of watercraft-related incidental take of manatees has been identified by the Florida Manatee Recovery Team as an action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

In the State of Florida, county, State, and Federal agencies engage in a variety of activities that may result in the incidental take of manatees, but that are outside the narrow exceptions to the take prohibitions defined above. Many of these activities relate to the use and regulation of watercraft operated in Florida waters accessible to manatees, including: (1) regulating boater behavior on the water (e.g., speed zones and vessel registration); (2) permitting construction of watercraft access facilities (marinas, docks, and boat ramps); (3) funding construction of watercraft access facilities; (4) operating watercraft access facilities; and (5) operating watercraft.

The Fish and Wildlife Service engages in, or has the authority to engage in, each of the above five categories of activities; therefore, our activities may result in the incidental take of manatees. For this reason, we have initiated the process of promulgating MMPA incidental take regulations to authorize take associated with government activities related to watercraft. Many other government agencies engage in some or all of the above activities including, but not limited to, the Florida Fish and Wildlife Conservation Commission, Florida Department of Environmental Protection, Army Corps of Engineers, U.S. Coast Guard, Florida Department of Transportation, Florida Inland Navigation District, Florida's Water Management Districts, and county governments.

There are other human activities that result in the incidental take of manatees, including but not limited to the operation of locks and water control structures, port operations, the operation of industrial warm-water outfalls, and activities that affect the quality and quantity of water flow from warm-water springs. These activities are not covered by this regulation, but may be subject to future rule-making.

Beyond the regulatory definition of "negligible impact," there is little available guidance we can use to help determine what level of watercraft-related incidental take would have no more than a negligible impact on manatees. To help focus our rule-making efforts, we have defined the following criteria for evaluating potential methods for determining the negligible impact threshold for manatees. The criteria for determining the negligible impact level:

- Must be based on the best available scientific information;

- Must be available for use within our rule-making time frame;

- Must meet the standards specified in the MMPA and implementing regulations;

- Must allow managers to continuously track performance measures against the standard (next year and over life of regulation) with minimal lag time;

- Must enable managers to track performance and take appropriate actions regionally;

- Must allow managers to forecast future levels of allowable human take (i.e., take during the following year and subsequent life of the regulation).

• Should be consistent with the findings, goals, and objectives of the Recovery Plan;

• Should consider the allowable level of human take after natural mortality is considered; and

• Should be as simple as possible, but no simpler.

With regard to criterion "2" per our settlement agreement, we are to publish our proposed rule in the Federal Register by November 5, 2002. To accomplish this, given our internal review process, the draft proposed rule needs to be completed for internal review by early August 2002. Before the draft proposed rule can be written, there must be extensive coordination among the agencies that will be affected by this regulation to determine such things as the measures that can be implemented per the regulations to meet the negligible impact standard, appropriate monitoring and reporting protocols, and rule management structure. To write the draft proposed rule by August, this coordination needs to be largely completed by June. The interagency coordination can not really begin until we have an idea of what will constitute a negligible impact. In other words, we can not anticipate what kind of protective measures to build into the regulations until we have established a negligible impact threshold.

Several alternative methods have been evaluated for use in making the negligible impact determination. The various methods that have been considered to date are briefly summarized here.

Method A —- In previous rule-makings under the MMPA, the National Marine Fisheries Service has used a species' Potential Biological Removal (PBR) level, or some percentage of PBR, to establish the level of incidental take that would result in a negligible impact on the species in question. The PBR formula allows resource managers to conservatively estimate an acceptable amount of human-related take of a given marine mammal stock based on very limited information. For many stocks of marine mammals, such a simplistic approach is warranted due to the lack of species-specific population data. However, there is a relatively large body of data regarding the Florida manatee population that is not utilized in the PBR formula. As such, the use of the PBR formula for management decision making would require managers to ignore the bulk of the best available scientific information (i.e., does not meet criterion "1").

