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Authors
Bauer, Gordon B.
Colbert, Debborah E.
Gaspard III, Joseph C.

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Learning about Manatees: A Collaborative Program between New College of Florida and Mote Marine Laboratory to Conduct Laboratory Research for Manatee Conservation

Gordon B. Bauer
New College of Florida, U.S.A.
Mote Marine Laboratory, U.S.A.

Debborah E. Colbert
Association of Zoos and Aquariums, U.S.A.

Joseph C. Gaspard III
University of Florida, U.S.A.
Mote Marine Laboratory, U.S.A.

Research with captive manatees initiated as part of a New College of Florida class project at Mote Marine Laboratory has yielded a wide range of research with substantive implications for management and conservation. Our training program directly supported investigations of blood chemistry, immune function, stress-related physiology, respiration, thermoregulation, and behavioral ecology. Our investigations of sensory processes included studies of visual acuity, color vision, passive and active touch, auditory frequency detection thresholds, auditory temporal processing rates, hearing in noise, and sound localization. Undergraduate and graduate students involved in this program have been successfully mentored in sensory processes, animal behavior, and conservation. Further validation of the educational benefits of studying captive manatees awaits formal research on attitude, behavior change, and public policy related to protecting manatees and other marine mammals in natural settings.

The work we have described was a team effort. In addition to the authors, the core of that team also included David Mann, College of Marine Science, University of South Florida and Roger Reep, University of Florida. Wendi Fellner contributed strongly at the beginning to establish the manatee program. New College students and Mote staff, interns, and volunteers were pivotal in getting the project off the ground. After the first few years of the project we were able to hire full-time trainers who contributed not only to training manatees but also to teaching undergraduates. These trainers included Brandy Littlefield, Jennifer Leach, Kim Dziuk, Adrienne Cardwell, and LaToshia Read. Heidi Harley and Donna Bauer contributed valuable critical comments on earlier drafts of this manuscript. Professor Harley has also always been available to offer her insights on our manatee research. Wolf Hanke has been a valuable consultant to the project. Guido Dehnhardt and Ulrike Griebel loaned us equipment and provided encouragement. Pritzker Marine Laboratory of New College of Florida has also provided equipment. We thank Randy Wells, who first invited one of us (GBB) to join Mote Marine Laboratory as a researcher, and John Reynolds who has supported our research within the Mote and marine mammal communities. Funding for research has been provided by the Florida Fish and Wildlife Conservation Commission, Columbus Zoo Conservation Fund, Research and Creative Scholarship Award from the University of South Florida, New College Faculty Development Grants, Walt Disney World Animal Programs, University of Florida College of Veterinary Medicine Aquatic Animal Health Program, National Science Foundation Grant, IOS-0920022, and the Enander and Thurell families. All of the sensory research was conducted under a series of permits to Bauer from the US Fish and Wildlife service, MA837923. Correspondence concerning this article should be addressed to Gordon B. Bauer, Chair, Division of Social Sciences, Peg Scripps Buzzelli Professor of Psychology, New College of Florida, 5800 Bay Shore Road, Sarasota, FL 34243, U.S.A. (bauer@ncf.edu)

In 1998 two of us (GBB and DEC) initiated a research training program at Mote Marine Laboratory with resident manatees, Hugh and Buffett. The program began as a class project including New College of Florida[1] students plus Mote interns and volunteers. The lines of research that this academic project generated have contributed to conservation goals as described in the Florida Manatee Recovery Plan, FMRP (U.S. Fish & Wildlife Service, 2001), a required document for federally endangered species (Endangered Species Act of 1973, 16 U.S.C. 1531 *et seq.*), and provided hands-on educational opportunities for students in psychology, biology, and environmental studies. In the years since, we have conducted research directly on sensory processes and our training program has supported additional studies on physiology and ecology. This paper is not a comprehensive review of manatee biology; rather, it is a survey of the research we have conducted at Mote Marine Laboratory, emphasizing examples of the opportunities we have had to learn about manatees and contribute findings important for their management and conservation.

