Advancing Behavior Analysis in Zoos and Aquariums

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Abstract Zoos, aquariums, and other captive animal facilities offer promising opportunities to advance the science and practice of behavior analysis. Zoos and aquariums are necessarily concerned with the health and well-being of their charges and are held to a high standard by their supporters (visitors, members, and donors), organized critics, and the media. Zoos and aquariums offer unique venues for teaching and research and a locus for expanding the footprint of behavior analysis. In North America, Europe, and the UK, formal agreements between zoos, aquariums, and university graduate departments have been operating successfully for decades. To expand on this model, it will be necessary to help zoo and aquarium managers throughout the world to recognize the value of behavior analysis in the delivery of essential animal health and welfare services. Academic institutions, administrators, and invested faculty should consider the utility of training students to meet the growing needs of applied behavior analysis in zoos and aquariums and other animal facilities such as primate research centers, sanctuaries, and rescue centers.

Keywords Animal training · Animal welfare · Aquariums · Behavior analysis · Environmental enrichment · Zoo biology · Zoos

Psychologists trained in behavior analysis have a long history of conducting basic and applied research with exotic wildlife in zoos, aquariums, and specialized marine parks. At one time, operant conditioning techniques were routinely deployed to train cetaceans (dolphins and porpoises) in studies of discrimination, sensory perception, and echolocation (Kellogg and Rice 1966; Pryor 1981; Tavolga 1966). Many studies of cetaceans and pinnipeds (seals, sea lions, walrus) have been published in psychology journals, including the *Journal of the Experimental Analysis of Behavior* (e.g., Beach

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and Pepper 1972; Herman and Arbeit 1973; Kastak and Schusterman 2002; Pryor et al. 1969). However, at the present time, only a small number of zoos, aquariums, and marine parks employ or collaborate with behavior analysts. Instead, there is a heavy reliance on animal trainers with little or no formal background in the science of behavior analysis. Currently, aquariums, marine parks, and zoos exhibiting marine mammals emphasize the show rather than the science of training, but research has demonstrated that shows have considerable potential for influencing conservation attitudes and behavior (Miller et al. 2013; Sweeney 2009). The story of how animals are trained, why they are trained, and what the process reveals about their “cognitive capacity” is information that should be widely shared in public performances. In addition, zoo and aquarium collections provide behavior analysts with unique access to a kingdom of biodiversity that allows for the examination of the phylogenetic breadth of behavior analysis (c.f., Grossettt et al. 1982; Miller and King 2013). Zoos and aquariums represent a niche well suited for the practice of behavior analysis and an opportunity to promote and extend the science of behavior.

Hal Markowitz (1978, 1979) first demonstrated the potential of behavior analysis in the zoo during his tenure as Director of Zoological Research at the Portland (Oregon) Zoo. Educated in the fields of biology, psychology, and engineering, Markowitz trained animals to manipulate operanda and delivered food and access to puzzles as reinforcers (Markowitz 1982). His fundamental understanding of how behavior is controlled in captive settings led to the development of the field of *environmental enrichment*. Today, environmental enrichment is an essential tool in the animal care protocol of all world zoos and a requirement for institutional accreditation in the Association of Zoos and Aquariums (Association of Zoos and Aquariums n.d., p. 60). Upon his appointment to the faculty of San Francisco State University, he continued his research at the San Francisco Zoo and opened the door for a succession of student collaborators. More than any other scientist working in zoos and aquariums, Markowitz demonstrated that behavioral research protocols could be developed to further the objectives of animal welfare.

Reconnecting Zoos, Aquariums, and Behavior Analysis

At a time in history when zoos and aquariums are committed to training for daily behavioral management, noninvasive medical intervention, and environmental and behavioral enrichment (Clark 2013), a majority of academic departments of psychology are no longer devoting sufficient resources to support animal research. As Normand and Kohn (2013) observed, the vast majority of graduate programs in behavior analysis currently offer terminal master’s degrees with faculty and students primarily committed to the treatment of autism and other human developmental disabilities. Behavior analytic animal learning labs were once ubiquitous on college campuses. The second author conducted a brief survey of master’s and doctoral programs accredited by the Association for Behavior Analysis International (ABAI; $n=19$) to examine this issue. Only 7 of the 19 (37 %) respondents reported that their program currently provides an active animal research lab. If respondents indicated that their department previously offered an active animal research lab, they were asked to provide a reason why the lab was no longer active. Survey respondents cited a number of factors responsible for this

trend, including the financial burden of maintaining animal facilities and the priority expansion of fields like human cognitive neuroscience. Although animal-based learning labs are no longer prevalent, behavior analysis has seen growth in other fields.