Method B —- We could determine that a level of human-related take that does not impede recovery time by more than a certain percentage would have a negligible impact on the Florida manatee. We could use the ESA recovery plan criteria and state that the negligible impact threshold would be that level of take that does not increase the time to achieve the recovery benchmarks by more than a specific percentage. More conservatively, the threshold could be that level of take that does not increase the number of years to achieve the recovery benchmarks.

Method C —- We could use a population viability analysis (PVA). For example, we could determine that a level of human-related take that does not increase the probability of extinction by more than a certain percentage over a certain period of time would have a negligible impact on the manatee. We would need to determine the period of time we are making projections over (Marmontel's 1,000-year horizon does not seem reasonable in terms of management decision making), and we would need to support the various assumptions that go into the model.

Method D —- We could base our negligible impact finding for the entire population on the observed performance of the Upper St. Johns and/or Northwest regional population groups. Based on the observed rates of population growth, recruitment, and adult survival in these subpopulations (which all appear to be nearly as good as possible), we could argue that human-related take is having a negligible impact on these subpopulations. Therefore, the negligible impact threshold for the entire State would be a level of take that is proportionate to the level of take within the Upper St. Johns and Northwest subpopulations.

Method E —- We could use the population benchmarks established in the recovery plan and determine that a level of human-related take that does not reduce the population parameters below the benchmarks would have a negligible impact on the manatee. For example, if the benchmark for adult survival is 94% (based upon the recommendation of the Manatee Population Status Working Group), then any human-related take that causes adult survival to fall below 94% would be considered to have a more than negligible impact.

This approach could be problematic, because it is clear that Congress intended the MMPA to be more protective than the ESA; therefore, it is likely that the threshold for simple achievement of "recovery" is distinct from that for "negligible impact." As such, this approach probably fails to meet criterion "3."

Method F —- We could use the population benchmarks established in the recovery plan in another way, specifically focusing on the target population growth rate benchmark. The Population Status Working Group recommended a target rate of population increase of 4% per year. As long as this occurred, we would consider any human-related take to have had a negligible impact on the species.

Method G —- We could also attempt to use population parameters such as adult survival directly. For example, adult survival has been cited as the most important factor affecting the rate of population growth or decline. Additionally, the definition of "negligible impact" in our regulations refers to effects on survival and recruitment. We know that the Upper St. Johns River and Northwest subpopulations have annual adult survival rates that are very high. We also know that the annual adult survival rates for the Atlantic Coast and Southwest subpopulations are much lower, and are at or below levels necessary for achieving population growth and our recovery goals. We could, therefore, say that human-related take would have a negligible effect on the manatee population if we could measure a statistically significant increase in adult survival rates in the Atlantic and Southwest populations over the 5-year life of the regulation, as compared to the period preceding the regulation. We would also state that there should be no significant change in the adult survival rate in the Upper St. Johns River and Northwest subpopulations.

None of the above methods meet all the criteria; therefore, it may be necessary to use a combination of methods. For example, we may use something like Method G above in terms of establishing our overall goals and success criteria for the regulations, but use something like Method F to track year-to-year progress and make short-term management decisions.

The question before us is, "How can we best use what we know about manatees to determine the level of incidental take that would have no more than a negligible impact on the manatee?"

The Use of Models to Achieve Management Objectives

Summary by Dr. Timothy J. Ragen, Marine Mammal Commission

The topic discussed in this session was the use of models to address management objectives and, more specifically, to assess the status of the Florida manatee. The session began with attempts to define the term "status." Several views were put forth, all of which were at least somewhat related. One view was that, in a realistic sense, the official status of the manatee is a policy decision resulting from a series of judgments by officials with responsibility for such decisions. Proponents of this view noted that the reliance on policy judgments was due, at least in part, to the lack of information on the manatee population, and research and recovery efforts should focus on providing the information needed for management purposes. Another view was that "status" is a description of a species as best indicated by its present trend, whether increasing, decreasing, or stable. Although it was not stated directly, the importance of the trend of the manatee population is that it could be construed as an indication of the status of the species in the future. These views were put forth by Federal and State managers mindful of the needs for better information on manatees as well as the practical realities of endangered species management in the complex public and political arenas where the question of status is debated.