The long term goals of our program have been to contribute to conservation through augmenting knowledge of manatee biology and increasing dissemination of information through education. Our biological research focused on two areas: 1) Training for husbandry and physiological research and 2) Investigation of sensory processes (FMRP, Objective 2.5, U.S. Fish & Wildlife Service, 2001). The education component of our manatee program emphasized undergraduate and graduate education with students from New College of Florida, University of South Florida, and University of Florida. Mote Marine Laboratory and Aquarium also provides an opportunity for researchers to engage the public directly through education (K-12 and adult) and public outreach (Mahadevan, 2007), areas of interest we will be assessing in the future.

Training for Husbandry and Physiological research

Our initial focus was on training the two, captive-born, male resident Florida manatees (*Trichechus manatus latirostris*), Hugh and Buffett, for health assessments by the veterinary staff. This focus served the first priority for keeping captive animals, maintaining their health. Furthermore, it served as a gateway for research on health-related issues. Investigations of the health of individual manatees contribute to understanding health issues in the population (FMRP, Objective 2.5, U.S. Fish & Wildlife Service, 2001), as well as developing more effective practices for maintaining captive animals. Hugh and Buffett were the subjects for all the behavioral studies to be described, although in some cases work was supplemented with additional manatees. Hugh was 13 and Buffett 11 years old at the beginning of training, and both remained healthy throughout the period of our investigations.

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[1]In 1998 New College was an autonomous unit within the University of South Florida. In 2001 it became independent as the 11th member of the State University System and changed its name to New College of Florida.

Good husbandry practices were certainly observed before we started our work, but with substantial effort and some risk to animal caretakers and stress to the animals. For example, in order to draw blood, manatees were dry docked and held stationary by large numbers of staff. Clean urine samples were obtained opportunistically and infrequently. Also, the difficulty and cumbersome nature of these procedures reduced their effectiveness as platforms for doing research that required frequent (e.g., daily) measurement of physiological parameters.

Our initial training efforts were directed toward bringing the manatees under stimulus control so that basic physiological assessment procedures could be conducted with the voluntary, stress-free participation of the subjects. In this case, stimulus control refers to training the animals to perform behaviors in response to specific signals: visual, auditory, or tactile. Subjects were successfully trained for weighing, morphometric measurement, venipuncture, urine samples, rectal core body temperatures, ultrasound for blubber thickness, and respiration volume and flow rate (Colbert & Bauer, 1999; Colbert, Fellner, Bauer, Manire, & Rhinehart, 2001). With this basic training foundation, supplemented with additional training procedures in some instances, we were able to contribute to the knowledge base for manatee blood chemistry (Manire et al., 2003) immune responses (Walsh et al., 2007), adrenocortical function (Tripp et al., 2010) respiration (Kirkpatrick et al., 2003), and thermoregulation (McCully et al., 2005).

Physiological Research

Blood chemistry, stress, and immune response

After manatees are released they exhibit a troubling characteristic, high serum creatine levels. Creatinine is a product of protein metabolism and usually an indicator of renal failure. However, when some of these manatees were recaptured they showed no evidence of kidney problems. Since rehabilitation of manatees to the wild contributes to maintaining the population of these endangered animals, the possibility of losing individuals to renal failure posed a serious concern, although lack of direct evidence of kidney failure was perplexing. Manire et al. (2003) addressed this conundrum with a study of the trained, Mote manatees. They manipulated four variables, salinity, food quantity, food type, and simulated transport, while assessing blood and urine parameters. This important study indicated that the high creatine levels were related to decreased food intake and changes in food type, both of which interacted with salinity level, but apparently were not associated with renal failure. A collateral finding was that dietary restrictions and changes in salinity potentially impaired immunity as indicated by lymphocyte proliferation assays. Based on this study, Manire and colleagues suggested that health threats might be reduced by pre-release exposure to the diet and salinity of the release site. In addition, the voluntary stress-minimizing, venipuncture procedures provided a time line for the development of cortisol responses associated with transport, a useful finding for assessing stress related to release.

Stress affects immune function. One of the important mediators of vertebrate immune response is nitric oxide (NO), but its role in the immune systems of marine mammals was unknown. As part of a broad, multi-site investigation, including captive and wild subjects, Mote manatees provided repeated blood samples which allowed the determination of optimal times for nitric oxide production by blood mononuclear cells (PBMC) following stimulation by LPS, TNF-α and IFN-γ, recombinant human proteins (Walsh et al., 2007). This research contributed importantly to discussions of how environmental stressors, such as red tide and cold water, can lead to immunosuppression, pathology, and death of manatees (Halvorsen & Keith, 2008).