Currently, applied behavior analysis is probably best known for its success treating autism and developmental disabilities, but these fields are not the only ones in which behavior analysis can exert significant influence. As Poling (2010) concluded, the science of behavior can be widely applied outside of the field of developmental disabilities, and strengthening alternative connections will ensure the survival and prosperity of the field as a whole. Friman (2010) suggested that one way to ensure relevance may be to enter the mainstream through integration into an already existing field. Integration may not be easy to achieve, but pushing the boundaries of behavior analysis will surely increase the long-term strength and viability of the field (Vyse 2013). Normand and Kohn (2013) recently identified other fields of interest that are perfectly suited for behavior analysts, including opportunities to work with animals. Similarly, Forthman and Ogden (1992) foresaw the value of behavior analysis in management of zoo populations (see also Tarou and Bashaw 2007). Fortunately, behavior analysis does not need to forge a completely new path, but instead simply reinvest in its animal research origins.

Reconnecting zoos and aquariums with behavior analysts may require only the linking of graduate students in behavior analysis with research, keeper, and curator employment opportunities in aquariums, zoos, sanctuaries, and related animal facilities. There is precedent for this strategy as graduate students working with Hal Markowitz at San Francisco State University (Maple 2013; Markowitz 1982, 2011) and those working with professors Maple and Marr at the Georgia Institute of Technology (Bloomsmith et al. 2007; Lukas et al. 1998) have conducted research in animal behavior and behavior analysis in zoos while earning academic credits for honor's, master's, and doctoral level degrees in biology and psychology. Many of those students were later offered full-time employment in zoos throughout the world (e.g., Brookfield Zoo, Cleveland Metroparks Zoo, Detroit Zoo, Disney's Animal Kingdom, Lincoln Park Zoo, National Zoo, San Diego Zoo, Singapore Open Zoo, and Zoo Atlanta). A key to securing employment in zoos and aquariums is familiarity with the work setting through internships and research collaborations. Nearly all zoos and aquariums offer these opportunities and compete for the most promising students.

To commemorate the scientific contributions of Hal Markowitz and to simultaneously conduct welfare-related animal research, the San Francisco Zoo recently established funded research positions for graduate students selected as "Hal Markowitz Fellows." The way to incorporate behavior analysis into such a program is to establish formal partnerships, simple memoranda of understanding between zoos and behavior analytic graduate programs or faculty, or dedicated endowments. The Atlanta model, which included behavior analysis, was supported by a privately funded endowment of \$3.5 million. Others seeking to create similar programs can pursue endowments with outlined provisions to ensure that behavior analytic research is included.

Many zoo and aquarium professionals utilize the technology derived from the science of behavior analysis (e.g., respondent and operant conditioning). Animals as different as crocodiles, chimpanzees, and gorillas, among other vertebrates, have been trained to shift on and off exhibit (i.e., move from night quarters to publicly viewable areas of the zoo; Bloomsmith et al. 2003), give blood (Augustine and Baumer 2012),

wear a sleeve to monitor blood pressure, accept ultrasound examinations (Maple and Perdue 2013), and tolerate medical (Amaral et al. 2009; Clay et al. 2008; Colahan and Breder 2003; Laule 1993) and dental examinations (Colahan and Breder 2003) without anesthesia, but behavior analysis has much more to offer. Operant conditioning is one of the most important tools available to veterinarians and zoo biologists, even if the full scope and potential of the science are not fully understood by zoo managers. The missing partner in the zoo-training paradigm is the experimental psychologist with expertise in operant conditioning (Laraway et al. 2003).

The Scientist-Practitioner Model in Zoos and Aquariums

Behavior is the most salient characteristic of living organisms, and behavior analysis as a natural science is best viewed as a branch of biology (e.g., Marr 2009). As Skinner (1974) himself remarked, “The experimental analysis of behavior is a rigorous, extensive, and rapidly expanding branch of biology” (p. 231). In fact, many sources (including analogies and models) for understanding behavior come from biology—selection in evolutionary biology being a major example. The convergence of zoo biology and behavior analysis may be the catalyst for a unified theory. Catania (2013) acknowledged the promise of this fusion of biology and psychology:

. . . psychological science cannot survive other than as a science of behavior; further, if it is a science of behavior it must be intimately tied to the biological sciences . . . It is my conviction that behavior analysis will come to be viewed as a major scientific advance of the 20th century, comparable to that of natural selection in the nineteenth. The role that psychology will play in what follows from that advance remains to be seen. (p. 139)