A third view essentially combined the first two to suggest that status can best be determined by taking advantage of all the available information to project the manatee population into the foreseeable future to determine its potential trends and the likelihood of extinction based on those trends. This view is consistent with the Endangered Species Act, which identifies threatened and endangered species on the basis of their likelihood of becoming endangered or extinct (respectively) in the foreseeable future.

The utility and reliability of this approach depends heavily on the information and methods for projecting the population into the future, and considerable discussion in this session focused on the question of how best to conduct projections that are of sufficient reliability that they can be used for management purposes. To be realistic, such projections should include all those factors that will determine the future trends of the species (e.g., life history traits such as stage-specific or, preferably, age-specific survival and reproduction rates, information on health and condition of animals [as it affects survival and reproduction], trends in quality and quantity of habitat, natural threats to the population, human-related threats, and the effects [both positive and negative] of management.) The projections must account for the effects of each of these factors singly and in combination, as their cumulative effect will determine the status of the species or its likelihood of extinction in the foreseeable future. The projections also must take into account the fact that some of these factors and their effects will change over time. As was pointed out in the discussion, the human population in Florida is expected to double in the next 30 years, and human-related threats to Florida manatees may increase in a corresponding manner. The difficulty of projecting into the future was emphasized by one participant who suggested that perhaps the most important determinants of manatee trends in the foreseeable future will not necessarily be related to manatee biology, but rather to socioeconomic and sociopolitical factors that will determine human demographics and activities in the future.

In effect, modeling provides a mechanism to use all available information about manatees and the factors that affect its population trends to project the species' status into the future and assess the risk of extinction. Based on such information, managers can then estimate the level of risk to the species and identify and implement strategies to minimize that risk while having the least practicable effect on related human activities. A related benefit of this approach is that models can be used to identify areas of significant uncertainty or areas where further research is needed.

Participants in the discussion were particularly mindful of the assumptions and uncertainties involved with such a modeling approach. Modeling approaches, such as population viability analysis, are designed to reflect such uncertainties by presenting their results in a probabilistic rather than deterministic manner.

In view of such uncertainties, the discussion then shifted to focus on the question of who should shoulder the burden of proof when management decisions must be made on the basis of uncertain information. One participant initiated this discussion by suggesting that the burden had apparently been shifted from proponents of potentially harmful activities to advocates for manatee protection. A second participant suggested that the burden of proof question applies more to the public interest than to the interest of manatees. A third participant pointed out that the burden of proof question had been resolved in the Endangered Species Act as interpreted and upheld in the courts, and that the more difficult question was the standard of proof. The standard may be best characterized in terms of the risk to the species, and risk is most usefully evaluated in terms of comprehensive models that take advantage of the best available information and attempt to project the likelihood of future trends, including extinction. Population viability analyses are an example of such modeling efforts, and although the limitations of such models are widely recognized, they provide the best known approach for projecting a species into the future to determine its status.

Finally, several participants emphasized the importance of educating and involving the interested public regarding management and science related to assessment of manatee status and other management objectives. In view of the present uncertainty about the status of the Florida manatee and the public's questions about the utility, efficacy, and necessity of various management approaches to facilitate recovery, managers and scientists should make every effort to (1) accurately explain their efforts (including modeling) to assess status, and (2) involve the interested public to ensure that they are well informed about management and research efforts and have suitable opportunities to participate in the management process. As one participant noted, the effectiveness of various laws and regulations in achieving manatee recovery will depend heavily on compliance by stakeholders and the public, and such compliance is more likely from a well-informed and actively participating public.

Question and Answer Session

Q. Why is PBR important now; was it used in the past?

A. Pete Benjamin: We have calculated PBR for manatees in the past and it has been used for other marine mammals. I don't think that the PBR we use today (based on estimates of maximum reproductive rate and minimum population size) are very useful given what we know about manatees—it doesn't make use of most of the best available information for manatees.

Q. Is PBR key to the final decision on negligible impact?

A. Pete Benjamin: I didn't mean to imply that.
Dave Hankla: Legal questions have spurred us to promulgate the rule as soon as possible. There are concerns that Federal agencies, particularly the Army Corps of Engineers, are taking manatees in the course of their operations. The objective is to determine negligible impact, not necessarily by using PBR.