Sometimes Hugh and Buffett did not provide unique contributions, but formed part of a larger subject pool. Such was their participation in a study of adrenocortical function, where they were two of a larger group of captive manatees compared to free-ranging and rehabilitating manatees (Tripp et al., 2010). Adrenocortical function is integrally related to immune function, and therefore important for understanding how various stressors may affect health. Low cortisol and ACTH levels, indicative of low stress, were found in the captive, healthy animals, including Hugh and Buffett, in comparison to unhealthy animals, free-ranging animals peracutely stressed from capture, and short-term rehabilitated animals.

Respiration

Large numbers of manatees are killed by exposure to brevetoxins from harmful algal blooms such as red tide (Bossart et al., 1998). To understand how brevetoxins are deposited in the lung and impact respiration, Kirkpatrick and colleagues (2003) initiated a study of vital capacity and flow rates. Although manatee lung anatomy was well known from post-mortem investigations (Bergey & Baier, 1987), the mechanics of respiration of live manatees were not. Building on the Mote manatees' core, trained behaviors, Gaspard and Colbert (2004) trained Hugh and Buffett to breathe into a resuscitation mask attached to a spirometer, which allowed measurement of lung mechanics. Although vital capacities were not obtained in this study, results indicated high volumes and flow rates accompanied by short inspiratory and expiratory durations. In another example of a fortuitous collateral finding, Kirkpatrick and colleagues (2003) determined that there was a positive correlation between lung volume and body size, a relationship important for determining anesthesia dosages for surgery on manatees.

Building on the respiration training, Rasmussen captured exhalation samples from Hugh and Buffett in a vacuum canister attached to the resuscitation mask for the purpose of determining the chemical composition of manatee exhalations. Unfortunately, Dr. Rasmussen died, apparently before she was able to complete this work. Similar work with elephants, a manatee terrestrial relative, has led to important contributions in our understanding of elephant reproductive cycles (e.g., Perrin, Rasmussen, Gunawardena, & Rasmussen, 1996). We expect that Dr. Rasmussen would have been able to contribute similar knowledge about manatees.

Cold stress and thermoregulation

Cold stress syndrome accounts for numerous manatee deaths and traumatic injuries (Bossart, Meisner, Rommel, Ghim, & Jenson, 2002). The current year, 2010, presents an especially bleak example with 237 deaths, 42% of the known total, attributable to cold stress occurring during the first half year (Florida Fish and Wildlife Conservation Commission, 2010). Despite the clear threat of low temperatures little was known about manatee thermoregulation when we began our research.

Manatees are tropical animals not well suited to the low temperatures of Florida winter waters (Reep & Bonde, 2006). They rely on natural and artificial warm-water refugia, such as natural springs and power plant outflows, to avoid long exposures to dangerously cold water (less than 19° C). Cold stress may become an increasing threat as these refugia disappear (e.g., warm water will become less available if obsolete power plants are shut down for economic reasons). McCully and colleagues (2005) initiated investigations of manatee thermoregulation that can inform potential management decisions related to the loss of warm water habitat. They reported on heat flux rates, thermal windows (body areas of high heat loss), and easy-to-assess metabolic rates in Mote's two manatees. Surface temperatures were easily measured as Hugh and Buffett were trained to position themselves for measurement with a heat flux transducer. However, investigation of internal thermoregulation by manatees required the training of a new behavior, intubation (Gaspard & Colbert, 2004). Subjects were trained to open their mouths and accept a vinyl stomach tube to be inserted down the throat and esophagus 50 – 60 cm. An iButton, a high-resolution temperature logger housed in a small stainless steel, cylindrical container about as large in circumference as a dime, was then inserted into the tube, and delivered to the digestive track by abruptly increasing pressure in the tube. The iButton then passed through the digestive system and was expelled with feces, where it was recovered and the data from the temperature logger downloaded. These digestive track measurements provided accurate measures of core temperatures and indicated a significant amount of heat generated in the hindgut (Mote Marine Laboratory, unpublished data).

