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Proceedings of Marine Mammal Welfare Workshops Hosted in the Netherlands and the USA in 2012

Sabrina Brando,[1] Ann E. Bowles,[2] Martin Böye,[3] Kathleen M. Dudzinski,[4] Niels van Elk,[5] Klaus Lucke,[6] James McBain,[7] Rebecca Singer,[8] and Magnus Wahlberg[9]

[1]*AnimalConcepts, Lelystad, The Netherlands*
E-mail: sbrando@animalconcepts.eu
[2]*Hubbs-SeaWorld Research Institute, San Diego, CA, USA*
[3]*Planete Sauvage, Nantes, France*
[4]*Dolphin Communication Project, Port St. Lucie, FL, USA*
[5]*Dolfinarium, Harderwijk, The Netherlands*
[6]*CMST, Curtin University, Perth, Australia*
[7]*SeaWorld, San Diego, CA, USA*
[8]*Georgetown College, Georgetown, KY, USA*
[9]*University of Southern Denmark, Odense, Denmark, and Fjord&Bælt, Kerteminde, Denmark*

Abstract

In 2012, two marine mammal welfare and well-being workshops were held: one from 19-21 March 2012 at the Harderwijk Dolfinarium in the Netherlands, and the other from 9-11 November 2012 at Hubbs-SeaWorld Research Institute in San Diego, California. Well over 150 international participants attended, from Europe as well as North America. Herein, we present a summary of the presentations. The aim of the workshops was to discuss topics relevant to marine mammal welfare and well-being from a holistic perspective, including training, enrichment, nutrition, habitat choice, social behavior, anatomy and physiology, acoustics, and cognition. Presenters were asked to apply knowledge and information gained from research on wild and captive animals in order to strengthen, improve, and build on existing marine mammal care programs. Many of these topics require more research for us to make evidence-based decisions on animal needs and preferences—what promotes the reduction of negative welfare and/or what increases positive welfare and well-being.

Introduction

In 2012, two marine mammal welfare and well-being workshops were held: one from 19-21 March 2012 at the Harderwijk Dolfinarium in the Netherlands, and the other from 9-11 November 2012 at Hubbs-SeaWorld Research Institute in San Diego, California. The following text represents a summary of the presentations. The aim of the workshops was to discuss topics relevant to marine mammal welfare and well-being from a holistic perspective, including training, enrichment, nutrition, habitat choice, social behavior, anatomy and physiology, acoustics, and cognition. Presenters were asked to apply knowledge and information gained from research on wild and captive animals in order to strengthen, improve, and build on existing marine mammal care programs. Many of these topics require more research for us to make evidence-based decisions on animal needs and preferences—what promotes the reduction of negative welfare and/or what increases positive welfare and well-being.

Both seminars started with a short introduction by Sabrina Brando to highlight the diversity of marine mammals under human care, reflecting the need to closely look at what might be the species-specific needs and individual preferences. Both seminars included presenters who work or have worked with wild and/or captive marine mammals. Not all speakers were present for both seminars, so different speakers covered similar topics. To keep a complete and in-depth overview of the materials presented, this synopsis combines presentations on the same topic given by different speakers.

Participants and speakers had time to both review background information and summarize ongoing research in their topic areas. Research on marine animal welfare in human care has lagged behind similar research in the terrestrial environment, and all speakers emphasized the need to educate staff and management of captive facilities, as well as to integrate new research and practical experiences (preferably supported with scientific data), and to test the results of innovations to ensure dynamic improvements in best practices. The collaborative, forward-thinking goals of the speakers are reflected in these proceedings.

The summaries below cover the latest information on marine mammal biology relevant to zoological settings. They describe research topics that benefit from collaborations between researchers and zoological facilities. Finally, they describe approaches, procedures (e.g., training methods), and technologies that have the potential to enhance the welfare and well-being of animals in managed care. All summaries have been updated to include relevant references and details up to the time of the final submission of the proceedings.

Marine Mammals in Managed Care

Sabrina Brando, B.Sc.

The theme of the workshops was to explore a wide variety of topics dealing with the well-being of marine mammals in captivity such as improvements of their habitats (including acoustic conditions), opportunities for enrichment and training, social life, and cognitive challenges. The focus here is on positive, beneficial approaches. Research using behavioral observations, physiological studies, and other methods is still highly necessary to develop our understanding of the biology of wild and captive marine mammals. In addition, the influence of managed environments on marine mammal welfare can be measured empirically as well as debated philosophically using scientific methods. Research on animal ecology, physiology, behavior, and cognition can improve both our understanding of marine mammals and can be used as tools for animal management. These workshops were designed to promote such issues both through education and discussion.

Marine mammals are a diverse group of about 120 species living in marine and freshwater environments, including seals, sea lions, manatees, dugongs, whales, dolphins, porpoises, sea otters and polar bears. Some species have a worldwide distribution, from the Arctic to the Antarctic, while others are only found in restricted areas (Stewart et al., 2002; Jefferson et al., 2015). For more than a century, marine mammals have been held in captivity in aquaria and zoos, where they often are trained for shows or are increasingly used for Animal Assisted Therapies (AAT) and other interactive programs. Some facilities train marine mammals to participate in research projects. The beluga (*Delphinapterus leucas*) was one of the first marine mammals held in captivity; they were housed at the Barnum's Museum in New York City in 1861 (Ceta-Base, 2010). Today, many species are held in marine parks and oceanaria. The most common species are the bottlenose dolphin (*Tursiops truncatus*), California sea lion (*Zalophus californianus*), common seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*), manatee (*Trichechus manatus*), walrus (*Odobenus rosmarus*), sea otter (*Enhydra lutris*), polar bear (*Ursus maritimus*), and killer whale (*Orcinus orca*).

Animal Welfare and Well-Being

Marine mammal professionals in modern facilities are well aware of the myriad of practical and ethical questions regarding animal welfare that can and should be raised when keeping marine mammals under human care. The workshops focused on the goal of maintaining a very high level of animal welfare in such facilities.

All the presenters at the workshops acknowledged the welfare and ethical questions raised when thinking about marine mammals kept under human care. At the same time, these questions were considered from the perspective of the biology and psychology of the animals rather than from an anthropocentric, ethical, or philosophical viewpoint. Issues relevant to whether marine mammals prosper in zoological environments include whether they were taken from the wild (including when and how) or raised there from birth, how are they housed and cared for, how much choice and control do they have in and over their lives, how enriching is their environment, what are their relationships with human caretakers and how do they perceive visitors, and do they lead fulfilling lives? Relevant to animal welfare as well as to education and conservation goals are questions like "What role do the animals serve and how are they portrayed to the public when used in entertainment?" and "How are show and interactive animals housed in comparison to the same species in another role such as a display animal?"

From a research perspective, the greater control provided by having access to animals in zoological facilities is essential for answering many scientific questions, but there is a second benefit as well: the changes that can be observed as animals acclimate to very different captive environments can clarify the function of cognitive and physiological adaptations in ways that would never be possible by observations *in situ*. Instead of taking as a truism that life in the wild is optimal, or the alternative truism that life in a constructed, managed environment is better (an idea that humans often accept unquestioningly when considering their own lives), researchers can explore the costs and benefits of life in both settings, ultimately improving our understanding of both settings as well as shedding light on the quality of life of the different species of marine mammals living in managed care environments. It will be more productive to reframe animal welfare issues from the perspective of the animals and in the context of managed environments to understand how they are coping and faring (Broom, 2001; Fraser, 2008). Replacing a vague notion of what is natural with procedures proven to promote welfare will require a body of research on what constitutes welfare for various animal species. In addition, more research is needed regarding ethical considerations for housing marine mammals under human care.

Behavior

In modern zoological parks and oceanaria, we believe that marine mammals under human care should have the opportunity to thrive and experience a good life. However, what constitutes a good life depends on the animals' lifestyles and adaptations. For example, the complex emotional and cognitive abilities of marine mammals become evident when observing individual animals as well as the cooperative hunting strategies of some species in their dynamic habitats. Such hunting strategies are specific to certain social groups or populations and local resources (Gazda et al., 2005). Their behaviors have been characterized as animal culture, particularly in dolphins and toothed whales (odontocetes), because they show tool-use and socially pass traditions on to their offspring (Krützen et al., 2005) such as shark-hunting in killer whales and sponge use in bottlenose dolphins (Whitehead & Rendell, 2014). Some species form relationships and alliances that can persist over decades (Connor et al., 2000) and use *signature whistles* (individually distinctive stereotyped vocalizations) to identify and recognize each other (Janik & Sayigh, 2013). There are marine mammals that seem to recognize individual conspecifics as well as themselves in mirrors (Reiss & Marino, 2001); and at least one cetacean, the bottlenose dolphin, can recognize the signature whistles of conspecifics for decades (Bruck, 2013). Language training experiments indicate that some marine mammals process semantic relations and understand basic syntactic information (Herman et al., 1993).

Sensory Systems

Dolphins and other marine mammals use many different sensory modalities for communication and for perceiving the world, and, thus, must have extensive cognitive abilities to process, abstract, encode, and retrieve information from memory (Reichmuth-Kastak & Schusterman, 2002). Understanding these sensory modalities and taking the animals' memory capabilities and other cognitive abilities into account should play an important role in the future treatment of marine mammals under human care. For example, understanding how marine mammals learn and what they understand can be used to improve and expand environmental enrichment and animal training programs, and to provide more choice, control, and reinforcing complexity.