Solange Brault: At least for the species protected under the MMPA that are reviewed by the National Marine Fisheries Service, the number of annual takes is reported annually. Right now there is nothing to replace PBR. If the number taken is above PBR, then a clock starts ticking. Under the MMPA, a take reduction team must be formed within 6 months to come up with a set of recommendations or changes that lead to a reduction in take. If the team cannot come up with a plan in 6 months, then the Federal government can come in and establish a plan. The reduction team is made up of many stakeholders. When there is a plan that is agreed upon by the take reduction team, the Federal government implements it. They must monitor the effect of the plan and conclude whether the plan has a positive reduction in take. The point is not having a take that is unrealistic, like one animal every other year. The point is to start a process to get close to an appropriate value for take.

Q. If incidental take was exceeded what would happen? This question was answered in part by Solange Brault. What has USFWS considered?

A. Pete Benjamin: This presents a bit of a conundrum. Take has been going on for years and it is all unauthorized. What happens if we do authorize a certain level of incidental take and it is exceeded? It will put us where we are now, and the Service and other agencies would continue to face liability. The goal of the rule-making would be to devise a set of measures that agencies can enact to ensure that the authorized level of take is not exceeded.

Q. Have you considered implications of this rule-making on the manatee population in Puerto Rico?

A. Pete Benjamin: No.

Q. Are we allowed to separate the manatee population into subspecies?

A. Pete Benjamin: The Antillean and Florida manatee are treated as separate stocks.

Q. The Federal agencies in Puerto Rico are the same as those the USFWS deals with in Florida, so when they evaluate projects they tend to look at the Florida manatee, not the Antillean manatee. This affects what we do in Puerto Rico.

A. Pete Benjamin: True.

Comment. We in Puerto Rico are concerned with what USFWS is doing in Florida because we only have about 100 manatees, which could make it more difficult to recover the species than in Florida.

Q. Given the definition of "take" under the MMPA, how do you ever know the number of animals that are taken by these activities?

A. Pete Benjamin: We don't. It is better, maybe, to look at a threshold, adult survival for example, rather than a body count to help us understand take. There is a certain amount of take caused by collisions with vessels that does not lead to direct death. It may be possible to, for example, measure the rate of new scars as a measure of sub-lethal take. Harassment would be very difficult to measure.

Q. When dealing with sub-lethal forms of take, would it be reasonable to assume that the same types of activities that lead to the death of a manatee are the same that cause sub-lethal affects?

A. Solange Brault: No. For example, boating activities affect habitat which we are not thinking about. If we consider the right whale, which is in a very similar situation as manatees, hits by boats are a form of take. There is such a thing as a harassment permit. Scientists must get harassment permits to study manatees.
Dave Hankla: When a manatee is struck and killed by a boat, the boater did not intend to disturb or kill the manatee. Part of this complex scenario is - who is responsible? Is it the boater, the county, the agency that authorizes the operation of the boat or established the regulations on the water? We have this standard that the law sets and we have these data about manatees. We as managers must make the two meet. What do we have in terms of information in hand that will allow us to make defensible decisions about negligible impacts?

Q. When we look at all the boats that operate in Florida and all the deaths that occur and all the animals that are scarred, and the effects this may have on calving, when you add all this up, aren't you setting us up to fail because there is no way to not violate the take limits?

A. Pete Benjamin: Maybe. The law directs us to do this. We need to first attempt to apply the letter and spirit of the law before we decide that we can't. Congress set a clear goal for manatee protection and we are tasked to try to achieve it.
Dave Hankla: There are a variety of outcomes that are possible. Regulations could be issued in some places and not others. Regulations could be issued to some agencies and not others. The litigation that was mentioned has already happened. We should go though the process to at least see if we can succeed. We can't go to the magistrate and claim it was too complex so we didn't try.