Behavioral Ecology

Our training program to establish basic control over manatee positioning and maintenance of posture facilitated laboratory pilot work for the use of CRITTERCAM to investigate behavior in the wild (Adimey, Abernathy, Gaspard, & Marshall, 2007). CRITTERCAM is an imaging and data-collection device worn by animals, which facilitates study of free-ranging behavior and ecology. Experiments with Hugh and Buffett demonstrated the ineffectiveness of some mounting strategies that had been used with other species such as belts around the torso and suction cup attachments. The efficacy of carrying the CRITTERCAM on a peduncle belt and various modifications of that design developed at Mote Marine Laboratory have allowed researchers to study “foraging behavior, traveling, socializing, resting, respiration, and vocalization patterns” (Adimey et al., 2007, p. 13) of both subspecies of the West Indian manatee, Florida (*T. manatus latirostris*) and Antillean (*T. manatus manatus*).

Sensory Research

The FMRP (U.S. Fish & Wildlife Service, 2001) explicitly describes the need for research on sensory systems (Objective 2.5.3) and related topics that require knowledge of sensory processes including orientation and navigation (Objective 2.5.4), foraging behavior (Objective 2.5.5), and effects of sound (Objective 2.5.7), especially the relevance of boat engine sounds (Objective 2.5.7.1). The detection of boat engines is important since boats kill such a large number of manatees each year, 25% of documented deaths of the endangered Florida manatee and 35% of deaths of known cause (Florida Fish and Wildlife Conservation Commission, 2007). We have addressed these objectives and integrated them with physiological and behavioral work of other laboratories to reach a more comprehensive understanding of the manatee’s perceptual experience.

Animals know the world through their senses, and their senses are critical to their survival. They need to be able to detect key aspects of their environments, to process stimuli, and to react in adaptive ways. However, humans introduce stimuli (e.g., noise, chemicals, and turbidity) that have the potential to disrupt what animals perceive and how well they can react to their surroundings. Unless we know what manatees sense, or in some cases may fail to sense (Gerstein, 2002), it is difficult to develop effective conservation recommendations to mitigate the various influences humans have on habitats. It is imperative to understand how a manatee receives information from and perceives its surroundings if we are to avoid activities that could threaten its health and survival.

Psychophysics, which addresses the relationship between physical stimuli and sensory responses (Gescheider, 1997), is the primary type of laboratory research we conduct. The finely tuned measurements employed in this type of research are difficult or impossible to do on free-ranging manatees because of the problem of identifying individuals in complex environments, difficulty of locating phonating animals in turbid water, controlling relevant stimuli, and long length of time required, multiple years in many cases. Therefore studies of captive animals are necessary. These studies are especially useful when viewed in conjunction with field research to understand how senses might be naturally employed and with neurobiological research to understand the mechanisms for processing sensory stimuli.

What is the sensory world of the manatee? To answer this question we have pursued a broad survey of manatee senses, including visual acuity, color vision, auditory sensitivity, masking (sensitivity in noise), temporal processing, and localization, and active and passive touch.

Vision

Using ganglion cell density in conjunction with the known dimensions of the manatee eye, Mass and colleagues (1997) estimated visual resolution at 20 arc minutes. Psychophysical testing of high contrast grating stimuli in a two alternative, forced-choice procedure in bright underwater conditions indicated that one of our manatees, Buffett, had an interpolated minimum angle of resolution (MAR) closely approximating this estimate, 21 arc minutes for horizontal gratings and 23 arc minutes for vertical measured from one meter (Bauer, Cobert, Fellner, Gaspard, & Littlefield, 2003). The other manatee, Hugh, had a minimum angle of resolution over a degree; later ophthalmic evaluation suggested that Hugh was visually compromised. A lack of improvement when Buffett was tested at a closer distance suggests that manatees are emmetropic (normal refraction with focal point on the retina) or hyperopic (far-sighted, focal point in back of the retina) underwater, consistent with the conclusion of Piggins, Muntz, and Best (1983) based on anatomical data. Further support for emmetropia/hyperopia was provided by a preliminary analysis of refraction using streak retinoscopy suggesting that Buffett was emmetropic-to-hyperopic both underwater and in-air (Murphy et al., 2003). The possibility of emmetropic vision both in-air and underwater would be an unusual combination, since the involvement of the cornea as a major refractive element in air coupled with its refractive neutrality underwater should typically lead toward specialization for only one of the environments, but not both. Notable exceptions are marine mammals, where dolphins (Herman, Peacock, Yunker, & Madsen, 1975) and sea lions (Dawson, Schroeder, & Sharpe, 1987) have developed specialized adaptations for focused vision in both environments (see review in Wartzok & Ketten, 1999). Follow-up behavioral and ophthalmological work with manatees is indicated to determine if the Sirenia constitute a third group of marine mammals with adaptations for both in-air and underwater vision.