Marine Mammal Habitats and Environmental Enrichment

The Directive 1999/22/EC regulates the keeping of wild animals in zoos in Europe. Additional, albeit limited, information on marine mammal care can be found in official laws, regulations and guidelines of various countries. Additionally, the European Association for Aquatic Mammals (EAAM) (2009) provides guidelines for housing requirements. These guidelines state that the minimum required pool area for keeping bottlenose dolphins should be at least 275 m^2 and with a minimum depth of 3.5 m (p. 13). However, considering that bottlenose dolphins can reach a length of 3.8 m, these standards seem very inadequate. Most marine mammals in captivity have been kept in concrete pools without (natural) substrates and/or vegetation; without currents and/or waves; and without soft substrates to haul out, rest, or sleep upon. These marine mammals lack opportunities to search for food or to hide (i.e., get away from each other). The land vs water ratio is also highly variant depending on the facility, and this does not necessarily reflect the needs and preferences of amphibious species such as various seal and sea lion species or of walrus and otter. Importantly, little research has been conducted to understand the needs and wants with regards to marine mammal habitats. Current habitats have been shaped by the need to keep animals visible to visitors under water and the challenges of maintaining animal health (e.g., water quality control).

Many modern zoological parks have been through transformations of their "terrestrial" animal enclosures to improve the habitats' quality and complexity for the animals. The original enclosures (very often empty pits with few opportunities of enrichment or for choice and control of the animal) have been enlarged and nowadays may include different substrates, viewpoints, flexible and fixed structures, and various opportunities for feeding and social interactions. Extensive environmental enrichment programs include, but are not limited to, foraging activities as well as problem solving and other cognitive challenges. They consider the animals' social needs and preferences. Also, the shift to open access between the different indoor and outdoor enclosures, allowing animals to choose where they want to be, have all resulted in positive changes and increased the standard and type of care provided for species of bears, elephants, and great apes worldwide. Although a shift in housing polar bears has been seen over the last decades, exhibits and enclosures for other marine mammals have lagged behind. Most odontocete cetaceans, seals, and sea lions as well as other marine mammal species in managed care are housed in empty tanks void of complexity, lacking many of the aforementioned features that would give the animals challenges, choice, and control.

The design of current and future marine mammal pools, including characteristics and surroundings, as well as water quality and additives, needs attention. Recent research on eye problems report that a large percentage of captive pinnipeds still suffer from ocular conditions such as corneal disease, premature cataracts, and lens luxations (Colitz et al., 2010b; Gage, 2011). Causative factors such as exhibit designs, water quality and water additives, and suggestions on how to correct them can be found in these papers and related references. Access to UV-protective shade should be readily available, and the preferred color of the pool should be earth tones—tan or brown colors—to avoid glare and reflections (Colitz et al., 2010b; Gage, 2011). Suggestions on feeding and training during sunny conditions are also offered (Gage, 2011).

Most enrichment items for marine mammals include floating hard plastic objects that animals can push around; they are given during daytime hours and often under supervision. A few facilities have dedicated lists outlining daytime and nighttime enrichment activities and safety criteria. Delfour & Beyer (2012) investigated the use of objects by bottlenose dolphins and found that only 50% of all presented objects elicited manipulative behaviors. Thus, not every toy is a successful enrichment device, and not every behavioral change subsequent to the introduction of a new object necessarily indicates an enrichment effect. Animals in captivity need challenges—for example, by working to get food; by solving problems; and by using the limited space they have for swimming, resting, exploring, or playing. Challenges can be created by providing a more interactive environment with animals being able to control their access to certain pools in indoor and outdoor areas or perhaps to choose what species of fish to eat, which objects and toys to use, or which other animals and/or trainers with whom to interact.

Some zoos find creative ways to increase positive welfare. The Kolmården Zoo in Sweden provided sonar-activated water enrichment for dolphins (Amundin et al., 2008). The creative use of substrates, like sponges or artificial vegetation (Edberg, 2004), could also encourage natural behavior. All enrichment and modifications must be developed systematically to ensure that they do not affect water quality or encourage harmful behaviors (e.g., rubbing or ingestion).

Marine mammal programs should be expanded to reflect the cognitive capacities as well as physical capabilities of the animals: "While most captive marine mammals are trained and this challenges their social-cognitive skills to a moderate or high level, their physical-cognitive skills are not being challenged to a high level by floating 'toys' in the pool" (Clark, 2013). Environmental enrichment should be species-specific and tailored to individual needs. Tools or procedures could take into account age, physical fitness, and individual preferences, but also safety constraints. Professional enrichment programs should be dynamic, analyzed, goal-directed, adaptive, re-viewed, scientifically documented, and readjusted on a regular basis.

Training

Initially, training of marine mammals was motivated by the entertainment industry and by scientific projects. Soon it became clear that training was very useful for daily care as well. Therefore, training has facilitated improved marine mammal husbandry practices. Many advances in marine mammal training have been made over the past 50 y. Husbandry behaviors such as dental work, blood draws, mammary presentation and milk collection, urine collection, and voluntary semen collection have all been trained with marine mammals, bringing many benefits in the form of preventive, active, and reactive health care (Kuczaj & Xitco, 2002; Desportes et al., 2007; Brando, 2010). By teaching animals to participate in their daily care, they gain more control and choice over their environment. Behavioral learning principles and related techniques have all been used to benefit the development of healthcare programs that allow for preventive and regular health screening of marine mammals under human care. Studies conducted in marine parks cover a wide variety of topics, including marine mammals who have been trained to voluntarily participate in research and conservation projects involving, for example, hearing (Nachtigall et al., 2006), physiology (O'Shea & Poché, 2006; Yeates et al., 2007; Scholtyssek et al., 2015), behavior (Gubbins et al., 1999; Dudzinski et al., 2010), veterinary care (van Elk et al., 2009; Osborn et al., 2012), language (Herman et al., 1993), and cognition (Delfour & Marten, 2001; Reichmuth Kastak & Schusterman, 2002; Marino et al., 2007).

Providing choice and control is the key to elevating animal welfare (Owen et al., 2005; Buchanan-Smith & Badihi, 2012). For example, by teaching animals that all high-energy behaviors are connected to a square symbol, all husbandry behaviors to a circle, and play and interactive behaviors to a triangle, we can let animals choose what type of training session in which they would like to engage (e.g., for ideas and related research, see Vonk & MacDonald, 2004). After a bridging stimulus, animals could also choose what reinforcer they would like—for example, food; a scratch on the back; or a favorite toy, companion, or a piece of jello or ice. Thus, current and future potential methods to foster greater animal welfare are vast.

Marine mammal trainers are not only concerned with the correct application of behavioral learning principles, but they also pay attention to and consider the effect of human body language, posture, and communication on the animals in their care (Davis & Harris, 2006).

Refining training methods can be achieved by increasing the "trainer's toolkit"—that is, increasing knowledge of the different learning principles and their effects, another topic that would benefit from focused and coordinated research (Bauer, 2003, 2009). With this approach, trainers could be more productive in determining what approaches help animals learn well and in understanding why an animal might refuse to do a task or learn poorly—problems that might be medical, social, contextual, or a product of boredom and disinterest. It is also important to focus on positive approaches, such as the use of positive reinforcement, patience, playing games, spending time, and building trust, even when animals are not cooperating. The choices we offer should be more than the sole option to participate or not. Modern training goes beyond behavioral learning principles and the "ABC" and/or S-R. Professional animal care programs consider animal cognition and affective states—to explore and be together; to develop friendships and bonds based on trust, play, and interactions; to "let be" and accept; to let go of some of the control we think we need; and to ask questions like "What is it like for you?" and "What can I do for you?"

According to McBain (pers. comm., 13 March 2008), "We should work with animals as if gates and doors weren't there; as if they could leave any moment they wanted. If they then decide to stay and work with you, then you can say you have a good bond and trust and the animal is truly interested in being with you." Training has many benefits for captive marine mammals; it is part of a complete and professional animal care program.

Performance

It is estimated that there are over 10,000 zoological facilities worldwide (Association of Zoos and Aquariums [AZA], 2016), and new zoological facilities are currently being constructed, including in countries where there is very limited experience with keeping animals in captivity. Therefore, there is a greater need than ever for innovations that engage oceanarium visitors while at the same time enhance the well-being of the animals. Objections to the way animals are presented to the public with regard to behaviors and messaging are not equivalent to issues with their care and welfare, and both were discussed during the workshops. Training dolphins to jump through hoops, dance the lambada, or wear sunglasses are not natural behaviors and have no educational or conservation value. Fortunately, in modern zoos and marine parks, there is a trend to give up such behaviors toward presentations that show voluntary husbandry behaviors and species-specific behaviors set in relevant context and theming.