Q. Can Mike elaborate on the stage-based model and the problem of density dependence?

A. Mike Runge: I was referring to assumptions of PBR calculations, like density dependence. PBR calculations use the maximum reproductive rate (r_{max}). In order to do something similar with our own models, we would need to know more about density dependence effects than we currently do. Use of a stage-based model might help calculate r_{max} , which feeds into using the PBR technique.

Q. Comments on r_{max} or PBR?

A. Dan Goodman: The problem we are facing is not confined to manatees and defining negligible impacts under the MMPA; it affects all environmental regulations. Viewed uncharitably, Congress has saddled us with lots of lofty language, but has not provided information on where to draw the line. We may wish to give them the benefit of the doubt and wonder what they were thinking. They are lawyers, not scientists. Lawyers believe that there are effects and some of these are so small that we wouldn't hold anyone accountable. One attempt to look at contexts where effects have been turned into a number is the EPA's standard on super-fund sites for tolerable residual pollutant level. This level is 1 in 1 million for long-term cancer exposure. The justification for this level is unknown. There are other standards, OSHA for example. If we are going to come up with a defensible standard for negligible impact, there are 3 properties: (1) framed in terms of a consequence that we care about (extinction), (2) framed in terms of the probability of that consequence occurring, and (3) the probability of extinction (vs. an individual dying) occurring needs to be very low. There are some precedents being worked out now with respect to ESA and MMPA that apply these properties. One can apply quantitative standards to defining recovery under the ESA, based on the PBR, e.g., (1) have 95% certainty of recovery in one hundred years or (2) have 95% certainty that recovery would not be delayed by more than

10%. Is this language acceptable? If so, build the best PVA model possible based on our knowledge of manatees. We should look at the carrying capacity of the system, not only for manatees, but also for human activities.

Comment. Pat Rose: The reason this is an issue is because the management strategy that USFWS was using began to change. They took a position that how many boats are in the water is not important, it's only how they behave after they are in the water that matters. Many considered this a formula for disaster because we would always have to deal with an unlimited number of boats with increasing regulations. We should look at the carrying capacity of the system, not only for manatees, but also for human activities.

Q. Dan proposed putting together the best possible PVA analysis. If that is true, could the parameters that we talked about today be used in our PVA models?

A. Yes.
Comment. Solange Brault: Concern is about the time frame. We were discussing this morning a 10-year horizon and this is probably not an inappropriate time frame for accomplishing a PVA. If we want to do this in a shorter time frame, then we need another tool to evaluate take. That tool is PBR.

Q. Regardless of what method we use to define negligible impact, it doesn't make sense that we can't come up with some figure for vessel-related activity. Why not total mortality or total human-related mortality?

A. Pete Benjamin: The law says we authorize incidental take for a specific activity in a specific geographic area, in this case watercraft-related take in Florida. It does have to be put in context and the law does require discussion of watercraft-related take as it relates to overall take, but we authorize a specific type of take.
Tim Ragen: There are a number of laws here. If you authorize take under MMPA you will still have to do a section 7 consultation under the ESA. You cannot consider this authorized activity in the absence of other information. Even with the MMPA, aside from negligible take, there are other standards, small numbers of take or reporting for example. When section 7 consultation happens it will be critical because the same agency will be both the action agency and the consultation agency, which can lead to an inherent conflict of interest. USFWS will need to provide for independence with the consultation. However USFWS goes forward, it needs a sound rationale that will have to encompass every bit of information, including models. The model that Dan mentioned earlier is important because you need to understand performance of the models and the benchmarks. They need to be explored very carefully. We are talking about a quota system vs. a risk minimization approach. The effect on the species needs to be clear. Quotas can be exploited by users. Focus on the species, not so much on the pressures like boating. We went through some incidental take authorizations for other marine mammals. Distinguishing forms of mortality from take is difficult. However, if you don't get a handle on the kinds of take, it doesn't mean that it doesn't occur.

Gil McRae: Quick clarification on the use of absolute mortality numbers. Are these numbers useful to look at trends? Yes, but a qualified yes. The establishment of speed zones is a useful application. I was trying to imply that the mortality history in an area is an important part of evidence in establishing speed zones. This is not the only evidence used.