We complemented our studies of visual acuity with physiological measures of eyes recovered postmortem from manatees that died in the field or other facilities. Using an anti-photopigment labeling technique we identified short-wave and long-wave length receptors in manatee eyes (Ahnelt & Bauer, unpublished data reported in Ahnelt & Kolb, 2000). These results were confirmed by Newman and Robinson (2006), and converged with morphological (Cohen, Tucker, & Odell, 1982) and psychophysical (Griebel & Schmid, 1996) evidence to indicate that manatees have dichromatic color vision in the blue and green range. Their relatively modest visual acuity in conjunction with dichromatic color vision suggests an eye adapted for intermediate to long distance viewing appropriate for seeing patches of plants.

Tactile senses

Prominent aspects of the manatee's perceptual environment are passive and active touch. In our passive touch experiments the subject was trained to position itself in the presence of a sinusoidally oscillating sphere driven by a computer-controlled calibrated vibration shaker, which generated a carefully controlled dipole, hydrodynamic stimulus. Using a go/no-go procedure with a staircase method, we found that Hugh and Buffett could detect particle displacement of less than a micron (Gaspard et al., 2009; Mann et al., 2009) at frequencies between 15 and 150 Hz. Their remarkable ability to detect small water movements makes it probable that they can discriminate objects that divert water flow in subtle ways, as well as track major currents. A preliminary analysis suggests that this ability is mediated by the vibrissae that are uniquely distributed over the manatee's entire body (Gaspard, Bauer, Mann, et al., 2009; Reep, Marshall, & Stoll, 2002).

In active touch, Hugh and Buffett discriminated between a standard of 2 mm, equal-width ridges and grooves and alternative targets with wider gratings in a two alternative, forced-choice procedure using a staircase method. Hugh and Buffett had interpolated discrimination thresholds of 2.15 and 2.05 mm, respectively, or Weber fractions of $k = 0.025$ and 0.075. Their ability to discriminate fine textures using active touch (Bachteler & Dehnhardt, 1999; Bauer et al., 2005) suggests they might give objects careful tactile scrutiny the way we give objects visual attention. This might also put them at risk — careful, tactile scrutiny of crab traps, fishing lines, or water-control devices can be lethal.

Audition

Hearing by Hugh and Buffett was investigated using a variety of techniques. Their audiogram, the array of detection thresholds for the range of frequencies within their hearing range, was determined using a go/no-go procedure and a staircase method. They were found to detect tonal sounds across a wide range of frequencies, as high as 90.5 kHz, greater than two octaves higher than a human adult, and as low as 250 - 400 Hz (Gaspard, Bauer, Reep, et al., 2009; also see Gerstein, Gerstein, Forsythe, & Blue, 1999). Hugh's most sensitive range was 8 – 23 kHz (detection thresholds fell between 71 -72 dB re 1 μPa) Buffett's was 16 – 32 kHz (detection thresholds were between 61 – 64 dB re 1 μPa).

The auditory temporal processing rate, measured as the ability of the nervous system to map amplitude modulated tones, was determined using an evoked potential technique. Hugh and Buffett were trained to accept the insertion of needle electrodes in the dermal layer, and remain still while neural responses to auditory stimuli were measured. We found that both subjects had high auditory temporal processing rates, up to 600 Hz, which suggested that they could localize sounds underwater (Mann et al., 2005). Later behavioral studies confirmed that they could localize broadband sounds well in the azimuth plane (Colbert, Gaspard, Bauer, Reep, & Mann, 2007; Colbert, Gaspard, Reep, Mann, & Bauer, 2009), perhaps an adaptation for navigation in natural conditions where they might be able to localize surf or moving bodies of water through auditory scene analysis (see Bregman, 1990).