This is also evident in the existing rules and guidelines for keeping marine mammals in captivity. The EAAM bottlenose dolphin guidelines state that bottlenose dolphins should not be unnaturally provoked for the benefit of the viewing public. The European Association of Zoos and Aquaria (EAZA), of which many facilities housing marine mammals are members, issued guidelines in 2014 on the use of exotic animals in public demonstrations. They state, "Many historical demonstrations may not reflect the role of zoos and aquaria as centers of education and conservation." These guidelines state that "Any practices that provide audiences with a misleading impression of the natural behaviors of wild animals, or makes claims about wild animal behavior that are not substantiated by scientific evidence" and "The use of props where their use cannot be shown to demonstrate or replicate natural behavior" should be avoided. Furthermore, the guidelines state that "Direct physical contact between humans and animals in a demonstration for the sole purpose of entertainment, where there is no accompanying demonstrable educational value" should also be considered outdated.

According to EAZA (2014) guidelines, the housing of any show animal needs to conform to the best practice standards and should be followed for all off-demonstration housing, pre- and post-demonstration holding enclosures, and areas and conduits used for moving animals between their enclosures and the demonstration space. EAZA does not support placing animals in a performance environment that does not reflect the EAZA minimum standards (see above), particularly where these conditions could cause them stress or physical harm. This also includes any animal demonstrations that are conducted by a third-party contractor on behalf of and on the premises of a member institution. These third-party contractors must also follow these guidelines. Members and nonmembers alike can use these guidelines and expand on them to suit species-specific needs and preferences.

It is important to ensure that marine mammal programs and presentations adhere to conservation, education, and research requirements and goals, with animal welfare as a main priority. Presentation issues are not equivalent to issues regarding the care and welfare of animals. From the animals' point of view, irrelevant themed shows, such as being an actor searching for the lost treasure on a pirate island, might not be seen as indignities. For the animals, all of these behaviors amount to a complex strategy for getting food, the fun of participating, or other rewards. The activities also are engaging in other ways such as providing social contact with trainers, exercise, and cooperation with one another. However, there is a growing belief within the zoological community among scientists, trainers, and the general public that portraying animals in ways that are representative of their natural activities is better than teaching them behaviors that are not species-representative. It asserts that realistic and respectful presentations should support husbandry conditions that promote the animals' well-being, both physical and psychological.

In addition, there is another possible benefit from focusing on the animals' natural behaviors. Explicitly and implicitly, many of the talks in the workshops emphasized the importance of giving visitors to zoological facilities a new appreciation of the animals they see so that they would work to preserve them in the wild. Professional educational programs and presentations that highlight their natural capabilities and adaptations and evoke respect for animals as individual, sentient beings can create powerful connections. This function of zoological parks is becoming increasingly important as evidence for the vulnerability of the ocean to global change mounts. We have recently experienced the extinction of the freshwater dolphin baiji (*Lipotes vexillifer*), once found in the Yangtze River in China. Other marine mammal species, such as the Mediterranean monk seal (*Monachus monachus*), are endangered; and the vaquita (*Phocoena sinus*) is critically endangered. Marine mammals worldwide face threats such as overfishing, habitat displacement and loss, bycatch, pollution, and hunting. Through engaging and relevant presentations of captive marine mammals, opportunities arise to empower the public to care and help protect animals in wild habitats.

Nevertheless, highly irrelevant themed shows still exist worldwide and may increase even as experts criticize a trend of "cartoonish representation" (Beardsworth & Bryman, 2001, p. 86) in postmodern exhibits involving such elements. The use of animals in entertainment could have serious consequences for their perceived conservation status. Schroepfer et al. (2011), in a study focusing on chimpanzees, had participants watching a video about chimpanzee conservation, commercials containing "entertainment" chimpanzees, or control footage of the natural behavior of wild chimpanzees. According to Schroepfer et al.,

> Results from a post-viewing questionnaire reveal that participants who watched the conservation message understood that chimpanzees were endangered and unsuitable as pets at higher levels than those viewing the control footage. Meanwhile participants watching commercials with entertainment chimpanzees showed a decrease in understanding relative to those watching the control footage. In addition, when participants were given the opportunity to donate part of their earnings from the experiment to a conservation charity, donations were least frequent in the group watching commercials with entertainment chimpanzees. The results firmly support the hypothesis that use of entertainment chimpanzees in the popular media negatively distorts the public's perception and hinders chimpanzee conservation efforts. (p. 1)

Therefore, we need to consider how animals are portrayed to the public, what behaviors they are engaged in, and how this affects the type and effectiveness of information transmission to the visitors. Connections to animals, particularly in communities that do not have access to wild habitats, can inspire participants to learn more about them and their wild counterparts, which hopefully will lead to greater protections.

Research is needed to understand how captivity affects marine mammal welfare. The overall effects of captivity on marine mammals are poorly understood and surprisingly little studied (Brando & Hosey, unpub. data). Extensive peer-reviewed publications on veterinary care or hearing capabilities are available for some species such as the bottlenose dolphin, but peer-reviewed publications with regards to environmental enrichment, training, nutrition, and specifically marine mammal welfare are few. This is evident especially in comparison with other species such as the great apes and elephants.

Based on studies on terrestrial mammals with respect to cognitive, social, physiological, and psychological challenges animals face in the wild, life in captivity can cause monotony and boredom (Wemelsfelder, 2005). Many of their activities and choices over the environment have been removed in captivity, like decisions about movements, social partners, and the need to search for food items. Well-designed environmental enrichment and animal training has the potential to increase choice and control over the environment. As animal care professionals, we must remain sensitive to the physical and psychological needs and preferences of the animals, all of which change throughout their lives. The methods we use must be based on well-designed research.

It is important to remember that training only constitutes a small part of an animal's day. One of the main challenges in the future will be to continue to strive for a suitable, healthy, and complex environment. Animal care staff are present approximately one-third of the day due to their working hours. Providing choice and control over a larger proportion of the day (24 hours per day/7 days a week) and across the animals' lifespan could make a fundamental difference in welfare. Semi-autonomous exhibits could provide more choice and control to animals in human care. There are already technologies in use such as levers to activate a shower (Legrand et al., 2011), infrared beams to activate water jets (Coe, 2006), and open access to indoor and outdoor areas. (For more information on this so-called "24/7 approach," see www.247animalwelfare.eu). Continuing to refine and investigate techniques related to marine mammal behavioral management is an ongoing process. Existing management and husbandry guidelines should be reviewed critically on a frequent basis, and coordinated effort should be instituted to fill gaps and develop best practices. Ultimately, all marine mammals under human care should have the opportunity to thrive and experience a good life.

Marine Mammal Habitats

Magnus Wahlberg, Ph.D. & Martin Böye, Ph.D.

A *habitat* is defined as the natural environment in which an organism lives or the physical environment that surrounds, influences, and is utilized by this organism (Davies & Krebs, 1993). A habitat can be divided into several components, with several measurable parameters which have to be taken into account when hosting animals in man-made environments. In recent years, much progress has been made in zoological institutions to provide animals with environmental conditions and simulations relative to their feeding needs, behavioral patterns, and general well-being, but there are certainly still many opportunities to explore and, importantly, to implement. Marine mammals are diverse, and so are their habitats (e.g., Hoelzel, 2002). In-depth observations of the challenges they face in the wild and how they interact with their environment should be an endless source of inspiration for facility designers and animal caretakers. Such knowledge should be used when adding complexity and variation to the facility, as well as in finding ways for the animals to make choices and have control over their own environmental settings.

Moreover, marine mammals are highly adaptive creatures; and while keeping their safety in mind, we should be creative in the environment(s) we provide to them. Animals in captivity may be enriched by being more physiologically challenged than what has previously been assumed. Daily extensive exercise may help to keep the animals in shape. Also, the amount of daily food could be varied depending on the season so that animals undergo a shrinking and growing period every year as might be reflected in their physiology in the wild due to variations in food abundance and ambient temperature (e.g., see Lockyer et al., 2003). Such changes may also be accompanied by variations in the animals' environment in terms of water temperature and light conditions.

Animals also may be enriched by being more psychologically challenged, with caregivers offering complexity through different microhabitats via varied substrates, depths, and interactive environmental features such as vegetation or other structures, which, in turn, allow for more choices and control. This may not only improve health in captive animals but also may make them more interested in participating in public displays and research projects. Last, but not least, presenting marine mammals to visitors in an environment reflecting their natural habitat, as well as being highly interactive and functional for animals, would greatly facilitate attaining the objectives of education and conservation sought by zoological institutions.

Social Life and Aggression in Marine Mammals

Martin Böye, Ph.D. & Kathleen M. Dudzinski, Ph.D.

A *social animal* is a loosely defined term for an organism that is highly interactive with other members of its species to the point of having a recognizable and distinct society. *Being social* reflects a level of social organization that goes beyond the mother–offspring bond and may include cooperative rearing of young, foraging or hunting, defense from predators and competitors, and social learning. A majority of marine mammals are social, with group sizes ranging from a few individuals (e.g., vaquita and manatees) to schools or rookeries of thousands (e.g., common dolphins and sea lions). Group organization relies on individual recognition. In marine mammals, there is strong evidence that individuals are able to recognize each other over decades (Datta & Sturtivant, 2002; Insley et al., 2003; Bruck, 2013).