EXPERT ADVISOR'S COMMENTS AND RECOMMENDATIONS

Edited by Dr. Lynn W. Lefebvre, U.S. Geological Survey

Advisory Panel: Dr. Solange Brault, Dr. Daniel Goodman, Dr. Aleta Hohn, Mr. Fred A. Johnson, Mr. Gil McRae, Dr. Helene Marsh, Dr. James D. Nichols, Dr. Kenneth H. Pollock

DANIEL GOODMAN

What questions are the review team supposed to answer? I will propose what I think are some of the management questions and grade them according to how well research has helped to answer them:

1. At what rate is the population growing or declining? A

2. What role does watercraft play in influencing the rate of population change? B

3. What will the effect be on the manatee population of shutting down powerplants in x years? Maybe an F

4. In 30 years when the population of humans has doubled, increasing pressures on aquatic habitats, what will that mean for the manatee? Maybe an F

The workshop discussions successfully raised the importance of manatee population and habitat assessment, and planning to develop a comprehensive model that can contribute to decision making. We have many of the pieces and just need to assemble them.

SOLANGE BRAULT

We do have a framework for evaluating population trends and thinking about effects of management actions on populations. Workshops such as this one facilitate people working together and evaluating each other's work. In future workshops, the goal should be to demonstrate clear progress in linking management and research.

Timeliness is important. Aleta said earlier that lack of a current, complete model is not a reason for delaying management action. Inertia is not an option at this point.

Given that we are talking about a species at risk of extinction, the primary framework should be the biology of this species. The social concerns should be a part of the equation, but we need to focus on the life-history and biology of manatees.

GIL McRAE

We can improve the way we answer questions about manatee status. First, status can be thought of in both the long- and short-term. Will the population be able to sustain itself without human help? If so, this ability would represent long-term persistence. Managers are more typically dealing with issues that may be getting better or worse over much shorter time periods; e.g., 3-5 years.

Second, status is clearly related to threats—are they increasing or decreasing, and what is being done about them? We need to focus more on threats in a risk assessment context. We can do better at management and research collaboration, at the State level and beyond. Merging of research approaches (e.g., those used by Runge and Ackerman) may be the best strategy.

The manatee population in some areas of the State is much better studied than in others. It is much more difficult to gather typical photo-identification data in some areas than in others. For those areas in which we can't do photo-identification, we need to be creative and try other methods that we can logistically implement.

FRED A. JOHNSON

It seems to me that manatee conservation is first and foremost about making decisions. These decisions are difficult and controversial. First, there is disagreement on the ecological consequence of the decisions or ambiguity about how we value the consequences, which are driven by social values. In my experience with manatees, it is difficult to identify which source of ambiguity is the primary culprit. I implore the collective to try to be a lot more explicit or systematic about the process of decision making that occurs at various scales and how we would involve researchers in the process.

For part of the decision process, where the focus is on the science, there seems to be a bit of preoccupation with past status and trends, and probably not enough about predicting future status and trends, given what managers can control and cannot control (e.g., hurricanes). In making good predictions, we need more synthesis than what we discussed this week. We should try to take these different sources of information and mold them into a statistical framework for which biases can be quantified. Retrospective studies can be used to explore hypotheses about the importance of various stressors on manatee dynamics. We need to go from a simple description of ecological patterns to an explanation of the patterns. In reviewing some of the methods and procedures used to determine population status, I see that there is often a reliance on things that are unproven; e.g., on indices where biases are rampant. We need to move away from these.

We need to rethink how managers and researchers work together. It should be an integrative endeavor. Management decisions are an opportunity to improve our ecological understanding. In trying to do this, one often runs into institutional and sociological barriers. We need to grasp a conceptual framework and find the time to think strategically and avoid reactionary management.

Communication, which might be beyond the scope of this conference, has many problems. Researchers are primarily responsible for providing information, not necessarily communicating with the public. Managers need to seek more help in communication strategies. We have tried this in the adaptive-management driven waterfowl program. Finally, the ease of communication should not be used as a criterion for scientific work.