In a study using techniques similar to the audiogram, Hugh and Buffett were tested for frequency detection in the presence of masking background noise.

Critical ratios, the decibel difference between the tonal signal and background noise, indicated that manatees were able to hear well in noise with values ranging from 18.3 - 34.1 dB for tonal frequencies from 4 - 32 kHz (Mann et al., 2009). This sensitivity is surprisingly strong in the range in which manatee vocal harmonic complexes frequently have tonal components (4 - 8 kHz). Broadband aspects of phonations would also be localizable (Gaspard, Bauer, Reep, et al., 2009; Mann et al., 2009; Mann, O'Shea, & Nowacek, 2006; Mann et al., 2009; Nowacek, Casper, Wells, Nowacek, & Mann, 2003; O'Shea & Poche, 2006).

Extrapolating laboratory findings, understanding them within the natural ecology of manatees, and determining the impact of human intrusion will be a lengthy process. Knowledge of hearing levels can inform studies of the effects of noise on vocalizations (e.g., Miksis & Tyack, 2009) and other social behavior. We also have evidence bearing on a critical problem for manatees, injury and death from boat strikes. Examination of the manatee audiogram and critical ratios, which measure the ability to hear in noise, in conjunction with directional hearing studies (Colbert et al., 2009) and measurement of boat engine sound levels, indicate that manatees should be able to hear and locate boat engines, at least under some circumstances (Mann et al., 2009; for contrasting conclusions see Gerstein, 2002 and Gerstein et al., 1999). Field experiments (Miksis-Olds, Donghay, Miller, Tyack, & Reynolds, 2007; Nowacek, Wells, Owen, Speakman, Flamm, & Nowacek, 2004) confirm that manatees react to approaching boats, presumably a response to engine sounds.

Chemoreception

Chemoreception also needs to be explored in a rigorous laboratory environment. Reep and Bonde (2006) suggest possible uses of chemoreception by manatees in natural settings. For example, chemoreception may be important as a way to sample the environment and to select appropriate habitat. Manatees show certain habitat preferences that can be extremely specific. How might they be able to return to particular canals in Florida's canal-rich coastline? How might they detect traces of freshwater and be able to follow them to a freshwater source to drink? How might an animal be able to show site fidelity to particular seagrass beds or embayments? Acoustic and tactile cues may provide part of the answer, but chemical reception may also play an important role.

The importance of pheromonal communication has been well-established in terrestrial relatives of the manatees, elephants (Rasmussen, Krishnamurthy, & Sukumar, 2005). Manatees exhibit several behaviors that suggest chemical communication. For example, various scientists (summarized in Rathbun, Reid, Bonde, & Powell, 1995) have noted that mating herds of manatees form when roving males encounter and accompany estrous females for periods of several days. It is possible that estrogen or other chemical cues from females in estrus are detected by the males and facilitate mating herd formation (Reynolds & Odell 1991). Manatees consume other manatees' feces (Reynolds & Rommel 1996), perhaps to obtain information about reproductive status or dominance. Thus, chemoreception may play a vital role in social and reproductive behavior of manatees.

Although field observations and phylogenetic relationships suggest a role for chemoreception in manatee orientation, navigation, and reproduction, laboratory experiments are required to establish the range and sensitivity of the chemical senses. Lacking such information, scientists are unable to determine how human activities may impair manatee abilities to orient and communicate based on chemical cues. Wartzok and Ketten (1999) note specifically that a major problem with being able to assess chemosensory abilities in most marine mammals is the paucity of captive animals with which to conduct controlled experiments.

Education

Experience in our manatee program has contributed to the education of numerous college students through hands-on participation in research and husbandry. Formal testing in the classroom and production of scientific reports for course credit demonstrated that students acquired basic understanding of manatee conservation and biology, including behavior, sensory processes, cognition, ecology, physiology, and neurobiology. Furthermore, many of these students have continued on to graduate programs, post-doctoral appointments, and employment in areas such as psychology, biology, and conservation that can yield long term benefits to animals. In addition, thousands of visitors to Mote Marine Laboratory and Aquarium have viewed our manatees, Hugh and Buffett, observed our studies, viewed related exhibits, or heard presentations from our staff, including docents familiar with our research. Nevertheless, these types of headcounts and qualitative assessments do not always get at core educational questions such as, “Has experience with our manatee research promoted conservation?”