Living in a group requires a communication system. Marine mammals use complex communicative signals. Sound, well propagated in water and in air, seems to be the primary mode of information sharing, but the use of postures, touch, and other behaviors have also been investigated in detail and play an important part (Tyack, 1999; Dudzinski et al., 2008). Group living must provide benefits for each individual; otherwise, the group would likely not persist.

In addition to the benefits of group living, there are costs such as fierce competition for food and access to reproductive opportunities. Marine mammals are social beings that exhibit and engage in both affiliative and agonistic behaviors. Agonistic activity includes aggressive and submissive displays that help maintain balance in both subgroups and larger groups. An aggressive action is likely forceful, maybe hostile or attacking, and potentially harmful. However, these behaviors are perfectly natural for these animals to use in given specific social contexts (e.g., establishing and maintaining dominance; MacLeod, 1998). Most marine mammals are top predators living in complex social groups where aggression plays a key role within the context of the group. However, aggressive behaviors can be problematic in managed settings. Good behavioral training, voluntary collaboration from the animal, and knowing the signs of aggression are some keys to preventing accidents.

Bruck (2013) showed that bottlenose dolphins were able to remember a former pool mate, even 20 y after having been separated. Australian fur seals (*Arctocephalus pusillus doriferus*) recognize their mother's call even after weaning and becoming fully independent (Pitcher et al., 2010). Dudzinski et al. (2010) studied flipper contact in bottlenose dolphins in the wild and in captivity; social contacts were expressed nearly with the same intensity in both situations. Social life is complex in marine mammals, and we have only recently begun to understand the various levels of detail of their societies under natural conditions. Facilities hosting marine mammals should integrate each species' social needs in the way groups are managed (e.g., sex ratio and age classes). Attention should be paid to which individuals are transferred between habitats or facilities as well as to their companions and family (e.g., age of transport and history in the group). This information also could be used with regard to facility design and how interactions with caretakers could be organized.

Anatomy and Physiology

Magnus Wahlberg, Ph.D.

Understanding the anatomy and physiology of marine mammals is essential for designing appropriate zoological environments. The cetaceans, or whales, are divided into two sub-orders: (1) odontocetes and (2) mysticetes. Odontocetes are toothed whales that forage on fish and squid; they can have only a few teeth in the lower jaw to ~100 teeth distributed between the upper and lower jaws. In general, the fewer the teeth, the more of the diet consists of cephalopods (Tinker, 1988; except for a few exemptions such as the sperm whale). Pinnipeds are divided into true seals (phocids), eared seals (otariids), and the walrus (odobenid). True seals have no external pinna and short front limbs. For most phocid species, there is a rather modest size difference between the larger males and females with one extreme exception: the elephant seal male can be more than three times larger than the female (Reeves et al., 2002). Eared seals (sea lions and fur seals) have pinna and larger forelimbs; they use forelimb propulsion in the water and are able to move more efficiently on land than the other seal species. Males are much larger than females with prevalent sexual dimorphism (Reeves et al., 2002). Walruses have large tusks, pinna, a more extensive set of vibrissae on the upper lip, and a diet consisting almost entirely of mussels and clams (Hoelzel, 2002). Manatees and dugongs are herbivorous marine mammals with small front limbs and a large tail that live in coastal waters and feed on algae and sea plants (Reeves et al., 2002). Sea otters are mustelids and have an incredibly thick fur coat. They live on clams and other invertebrates that are collected during dives and brought to the surface to be consumed (Berta et al., 2006). Polar bears, found only in the Arctic, are the largest of all ursids and are closely related to the brown bear. Polar bears are well adapted to swim long distances in Arctic waters (Hoelzel, 2002).

The fusiform, streamlined marine mammal body conserves heat and helps reduce drag while swimming. Additionally, marine mammals have either a dense fur coat or a thick blubber layer to conserve heat. These adaptations yield extremely efficient heat retention such that marine mammals have evolved counter-current heat exchangers to keep their core from overheating (Hoelzel, 2002; Berta et al., 2006). Many marine mammals are extreme divers, both in terms of dive duration and depth. Still, lung volume compared to body mass is usually not that large. Also, lungs collapse as ambient pressure increases when reaching a depth greater than about 100 m. Therefore, instead of relying on increased storage of oxygen in the lungs, diving marine mammals have impressive stores in the blood, muscles, and in some species also in the spleen (Williams & Worthy, 2002). When an animal is diving, a series of reflexes set in: the heart rate slows, and blood is shunted to the most important places. When all oxygen has been consumed, the animal passes the aerobic dive limit and must either go to the surface or start to metabolize anoxically, which results in a build-up of lactic acid.

Another important issue for a mammal living in marine water is the salt and water balance. Usually mammals obtain water by drinking it or by metabolizing it from their prey. Marine mammals usually do not drink fresh water but must rely on the water content inside their prey (Hoelzel, 2002). This can pose much demand on both the salt and water transport systems within the digestive system and the kidneys. Marine mammal sensory systems have evolved for a fully aquatic or amphibious lifestyle, depending on the species. The sensory systems include auditory (e.g., hearing and sound production), visual, chemical (e.g., smell, taste, etc.), and tactile modes for information sharing. At least one species, the Guiana dolphin (*Sotalia guianensis*), is able to detect weak electric fields (Czech-Damal et al., 2012). These channels can be used when interacting with conspecifics or with prey/predators.

Many species of marine mammals undergo drastic anatomical and physiological seasonal changes in ambient water temperature and light conditions (e.g., Lockyer et al., 2003). Varying such parameters may significantly improve the living conditions for animals in captivity. Also, it is important to stimulate the animal's sensory environment through improving both underwater acoustic conditions and also considering the available visual and chemical stimuli. You should think about the animal's environment from the animal's sensory perspective, his or her *Umwelt* (*sensu* von Uexküll & Kriszat, 1934). For example, decorating the seal pool with colorful patterns is of little help to stimulate seals, which are almost or entirely color blind. At the same time, for some toothed whale species, the ambient electric field of the pool should be investigated so as to not cause obnoxious sensations.

Feeding Ecology

Magnus Wahlberg, Ph.D.

Recent technical developments have significantly transformed studying the feeding ecology of marine mammals. Many breakthroughs in tagging technology have resulted in detailed measurements of animal location and depth, acceleration, swimming velocity, and acoustic signals associated with foraging behaviors (Johnson et al., 2009). There are also applications of high-resolution sonars, acoustic cameras, echo sounders, underwater video equipment, and autonomous gliders to further increase our understanding of interactions between marine mammals and their prey (e.g., Nøttestad et al., 2002).

Most species of marine mammals feed on squid or fish. Walruses feed on clams, and sea otters dine on a variety of crustaceans and mollusks. Baleen whales have diverse feeding preferences, ranging from small copepods and amphipods to krill and schooling fish depending on the species. There is wide variation in hunting techniques, both between the different species but also within the same species for different prey choices. Marine mammals either forage solitarily or in groups. In some species, such as killer whales, there is a clear collaboration between individuals during foraging (Similä & Ugarte, 1993). In other species, such as in harbor porpoises (*Phocoena phocoena*) and several species of seal, it is less clear how much collaboration occurs during gregarious foraging events.

Wild marine mammals make use of all their senses to find their prey. A considerable amount of time is spent traveling to and from the feeding grounds and for detecting and pursuing prey. For marine mammals in captivity, playing hide-and-seek with food resources may elicit some of their natural feeding behaviors. This approach can function as enrichment for the animals but also may spur adequate physiological responses that are important for their well-being. In some facilities, it might be possible to use live prey (whose welfare must be considered, too) on occasion, which may serve as an additional enrichment complement, challenging the animal's senses even further.

Marine Mammal Communication

Ann E. Bowles, Ph.D. & Kathleen M. Dudzinski, Ph.D.

There is a mismatch between the lay-language concept of communication, of information sent and received between individuals, and how experts characterize animal communication. No animal other than humans is known to exchange information in the quantized, context-free, arbitrarily extendable form that we take for granted as language (Stegmann, 2013; Kershenbaum et al., 2014). Instead, animals call because they feel like it (e.g., to maintain mother–offspring contact) or because they want to induce another animal to do (or not do) something (and maybe a mix of the two). The information they send tends to be context-sensitive, especially to behavioral state.

In turn, receivers make inferences based on what they hear; they react according to their perceptions of the signals, which are influenced by their emotions and their physiology, which, in turn, are influenced by their genetic heritage (Bradbury & Vehrencamp, 1998).

Animal emotions are often denigrated as being unmanageable or uninterpretable by scientists. In many animal species, they actually evolved, just as cognitive abilities did, to help individuals to perform functions like avoiding danger, getting food, raising young, or navigating complex social landscapes successfully for millions of years (Burgdorf & Panksepp, 2006). Thus, vocalizations and associated behaviors can be used as assays for social and emotional states (Lemasson et al., 2012). They are potentially non-invasive tools for assessing welfare in social mammals. Unfortunately, vocal communication has not received the attention it deserves as a tool for management and promoting welfare, particularly in the zoological environment. It operates in a number of important contexts, including initiating and maintaining contact in obscured habitats, social bonding, agonistic exchanges that adjudicate access to resources or power, group defense, coordinating predation, and parent–offspring interactions.