JAMES D. NICHOLS

As far as the parameter estimation work that is going on, it seems to me that the researchers involved are to be commended. I was also particularly struck by the importance of the boat-related mortality data. There is potential to do some integration of the MIPS and carcass recovery data.

Estimates are not helpful by themselves. We are interested in status and, more importantly, how can we make estimates under real-life changing conditions? For example, what are the effects of management actions on the population? A primary objective for research should be to look for more opportunities to integrate research and management so that we can explore effects of management actions.

The question of how vital rates are influenced by management actions can be thought of as an estimation problem. Another way to address this question would be to bring in other stakeholders or control systems, and cast them conceptually in competing models to compare different hypotheses. Researchers can develop monitoring programs to help determine which hypotheses make more sense. There will always be models that no one is happy with, and rarely one that everyone is happy with. Integration among researchers, managers, and stakeholders is needed.

KENNETH H. POLLOCK

I agree with others that there are serious problems in coordination among researchers, managers, and stakeholders. This means that the objectives are not clear, which makes it difficult for modelers and statisticians.

I am interested in the scale for which the models operate and this is also not clear, due in part to unclear objectives.

Managers and researchers need to be proactive; they need to design research with questions in mind.

Specific comments:

Aerial survey data and counts. People like to rely on counts because they are easy to collect and folks can come up with models that rely on the counts. Changes in population size and detectability over time are confounded. You can do fancy statistics in an attempt to separate them. However, they still appear to be confounded. You need to look at detectability. Some researchers have started this work, and need to continue to do so. Otherwise, aerial survey data will remain unclear. This lack of clarity was mentioned 10 years ago and the problem is still there.

Counts and sampling effort. Winter surveys are focused on powerplants because that's where the animals are. However, you need to sample everywhere. Why not sample everywhere during the synoptic counts? Consider adaptive sampling where you have clustered rare populations. There is lots of research on adaptive sampling; check fisheries literature.

Photo-identification—Monitoring the status. This work is going well—emphasis should be increased on how to estimate changes in rates given changes in land use or management actions.

PVAs. I hope that this work goes ahead. The functional form is not clear and elements of population dynamics are not clear, like density dependence. This will be crucial to the future work.

HELENE MARSH

I envy the long-term data sets, primarily in photo-identification, that are available for manatees. I am impressed with the work that has been done with the data. A high priority should be the maintenance of that program. I am disappointed that the problems associated with aerial surveys have not progressed since the last workshop. There are a lot of opportunities to improve those counts. As Ken Pollock pointed out, there is confusion between attempting to count the most animals (the broad-scale synoptic survey approach) and obtaining population estimates. Getting the best estimates should be the priority. I was interested in Tim's advice with respect to the ESA and habitat. Research on manatee/habitat associations is vital. Lots more could be done. I am less worried about the classification of a species' status (e.g., as endangered or threatened, etc.). The status of the manatee will always be of concern. Therefore, it is important that we consider listings as artificial constructs that should not drive management priorities. It is important that managers, scientists and stakeholders all get involved in setting strategic priorities of research. If stakeholders are involved in setting goals, they are more likely to be committed to the outcomes of the research. In the U.S., society tends to resist rules, so we need to rely on stakeholders to follow the law. Stakeholders, therefore, need to trust that the decisions are principled.

<u>ALETA HOHN</u>

I endorse the comments of the panel. I also want to review the points that John Reynolds made in his opening talk, referring to progress made since the first manatee recovery plan: (1) things have gotten better; (2) bringing in outside experts helps the program; (3) there are long-term databases; and (4) state-of-the-art methods have been developed for estimating survivorship. We will need to apply a variety of tools in assessing stocks. Visibility of the manatee issue has to be kept in mind while we move forward. Lawsuits can create stress but also opportunities. I think that we can look at the current situation positively despite the stress caused by lawsuits.

Sufficient resources need to be appropriated to address the key questions. The manatee situation is similar to some marine mammal/fisheries scenarios in terms of inadequate resources and direction.