Many of us feel intuitively that viewing animals in captivity educates the public and ultimately serves to benefit species in the wild, presumably through heightened awareness and action leading to conservation (Reeves & Mead, 1999). These beneficial effects have been very difficult to verify empirically, until recently. The Association of Zoos and Aquariums, AZA (Falk, Rhinehart, Vernon, Bronnenkant, Deans, & Heimlich, 2007), and the National Research Council, NRC (Bell & NRC, 2009; Fenichel & Schweingruber, 2010), have provided excellent sources that review relevant literature, describe valid assessment techniques, and demonstrate that the types of informal education provided by zoos and aquariums do in fact yield changes in attitude and behavior that promote conservation. To our knowledge formal analysis of manatee or other marine mammal exhibits has not been reported in the peer-reviewed literature, although as a working hypothesis we suggest that the positive effects of zoos and aquariums on learning reported by the AZA and NRC should generalize to marine mammal displays.

Summary and Conclusion

The integration of the New College of Florida academic program with the manatee facilities provided by Mote Marine Laboratory and Aquarium has yielded an array of research and educational opportunities in service to manatee conservation. The Society for Conservation Biology (2010) lists a set of goals, four of which in conjunction with the FMRP serve to guide our program: conservation science, conservation management, education, and policy. We have met the science goal through our ongoing experimentation and reporting of results in professional journals and conferences. We have contributed to the management goal by providing scientific information on manatee biology to the United States Fish and Wildlife Service and Florida Fish and Wildlife Conservation Commission.

Although we have provided learning opportunities to college students since the inception of our manatee research in 1998, our educational program needs to become more comprehensive and empirically based. During the years 1995 - 2005, the percentage of known manatee deaths attributable to human-related causes was over 38% (Florida Fish and Wildlife Conservation Commission, 2007; also see Reep & Bonde, 2006 and Reynolds, 1999 for summaries). Central to reversing the anthropogenic threat to manatees—the deaths caused by boats, water control devices, fishing gear, and perhaps toxic chemical exposure (FMRP, U.S. Fish & Wildlife Service, 2001)—is the need to change public attitudes and behavior, as well as public policy affecting manatees and other marine mammals.

Research on the effectiveness of informal education about animals is difficult to do; it is not something that scientists who study marine mammals are usually trained to implement. Investigation of human behavior and policy change requires specialized skills drawn from a variety of education and social science professions including social psychology, cultural anthropology, behavioral economics, and political science.

If we are going to adequately protect manatees from natural and anthropogenic threats, we need to develop effective education programs. A first step in that process is to involve a variety of disciplines outside of the domain of animal behavior processes to assess the effectiveness of the informal education available where captive marine mammals are displayed for the public. Recent AZA (Falk et al., 2007) and NRC (Bell & NRC, 2009; Fenichel & Schweingruber, 2010) reviews now provide a framework for developing more effective formal and informal educational opportunities. Similarly, developments in political science suggest processes for translating scientific findings in the laboratory into government policy (e.g., Cash et al., 2003).

Pryor and Norris (1991, p. 1) observed "… that we learn the most about cetaceans when we study them both in the wild and in captivity; captive animals offer us understanding that cannot be acquired at a distance, and such understanding is fundamental to caring about cetaceans." I think we can safely broaden their observation to include manatees and other marine mammals and similarly emphasize the importance of "caring." Pryor and Norris do not use a more neutral term such as "understanding" or even "conserving." They talk about caring with all the compassion that word conveys. For many, and I expect most, manatee and other marine mammal researchers, their work is not simply a matter of biological understanding. Their research is integrally bound with concern for the well-being of marine mammals. And, if we care about these animals, we need to understand them through as many avenues as possible, including not just studies in the wild, but research in captive settings drawing on an array of methods drawn from education, social sciences, and natural sciences.

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