Humans often assume smart animals have dialects. However, most social mammals do not encode group identity explicitly in their vocal repertoire. As of this writing, only one marine mammal is characterized as having a social dialect—the killer whale. It is known that social dialects in birds are learned, but birds have a pre-adaptation in the form of anatomical specializations for complex song (Colbert-White et al., 2014). Only a few species of nonhuman mammals seem to be able to learn complex and arbitrarily structured new vocalizations (Schusterman, 2008; Tyack, 2008). Among primates, which are the closest relatives to humans, vocal learning is limited to small modifications of species-typical vocalizations (Watson et al., 2015).

The general term for the ability to produce novel sounds is *vocal plasticity*. We neither know why vocal plasticity is present in some species but not in others nor how anatomy and physiology of sound production and learning interact; however, odontocetes appear to be among the mammals with the appropriate adaptations for substantial vocal plasticity (Miksis et al., 2002; Foote et al., 2006; Ridgway et al., 2012; Musser et al., 2014). Understanding why plasticity is adaptive for toothed whales may help us determine the value of dialects for social species generally. Dr. Bowles' laboratory has been studying vocal learning and its relationship to social context in killer whales. Killer whales produce a repertoire of discrete pulsed calls made up of multiple components. It is called a dialect because free-ranging killer whale matrilines use unique pulsed call repertoires that appear to be passed across generations (Ford, 1991). However, individual call development and usage has not been easy to study in the wild. In the zoological setting, there is the opportunity to document stages of vocal development (Bowles et al., 1988) and to conduct adventitious cross-socializing experiments, which are among the best tools for documenting learning in social mammals (Crance et al., 2014; Musser et al., 2014).

This work has shown that killer whales develop their discrete, stereotyped pulsed calls gradually in a process that looks a lot like learning (Bowles et al., 1988). They begin with uncontrolled and unstereotyped screams, burst pulses, and whistles in the first month or so. As they gain control of their vocal apparatus, they produce a wide range of sounds, reminiscent of babbling in human toddlers. Between about 4 mo and 1 y old, they begin producing a recognizable subset of the mother's stereotyped repertoire, gradually emitting better and better approximations of the mother's call templates.

While this progression is suggestive, some or all of the changes could result from maturation of vocal structures. Dr. Bowles used the cross-socializing paradigm to study vocalizations of young killer whales associating with whales having different dialects and with another species. Killer whales begin producing novel pulsed calls matching those of another dialect when they form new social associations, whether as calves or during shifts in association in their juvenile and subadult years (Crance et al., 2014). This type of learning is called production learning. They also produce species-typical sounds like clicks and whistles more often when associating with bottlenose dolphins (Musser et al., 2014), which is evidence for contextual learning. In both cases, there appears to be a strong motivation to match the vocal behavior of social partners. It is not clear whether killer whales retain their plasticity throughout their lives. Evidence indicates that young killer whales learn (Bain, 1986; Foote et al., 2006) and that learning is most prominent in younger animals (Crance et al., 2014; Musser et al., 2014). There is no evidence that mature adult females learn; however, no study has so far been able to test this critically, and, therefore, it is unclear whether adult females couldn't learn new signals (e.g., because older animals have difficulty learning to produce novel vocal elements) or wouldn't (e.g., because imitating another individual presents social challenges).

By understanding how and why killer whales learn, we can gain insights into the adaptive benefits of vocal learning in social species generally.

There are management implications to this understanding. If groups use learned vocal repertoires to maintain cohesion and regulate activities, such as hunting or resource defense, then having a critical mass of signalers that are members of an "in group," marked by use of the dialect, may be important. This suggests powerful adaptive reasons to belong to an "in group" and exclude members of "out groups" (e.g., Rendell & Whitehead, 2001). If the "in group" signals also determine mating preferences, then dialects may not only promote important group activities but genetic isolation. If isolated or decimated groups refuse to join with others due to their vocal behavior or other social signals, a socially mediated downward population spiral might be aggravated (Wade et al., 2012).

There is mounting evidence that other smaller toothed whales have stereotyped calls, including short-finned pilot whales (*Globicephala macrorhynchus*; Sayigh et al., 2013), belugas (Vergara et al., 2010), and melon-headed whales (*Peponocephala electra*; Kaplan et al., 2014). Combined with evidence for motivation to imitate (DeRuiter et al., 2013; Alves et al., 2014), this suggests that their acoustic behavior may have features similar to the dialects of killer whales. At least they may be producing individual-specific stereotyped calls like those of smaller dolphins, which imitate one another's signature whistles to promote bonding. In either case, vocal learning should be seen as broadly relevant to management.

In oceanaria, vocal communication is an important source of information about the condition of individuals. First, knowing what types of calls are produced and who is producing them can help in monitoring behavior because vocalizations are relatively easy to collect and process and can be recorded around the clock, even in dark or turbid water. Second, evidence that vocal imitation is a measure of social association suggests that exchanges can be used to monitor animal relationships. Third, patterned vocalizations might be useful as a measure of stereotypy and would be easier to quantify than visual behaviors. Finally, vocal behavior could provide insights into physical health. For example, if an animal had hearing loss or damage to structures that control vocalizations (including the brain), its vocalizations would change or have properties associated with these dysfunctions. For all of these reasons, we strongly advocate studying vocal communication in zoological settings—it is an underappreciated tool for understanding wild populations and for improving animal welfare in captivity.

Acoustic Communication and Echolocation

Magnus Wahlberg, Ph.D. & Kathleen M. Dudzinski, Ph.D.

Sound travels differently in air vs water because of the differences in density, speed of sound, and other features of these two media. Experiments have demonstrated that low-pitch sounds can travel from one end of an ocean and be picked up at another end (Munk et al., 1994). Thus, it is conceivable that some whale species may communicate using sounds over extremely large ranges (as suggested by Payne & Webb, 1971; Tyack, 1998).

Marine mammals rely on acoustics for navigation, communication, and prey detection. All studied marine mammals can detect sound and vibrations, and they can all produce sounds. Toothed whales produce whistles and burst-pulsed calls primarily for communication, and ultrasonic echo-location clicks for foraging (Au, 1993; Tyack, 1998). Pinnipeds produce species-specific calls in air (e.g., barks and roars) and under water (e.g., trills), and also make noise with various body parts (e.g., splashes with their flippers) as do other marine mammals (Tyack, 1998). Some seals have vocal learning abilities (Ralls et al., 1985). Sirenians create relatively high-pitched squeaks, presumably used during social interactions (O'Shea & Poché, 2006).

Marine mammal hearing and sound production can be studied in the field and in the laboratory. Animal hearing is most efficiently studied either using psychophysics or auditory brainstem recordings with trained animals (Au et al., 2000). It is important to understand the acoustic features of an enclosure or pool in which the animals live when studying their hearing or sound production. For example, if pool walls are acoustically reflective, animals may not perform natural echolocation behaviors (Au, 1993), and stimuli presented during psychophysical trials may not be easily controlled (Gray et al., 2016). To perform psychophysical experiments under more natural conditions, a few studies with trained dolphins under free-range conditions have been conducted (Ridgway & Carder, 2001).

Echolocation is an important sensory modality in all toothed whales. Dolphins are excellent at discriminating between targets of different material and shape with their echolocation (Au, 1993). Attaching opaque suction cups over the eyes to occlude vision during voluntary training sessions can stimulate echolocation behavior. This can be done through voluntary conditioning. It is important that the specially designed suction cups only deliver very soft suction so as not to risk damaging the eyes.

There is currently exciting results generated from studies for which data are collected from the hearing system of toothed whales while an animal is echolocating (Nachtigall & Supin, 2008). These studies show that the animal not only has an ability to modify the outgoing signals (Au & Benoit-Bird, 2003) but also to modify its hearing threshold depending on range to target. This mechanism is presumably used to obtain the best possible perception of echoes and thereby improve detection and classification of targets.

All marine mammals studied to date have excellent underwater hearing abilities. Pinnipeds also hear well in air (Reichmuth et al., 2013), whereas probably all cetaceans have some difficulty receiving air-borne sounds (see Kastelein et al., 1997, for a psychophysical test of in-air hearing in a harbor porpoise). This may be important for how trainers interact with the animals in their care. For example, acoustic cues from the trainer may work much better for seals than for dolphins. High underwater noise levels (e.g., from pumps and filtration systems, etc.) in some facilities may cause stress or hearing problems in captive animals. Other facilities may be extremely quiet, and, instead, may have the problem of creating an exciting acoustic environment for the animal; therefore, the ambient noise levels in the facility should be measured regularly for the whole frequency range of interest for the species in residence. More research is needed to better understand the effects of underwater and above-water noise levels in aquaria on marine mammals.

Perspectives on Noise Control and Acoustic Enrichment from Oceanaria

Ann E. Bowles, Ph.D.

Globally, marine mammals are exposed to anthropogenic noise. The list of sources is familiar and long, including, but not limited to, seismic surveys, launch vehicles, pile driving, sonars, and ship noise. It is a truism that the ocean is noisy, but on an "apples to apples" basis, it is not inherently noisier than the terrestrial environment (Dahl et al., 2007). The quiet ambient environment in the ocean is comparable to a terrestrial residential neighborhood (rather than the bottom of the Grand Canyon) because both environments are exposed to traffic. Terrestrial vehicular and aircraft noise penetrates into even remote areas (Mennitt et al., 2014). The same is true of vessel noise in the marine environment. The big difference between the two is that, all else being equal, noise propagates much more efficiently in the ocean and, hence, more widely.