SUMMARY

The Manatee Population Ecology and Management Workshop was held in Gainesville, Florida, during April 2-4, 2002. The goal of the workshop was to better understand and integrate the roles of research and management in achieving recovery of the Florida manatee. Approximately one hundred people participated in the workshop. The results of new data analyses were presented, and a group of scientists with expertise in wildlife population assessment reviewed the current techniques used to assess manatee population status. Participants were a mixture of research and management biologists from agencies, institutions, and private organizations, as well as representatives from environmental and boating groups.

Research presentations were arranged to provide approaches and results on five major topics: population models, survival estimation, causes of death and mortality estimation, reproduction, and population structure.

John Reynolds gave the first of 14 presentations, briefly reviewing the history of manatee population research and its application to manatee recovery efforts. He emphasized that we have more and better quality data on Florida manatees than on any other marine mammal. He also pointed out that long-term manatee data sets, some of which date back to the late 1960s, increase in value over time. The quantitative population criteria that appear in the third revision of the Florida Manatee Recovery Plan were based on analyses of long-term life history data, published in the proceedings that resulted from the 1992 Technical Workshop on Manatee Population Biology (*Population Biology of the Florida Manatee,* 1995, O'Shea, Ackerman, and Percival, eds., copies available from USGS or FWC).

Among other research findings, biologists reported new information on the age structure of dead manatees, adult survival rates, reproductive rates, and use of models to determine population growth rates. Although the workshop did not attempt to incorporate habitat and carrying capacity issues, the need to integrate population and habitat data was voiced by both researchers and managers.

During the morning of the second day, four concurrent working group sessions reviewed the following research approaches: (1) survival estimation based on long-term resighting data; (2) population status based on mortality database and distribution; (3) estimation of reproductive parameters based on long-term resighting data and examination of carcasses; and (4) population trend estimation based on aerial surveys.

On the afternoon of the second day, all participants reconvened to review the results and recommendations of each working group. During the morning of the third day, all workshop participants reviewed management information needs in light of the recommendations developed in the population ecology session, and developed recommendations for enhancing integration of research results with management actions.

The reviewers were unanimous in their rejection of the synoptic survey data as a means to determine population trend. Helene Marsh and Ken Pollock expressed disappointment that methods to deal with bias problems associated with aerial surveys have improved little since the last population workshop was held in 1992. However, several managers felt that having some idea of the minimum population size was useful. Use of aerial surveys to determine manatee distribution and habitat association was strongly supported by both researchers and managers.

The panel of advisors recommended that future studies be designed to better understand causal relationships between management actions and population response, rather than simply being retrospective. Examples would be development of an adaptive management model to evaluate the potential impacts of changes in warm-water availability on manatees, and determining efficacy of management actions to reduce deaths caused by manatee/watercraft collision.

Dan Goodman emphasized that managers will need to trust complex models that integrate information from different data sets in order to make sound decisions. The influence of habitat quality and nutrition on reproductive rates must also be incorporated. Gil McRae highlighted the link between manatee status and threats, and the need to focus more on risk assessment of specific threats, such as watercraft collision-related mortality and potential loss of warm-water habitat in the winter.

Solange Brault, Gil McRae, and Aleta Hohn expressed concern about the lack of information on manatee reproduction in the Southwest region. They cautioned against extrapolating parameter estimates from other regions to the Southwest, and suggested that genetic markers and other tools need to be further developed to understand potential differences among regional groups.

The reviewers and many other participants believed that Population Viability Analysis (PVA) would be the best way to integrate available data sets and estimates to develop a forward-looking projection of manatee status. The impact of human population growth in Florida (projected to double in the next 30 years) cannot be overlooked in development of a manatee PVA.

The reviewers unanimously called for better communication among managers, researchers, and other stakeholders concerned with manatee recovery issues. This workshop was a huge step in the right direction, but continued commitment to improve communication is essential to allow managers and researchers to work together in a truly integrated way. Fred Johnson and Jim Nichols emphasized the need to avoid reactionary management and take the time to develop a conceptual framework of management needs and research priorities that is mutually satisfying to researchers, stakeholders, and managers.

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