Noise from human activities, predominantly heavy shipping, has raised ocean ambient levels fourfold in the last half-century (Hildebrand, 2009) and has been described graphically as treating the ocean as "an acoustic garbage dump" (Clark et al., 2007, p. 336).

Noise is prevalent in zoological settings as well as in the ocean. We still do not have detailed comparisons of noise in the two media, although it is likely to be lower in managed environments than in the field, mainly because of the absence of noisy sources like vessel traffic and biologics (e.g., snapping shrimp). We do not know very much about the valence of this noise—positive, neutral, or negative—from the marine mammal perspective.

Noise is defined as *unwanted sound*. Wanting or not wanting a stimulus is an emotional response that may or may not be easy to detect in animals. If we as humans do not want to listen to a sound, we can make life difficult for the producer. However, in animals, the neurophysiological elements of their emotional responses to sound, and the behavioral sequels, may be difficult to document or understand. For example, they may freeze or exhibit overt habituation, which would be difficult to distinguish from an absence of response even when they are experiencing strong physiological changes (Bejder et al., 2009). To predict the effects of noise, it is important to connect these responses with their adaptations for coping with danger or interference with important functions like navigation. Unfortunately, the tools for detecting and interpreting animal emotional responses are still poor.

The intensity of animal responses to noise has been treated as a measure of potential for biologically important effects (Southall et al., 2007). However, only by understanding the adaptive benefits and costs of physiological and behavioral responses can we predict and prevent noise effects that are significant from a population perspective (Stankowich & Blumstein, 2005). Surprisingly, there has been little detailed work on positive or negative responses to sounds in oceanaria (but see Romano et al., 2004; Clark, 2013; Ridgway et al., 2014). Development of good tools for measuring the impact of noise would be an important contribution from scientists working in zoological environments.

The fight-or-flight response to loud, aversive noise is recognized as protective (Baldwin, 2013). Together with freezing in position (Hagenaars et al., 2014), these responses are nearly universal defenses among vertebrates. However, a range of other species-typical "survival circuits" (LeDoux, 2014)—adaptive neurophysiological, behavioral, and cognitive responses—may be elicited by exposure to alarming or negative stimuli. One example is the "tend-and-befriend" response of parents with young (Taylor, 2006). Thus, we cannot assess noise effects based on any single behavioral response. And, because behavioral responses are tightly linked with physiology, they should be studied in tandem (Kight & Swaddle, 2011).

Humans cope well with noise, even at levels that can damage hearing, but they are highly intolerant if the noise interferes with desired functions such as sleep, speech, or thought (Kryter, 1994). This suggests the formulation of a more general hypothesis: marine mammals will be intolerant of sounds that interfere with essential, ongoing functions or activities but may ignore sounds that do not. This hypothesis falls within the scope of behavioral ecology, the goal of which is understanding why particular responses are adaptive. As an example, "hard wired" aversion—for example, the startle reflex—occurs in response to loud sounds regardless of context, although the definition of "loud" may vary with ecological niche. If a species is ecologically predisposed to sensitivity (e.g., because it is prey to larger marine mammals), anthropogenic noise that causes significant effects may be much less intense than that affecting larger predators. For example, harbor seals and small porpoises avoid pinging instrumentation at very moderate levels (Kastelein et al., 2006; Teilmann et al., 2006; Southall et al., 2007; Bowles & Anderson, 2012). Work in zoological environments has been invaluable in understanding the relationship between acoustic features and responses of these species.

To come up with predictive tools, effects can be broken into levels, each subsuming the one below, ranging from the individual (and potentially trivial) scale to effects that are significant at population and ecosystem scales. The steps from one to the next can be summarized as a series of questions: What aspects of sound are inherently aversive to individuals given species-typical survival circuits? When do sounds interfere with biologically important activities (functional effects)? What response strategies will individuals adopt given other priorities? At what point will their capacity to cope be overwhelmed? If overwhelmed, will the resulting damage be sufficient to cause declines in reproduction or survivorship? Will this happen often enough for population-level effects? Will populations abandon favored habitats? What then happens to ecosystems for which marine mammals are keystone predators? Or, if noise affects species on which marine mammals depend, what will happen to the marine mammals?

There is evidence from the terrestrial environment that ecosystem-scale effects can result from exposure to chronic, high-amplitude noise (Francis et al., 2012). The terrestrial experience justifies modelling efforts now underway for marine mammals (National Research Council [NRC], 2005). For the models to be useful, however, they need inputs from coordinated research at individual to ecosystem scales. In addition, noise regulation for wildlife must be balanced against the needs of industry and society if it is to be enforced. Rules will be more effective and more enforceable if based on solid scientific facts (Southall et al., 2007). First-order, science-based regulations have been proposed to protect marine mammal hearing (National Oceanic and Atmospheric Administration [NOAA]/National Marine Fisheries Service [NMFS], 2013), and we have some understanding of how basic perceptual capabilities should be integrated into the regulations (Hawkins & Popper, 2014). The more difficult challenge will be to predict and prevent significant behavioral/physiological effects (i.e., non-auditory effects). It is already clear that these effects are not a simple matter of dose and response (Southall et al., 2007; Ellison et al., 2011).

For human communities, annoyance is a sensitive indicator of effects and the most common municipal benchmark for regulation (Suter & von Gierke, 1987). On the other hand, the U.S. federal entity charged with protecting human welfare in the workplace, the Occupational Safety and Health Administration (OSHA), only uses damage risk criteria designed to prevent hearing loss (OSHA Standard 1910.95). Marine mammal criteria have developed similarly. The guidelines now in existence are designed to limit avoidance (e.g., NOAA/NMFS, 1995) and temporary threshold shift (TTS) as a proxy for permanent threshold shift (PTS). These are still the only two effects that are regulated (NOAA/NMFS, 2013). Effects on detectability of communication signals, the analog to speech, have been analyzed (Clark et al., 2009) but not regulated. Ultimately, criteria may need to be developed across the range of possible functional impacts, including effects on sleep, communication, adult social relationships, stress (e.g., cardiovascular function), detection of predators or prey, navigation, territory maintenance, and parent–offspring interactions.

Intelligent marine mammals have a great capacity for habituation and behavioral adaptation, even if "sensitive." As an example, in the 1980s, harbor seals were characterized as "sensitive" to disturbance, but they are now adapting to urbanized habitats (Grigg et al., 2012). They can learn that they are safe and modulate their responses based on very subtle differences in sounds (Deecke et al., 2002). However, in this example, other processes could also have been at work (such as genetic drift). Because zoological facilities constantly strive to identify features of environments that are supportive of animal well-being, and also because they train their animals to be handled, they are good places to study this kind of adaptability over time.

We know of only a few types of sound that are reinforcing, and the nature of the positive experience remains almost unstudied. Observationally, vocal interactions among social partners, including mothers and calves, are mutually rewarding. Animals also produce sounds to fulfil their own needs by manipulating other individuals in less mutually beneficial ways. These include making noise to annoy, repulse, or punish. Other reinforcing sounds are training signals, which Ridgway et al. (2014) have associated with the release of dopamine when an animal makes a correct response. Sounds made by animals themselves in an effort to cope with boredom or social stress may also be reinforcing, but the topic has received little study, even in domestic species. Finally, broadband masking noise at moderate levels can obscure disturbing sounds such as noise from territorial rivals or predators (Wells, 2009).

Appropriate research on both positive and negative responses to sounds in zoological environments is well worth pursuing. Marine mammals are adapted to environments where sound is an essential source of information. Understanding which sounds are inherently agreeable vs disagreeable would enrich their lives and help us tease apart the levels of effect for the benefit of free-ranging marine mammals.

Marine Mammal Cognition

Rebecca Singer, Ph.D.

Cognition is the study of thought processes and may involve the study of attention, memory, categorization, language, and many other abilities. These same processes can and have been studied in animals, including marine mammals. The study of cognition in marine mammals aids animal caretakers, administrators, and researchers in making decisions about housing and welfare for their animals. Memory has been studied in many species using a delayed match-to-sample design. Animals are first shown a sample object and then must wait out a delay before being able to choose between two, three, or more alternative comparison stimuli. The task is to pick the comparison object that matched the original sample (Mercado & DeLong, 2010).

One implication for animal welfare of such research topics relates to enrichment. Objects may need to be rotated more frequently with a larger variety introduced to the rotation schedule to avoid habituation and boredom. It is unlikely that animals will forget they have seen a previous enrichment item, but having a longer time between repeated exposures may be beneficial to the animal.

The methodology for studying memory also may be used to investigate questions of categorization and self-awareness. Mercado et al. (2000) demonstrated that dolphins could succeed at same/different training in which the animal must report if two items are in the same or different categories. The ability of marine mammals to categorize like items is not surprising given their need to forage in the wild and recognize members of their own group vs intruders; however, it demonstrates a flexibility and level of problem solving that trainers and researchers can use to their advantage.

Self-awareness research is closely tied to animal welfare. Mirror self-recognition (Reiss & Marino, 2001) and imitation (Jaakkola et al., 2010) are two examples of self-awareness in dolphins. In mirror self-recognition studies, a mark is placed on the animal's body that they cannot investigate without the use of a reflective surface. In imitation, the animal is asked to perform a behavior they have recently seen or performed themselves. Both areas of research provide evidence that marine mammals are capable of understanding both motivation and outcome of their own behavior and the behavior of others. Animal housing and social interaction schedules need to take these abilities into account.

One prime example of using social interaction research to improve captive habitats comes from polar bears. Renner & Kelly (2006) provided suggestions, such as multiple routes within an enclosure and the need for several different substrates, based on the solitary nature and behavior of polar bears. Studying species-typical behaviors informs enrichment choices.

Enrichment may take many forms. Some items may provide sensory stimulation such as tactile or auditory. Others may encourage manipulation such as with toys. Enrichment also involves creating a stimulating environment and may also mean providing meaningful social interactions with other animals. Finally, research and training sessions may serve as enrichment tools for animals under human care. Cognition research will help inform enrichment decisions. The most effective enrichment items are based on the animals' biological, social, and cognitive needs. They are mediated by an individual's history and species-typical behavior (Disney, 2009).

Research not only guides welfare decisions but may be used to inform the public through conservation and education programs. The days of research being conducted behind the scenes is nearing an end. Researchers and curators must work together to develop programs that the public can witness and, at times, in which they can participate. A starting point would be to incorporate some cognitive research findings into daily keeper talks and presentations. Conservation efforts could certainly be aided by the public's greater understanding of marine mammal cognition.

Cognitive Dissonance and the Value of Reward

Rebecca Singer, Ph.D.

Cognitive dissonance is the discomfort a person feels when their behavior does not match their belief. For example, if a person believes that smoking is detrimental to their health but they smoke anyway, they would likely experience cognitive dissonance. One specific type of cognitive dissonance involves justifying high effort by increasing one's perception of the ensuing reward value. For example, if someone goes through a difficult rite of passage, they would value group membership as a way to justify what they had just experienced (Aronson & Mills, 1959).

One way to look at the mechanisms responsible for justification of effort outside of social factors is to use an animal not particularly known for its sociality or intelligence. When pigeons are tested in high effort vs low effort conditions, they prefer the rewards associated with the high effort condition (Clement et al., 2000; Singer & Zentall, 2011). However, the explanation for this preference is far less cognitive than the one given for humans showing the same preference. The proposed explanation is called *within-trial contrast*, and this model predicts that reward will be more highly valued following any aversive event when that event is compared to a less aversive event. For example, high effort is more aversive when compared to low effort. A delay to reinforcement is considered aversive when compared to no delay. Absence of food would be aversive in comparison to presence of food. Animals show a consistent preference for the reward associated with the more aversive event in all of the above examples (DiGian et al., 2004; Friedrich et al., 2005).

Theoretically, the contrast effect has implications for animal training and welfare. First, animals may have preferred and nonpreferred behaviors. However, a nonpreferred behavior would seem to be preferred when compared to an even more aversive behavior. This is not to imply that trainers should force their animal to perform under threats of unpleasant consequences. This is simply to suggest that it is possible to allow an animal to make a choice between two behaviors, and this may increase voluntary participation in certain behaviors. Second, we may be able to increase an animal's perception of reward value by increasing the effort required to obtain the reward. This may be particularly useful in an animal that is showing some disinterest in certain food types. Increasing the value of the reward may increase consumption.

The previous two implications are directly related to reward value and contrast. The next potential implication involves the additional cognition of expectation of reward. Trainers and scientists working with marine mammals know that the animals easily learn to expect certain rewards. It is possible that trainers may get in the habit of giving the same type or amount of reward for certain behaviors. Violating that expectation can lead to breakdown of behavior and aggression. For example, primates will consume pieces of lettuce without hesitation during experimentation. However, showing a coveted piece of banana but then secretly switching the reward to a piece of lettuce caused distress and refusal to consume the lettuce (Tinklepaugh, 1928). It is a cautionary tale to avoid setting up expectations of reward values for specific behaviors.

Finally, marine mammal trainers use a combination of primary and secondary reinforcers to maintain behavior. Primary reinforcers are biological in nature. They are essential for the well-being of the animal such as food and water. Secondary reinforcers are items or actions that the animal learns to value such as praise or touch. It is actually possible that work itself can become a secondary reinforcer. This is a relatively new concept called *learned industriousness* (Eisenberger, 1992). If an animal is reinforced for hard work, the sensation of high effort may become a secondary reinforcer. The implication is that trainers and researchers may want to encourage high effort over low effort. Research indicates that it is easier to get an animal to learn a difficult task if they have already learned another difficult task. They learn to persevere and get rewarded. Humans with learned industriousness tend to work harder, longer, and with greater patience than those who continually get easy tasks. Attention to reward value and work ethic may require some initial investigation, but the potential rewards for both animal and trainer are certainly justified.

Research Training

Rebecca Singer, Ph.D.

Marine mammal researchers are interested in asking complex questions about behavior and cognition that inform our decisions about care and conservation. Collaboration between trainers and researchers is notoriously known for creating problems; however, they are slowly becoming more normative, even though there remain challenges in such collaborations. A greater understanding of one another's viewpoints will lead to more successful projects. Trainers and researchers have different goals for working with marine mammals. Most trainers have one or more of three primary goals: (1) training of husbandry behaviors, (2) training of show behaviors, and (3) training as enrichment. Researchers are primarily interested in training attention to task and specific behaviors related to complex research questions. While trainers and researchers may approach a training session with different goals in mind, the underlying characteristics may not be as disparate. Both trainers and researchers likely choose their field because they are interested in working with marine mammals and raising awareness. In addition, both trainers and researchers are dedicated, detail-oriented, and patient, often working long hours for little financial reward. Both must learn to pay attention to small details.

While the priorities of trainers and researchers are different, their underlying traits are quite similar and can be building blocks for collaboration. Such collaboration also involves being mindful of the specific requirements of each participant. Researchers must be willing to work within already established routines, respect the animals' feeding schedules, and not design projects that use the animal's entire daily dietary intake. Researchers need to be aware of the social dynamics of the group and understand that separating animals for testing may not always be in the best interest of the group. Research behaviors should not be inconsistent with previous training. For example, trainers must be allowed to address inappropriate low criteria and/or aggressive behavior during a break in the research session to maintain consistent high standards of behavior. Finally, researchers need to be flexible and work around animals that do not want to move from one exhibit location or social situation to conduct data collection or participate, and be able to adapt to the situation.

Researchers have their own specific requirements. First, it will almost always benefit the researcher if several animals can participate in the study: the larger the sample size, the more robust the findings. Second, the researcher will set up a protocol that can be used for all animals involved in the research project, and trainers should consistently follow the protocol. Researchers should clearly communicate the protocol and reasons behind it, and trainers should express concern about any part of the protocol *before* a research session begins. While research protocols might come across as too rigid, controlling for and eliminating alternative explanations of behavior through experimental consistency is the only way to know what an animal can and cannot do and why.

When researchers design an experiment, they try to account for all possible variables and control for them to the greatest possible extent. Trainers need to be aware that these protocols are not put into place to make daily husbandry and training difficult but because the data are meaningless without all these controls in place. Finally, the different phases of an experiment should be clearly explained to all personnel. In many research protocols, there are habituation trials in which the animal is exposed to a new apparatus. This prevents any reactions recorded during training or testing to be due to novelty effects. Habituation is often followed by a training phase in which an animal is taught, using differential reinforcement, what the correct behavior is. This means that a reward is given for the correct answer while none is given for an incorrect behavior. The final phase is the test phase in which the researcher asks if the animal understands the concept that had been taught during the training phase. No differential reward should be given during the testing phase because the point is to test the knowledge or understanding of the animal, not to train the correct answer.

Remember that test trials are important, and an incorrect answer is okay. Those "wrong answers" are also important data. Trainers need to be careful not to cue unintentionally or train the animal to respond in a certain way so that the researcher can more easily interpret the findings. There are several practical steps that facilities and researchers can take to encourage collaboration. First, all those working on a research project should meet to go over the goals and specific protocols of the research. This allows time for questions and concerns to be raised and modifications to be made. Second, trainers should be asked how involved they wish to be and given the opportunity to participate in the project if they wish. Third, trainers and researchers should stay focused on the project and maintain an attitude of collaboration. If something is not going well, it is time to take a break, talk about it, and fix the problem. Fourth, a simple thank you to the staff who took their time to make the research possible goes a long way. Finally, scientists need to share their research with those who have given their time and energy. A little planning and extra consideration on everyone's part will lead to more successful collaboration in the future.

Auditory Studies on Harbor Porpoises (*Phocoena phocoena*) in Captivity: The Complexity of Research Design and Animal Training

Klaus Lucke, Ph.D.

Designing and successfully conducting research in captive marine mammals requires a functional communication and understanding between animal trainer and researcher. While the animals' and peoples' health has highest priority, all parties involved in animal research need to understand and respect the requirements resulting from the different approaches from which each "side" is operating. Auditory studies on harbor porpoises are taken as an example of the complexity of problems commonly encountered in the conduct of these studies. A number of relevant aspects emerge, but the key factor for a successful study is good communication between trainers and researchers.

Knowledge on the hearing sensitivity of marine mammals has become an increasingly hot topic over the past decades. A variety of scientific approaches have been employed to evaluate hearing in these species. The best method, the classical approach of conducting a behavioral psychophysical hearing test, involves repeated access to well-trained animals. The alternative approach to obtaining direct information on the animals' hearing sensitivity is to measure auditory evoked potentials (AEPs). The advantages are that the measurement can be done in a relatively short period of time (hours) and can even be conducted on free-ranging animals. The following highlights some general aspects in the trainer–researcher relationship that are important to consider—for both the trainer's and the scientist's points of view:

- Animal health and ethical issues must be carefully considered; in many cases, the national authorities must grant an animal experiment permit.
- The procedures need to be repeated several times in the same way to ensure reproducibility of results.
- The animals' behavior needs to be reliable and under good control before data collection commences (to avoid breakdown of behavior and to increase reproducibility).
- Trainers and researchers need means of monitoring the animals' behavior during experiments.
- Environmental conditions (e.g., current, wind, and waves) need to be taken into account.
- Limited resources: fish and training time
- Cost effectiveness and funding requirements (i.e., what had been promised to the funder)

In summary, conducting research studies that include trained animals requires careful planning.

For all of these aspects, communication between trainers and scientists is the key to success. Both, trainers and researchers need to understand the needs and requirements of each other. For trainers, it works best if they are open for new challenges—for themselves as well as for the animals. They need to communicate the training progress and problems encountered to the researcher and anticipate that scientists have a different background than trainers. Scientists need to understand the training, husbandry and health requirements and not ask for the impossible. They need to be open to the trainers' insights regarding the animals' health, be willing to communicate the research progress, and also to anticipate that trainers have a different background. Working as a team is the best and most enjoyable way to come to a successful end of a research study. Above all, ensuring the animals' (and peoples') health and well-being has to take priority over results.

The Importance of Observation

Niels van Elk, DVM

In the veterinary profession, success is utterly dependent upon the quality of observations made. Observations are the foundation of any analysis, and no analysis is stronger than the foundation on which it rests. Trainers and animal care staff are excellent observers. A symbiosis thus occurs in which the animal care staff may save the reputation of the veterinarian, and then hopefully the veterinarian may save the animal.

There are a few points to note about the process of observing that may help to improve the quality of observations and raise awareness about pitfalls. An observation is the result of the work of our senses and our brain. Both have been created through the process of evolution, and we must understand that our power of observation is geared towards helping an ape (i.e., ourselves) survive on the savanna. Our senses operate in an evolutionary appropriate manner with regard to speed, spectrum, and amplitude. We cannot see a bullet fly or a mountain rise because the speed of these processes has no evolutionary relevance to our species. We must be aware of these limitations of our senses and help ourselves by, for example, viewing pictures taken at large time intervals to become aware of slow changes.

The universe is endless. In a single room, a lifetime can be spent by making all possible observations. Our brain selects continuously and subconsciously to make sense of all the sensory input our brain receives. We ourselves also have to make a very careful selection of what we wish to observe in order to make sense of all the possible observations that can be made of an animal. Furthermore, when we observe, we should be aware of the two most common pitfalls in proper observation: (1) prejudice and (2) distraction. Some anecdotes on the importance of observation: first, the inability to observe a stiff shoulder for several months as it was not specifically looked for; and second, the diagnosis of an endometritis (uterus inflammation) by the sharp observation of a trainer who noticed singly yellow floc drift from the genital slit of a dolphin.

Finally, we should not overestimate our own powers of observation. To the expert audience, two pictures of the same killer whale under water in full horizontal view were shown. The audience failed to notice correctly which picture showed the heavier killer whale even though there was a 20% weight difference. Observing remains a task that requires complete dedication.

Cetaceans in Human Care

James McBain, DVM

The quality of cetacean life in the care of man is largely dependent on the choices and decisions made by a large group of people—someone must advocate for the animal. If you have chosen to work with captive cetaceans, you need to embrace the nature of the word *captivity*. This word has been used to promote a negative view of zoos and marine parks. The *Macmillan Dictionary* offers a useful definition of "captivity": "a situation in which wild animals are kept in a place such as a park or zoo instead of living in their natural environment." In contemporary zoological parks, enrichment, health, well-being, and general welfare are primary considerations; this is very different from goals associated with the alternate form of captivity, a prison. I suggest that the life of a marine mammal in human care is not inherently better or worse than life in the wild. It's just different.

The quality of life of a wild animal or a captive animal is not defined by where it lives. Consider differences between life in the wild and life in a marine park. Space is the feature that dramatically differentiates the two. Is space the primary determinate of cetacean quality of life? Does a cetacean sometimes swim 80 or 160 km in a day because it can or because it must? There is evidence that the range of most predators is in large part a function of food availability. In a marine park, the challenge of finding prey is removed.

Annual survival rates and reproduction are not negatively impacted by space available to cetaceans in contemporary marine parks. In the wild, parasite infestation is the norm; and injury, illness, misfortune, or food shortages often lead to death. Cetaceans in human care rarely experience parasite infestations and are protected from many of life's misfortunes. That protection is best described as a *preventative healthcare program*. The goals of these programs are to prevent disease in the population, to diagnose it and treat it in its very early stages, and to reduce the impact of existing disease.

In the care of man, a captive cetacean's quality of life decisions are impacted by the goals and choices of a group of individuals and institutions, including government, owner/CEO/director, manager, life support operator, trainer/keeper, veterinarian, and the animal. Aside from the obvious job descriptions, advocacy for individual animals is a vital responsibility of trainers and veterinarians. The individuals best qualified to advocate are those who work with the animals on a daily basis.

Cetacean training activities provide for intellectual challenges that are part of any natural environment. The desire to provide additional self-directed mental stimulation for animals has led to contemporary interest in environmental enrichment. Over 20 y ago, Markowitz & Gavazzi (1995) published "Eleven Principles for Improving Quality of Captive Animal Life." The following is a summary of those principles that are especially relevant to environmental enrichment for cetaceans in human care:

- Animals usually prefer actively working to gain access to food—Ad lib feeding is not the most humane approach.
- Novelty is an important component of environmental enrichment.
- Within limits, the responsiveness of the environment has more impact on an animal's well-being than the amount of space provided for housing.
- Effectively enriching environments requires regular, systematic observation of each animal in the facility.
- Environmental enrichment design(s) should increase opportunities for species-appropriate behaviors.
- After designing more responsive environments, we would do well to observe the animals' methods for dealing with new challenges rather than trying to refine the apparatus or procedure to lead to a predicted result.
- If enrichment programs are not part of the formal job responsibilities of the staff, they eventually will become an inconvenient, time-consuming extra.
- Animal care experts should not leave habitat design to architects and engineers.

The appropriate social grouping of cetaceans in our care provides for an environment with ramifications for well-being. A member of a social group with no positive relationships will likely suffer the effects of chronic stress. My simplistic aphorism for this thought is "Every dolphin needs a friend." In humans, there is an inverse correlation between the quality of social relationships and mortality rates. Animal studies also suggest that social isolation is a major risk factor for mortality. Three social constructs appear to influence health: (1) *social support* is stress buffering, (2) *social integration* yields a positive social state and is beneficial regardless of degree of stress, and (3) *negative interactions* occur because social networks provide opportunities for conflict and spread of disease (Cassel, 1976; House et al., 1988; Cohen, 2004).

The early recognition of illness and initiation of appropriate therapy yields the best medical outcome and is a shared responsibility of trainers and veterinarians. Deviation from normal is most readily identified early if the trainer knows what is normal. This is made more difficult by the aquatic environment and the ability of cetaceans to disguise signs of illness. The more objective normal physical and behavioral information trainers possess for individuals in their care, the earlier they will be able to recognize and respond to change. Objective visible features include skin, eyes, blowhole, genital-anal area, mouth, tongue, teeth, buoyancy, resting posture, respiratory characteristics, bowel movements, urination, appetite, weight, and body temperature, to name a few. Revealing social or behavioral features include interaction characteristics with conspecifics, friends, and trainers before, after, and during training sessions as well as when trainers are not present in the area.

Inflammatory diseases, as a group, are usually amenable to treatment or prevention but have the potential to kill if unrecognized and unchecked. Trainers should know the early signs of inflammation: redness, swelling, heat, pain, and loss of function. Noticing one or all of these signs can be significant.

Regurgitation is a natural tool for female cetaceans introducing their calves to solid food. This may explain why regurgitation can appear in apparently normal, socially well-adjusted cetaceans. The condition we often call *regurgitation* may be better described as *rumination*. It is characterized by repetitive, effortless regurgitation of recently ingested food followed by re-chewing, re-swallowing, or expulsion. It is a habit with the purpose of self-stimulation and may be exacerbated by boredom, excitement, or anxiety (Wemselfelder, 2005).

As advocates for the cetaceans in our care, we should assure that the animals have a life that includes happiness and purpose. I am often asked, "How do you know when the animals are happy?" The people that make a career of working with marine mammals work very hard every day to understand the welfare of the animals through careful observations and other methods to assess animal welfare. They provide choices and opportunities that make animals happy, and that is fact.

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