The iconic Swiss zoo director Heini Hediger was the first to describe the science of zoo biology in his book *Man and Animal in the Zoo* (1969). Hediger regarded research as one of the primary justifications for the existence of zoos and aquariums. As the acknowledged foundation of animal welfare in agriculture and biomedicine, research is also a cornerstone of zoo animal welfare (Maple and Perdue 2013). For Hediger, and for all zoo directors, the greatest challenge continues to be the allocation of sufficient funding to implement reliable institutional research resources. When zoo research is properly funded, the welfare of animals is immediately elevated to a higher priority.

Hediger, who also lectured in ethology at the University of Zurich, was a prime example of the scientist-practitioner operating at the executive level of a zoological institution. The fact that CEOs at Disney’s Animal Kingdom, Cleveland Metroparks Zoo, Oklahoma City Zoo, St. Louis Zoo, and the Toledo Zoo have been hired with earned doctorates suggests that evidence-based management might be gaining traction at the executive level in North America. German zoos are more often led by CEOs with doctoral degrees, and scientific partnerships between universities and zoos have also been established throughout the UK (Holden et al. 2006; Melfi 2009; Clark 2013) where many zoos have also recruited executives with scientific credentials. Curators with doctoral degrees are a recent trend in the zoo profession, and they too qualify as scientist-practitioners given the demand of their management responsibilities (Ross and Lukas 2006).

A series of surveys has consistently demonstrated that zoo and aquarium managers generally welcome outside scientific collaborators (Anderson et al. 2008, 2010; Finlay and Maple 1986; Stoinski et al. 1998). Although formal scientific programs have developed slowly and cautiously in North America, the San Diego Zoo, Smithsonian National Zoo, and Chicago's Brookfield Zoo were pioneers in building dedicated scientific units committed to evidence-based animal and medical management (Erwin et al. 1979; Maple and Bashaw 2010; Maple and Lindburg 2008). Other North American zoos currently committed to research—both systematic observation and experimental analysis—include Cleveland Metroparks Zoo, Denver Zoo, Detroit Zoo, Disney's Animal Kingdom, Lincoln Park Zoo, Oregon Zoo, San Francisco Zoo, Woodland Park Zoo, Zoo Atlanta, and many other accredited zoos and aquariums. Each of these institutions has recruited a team of doctoral level staff or formed scientific partnerships to ensure quality, productivity, and impact. New York's Bronx Zoo (Wildlife Conservation Society) has built a formidable endowment to support global research in field and conservation biology, but Bronx zoo biologists have also utilized methods of behavior analysis to manage their animal collection (e.g., Savastano et al. 2003). It is clear that research-oriented zoos and aquariums are promising partners for expanding the science and practice of behavior analysis.

One of the oldest continuous scientific programs in a European zoo was founded in 1828 at Amsterdam's Artis Zoo. In the nineteenth century, the combination of a zoo, scientific collection, and zoological laboratory represented the beginning of a new form of learned society (Mehos 2006). In 1928, the zoo built a dedicated animal behavior laboratory directed by the distinguished professor of ethology, J. A. Bierens de Haan, who was affiliated with the University of Amsterdam. Another Dutch zoo, Burgher's Zoo in Arnhem, is also committed to research with a strong working partnership with the State University of Utrecht. Arnhem-Utrecht behavioral scientists have been highly productive for more than five decades, during which time the zoo has been a primary venue for conducting doctoral dissertations in primatology (e.g., Adang et al. 1987; Adang 1986; te Boekhorst et al. 1990; Hooff and Wensing 1987; Nieuwenhuijsen and de Waal 1982).

Arguably, the strongest scientific relationship between a zoo and an academic institution in Europe is Max Planck's historic partnership with Zoo Leipzig. Scientists at the Max Planck Institute for Evolutionary Anthropology are investigating the cognitive capacity of diverse species, but they are especially well known for their benchmark work on great apes (Call and Tomasello 1999; Seed et al. 2009). Observations and experiments are conducted at the Wolfgang Kohler Primate Research Center located in the zoo where visitors can witness research as it is being conducted by collaborating scientists and their students. Institutions like the ones mentioned above are appropriate collaborators for behavior analytic scientists and practitioners. Behavior analytic research methods could easily translate to such an environment, and doing so may even help with the dissemination of knowledge about the field.

Adopting the scientist-practitioner model and interdisciplinary collaborations are beneficial when the results are disseminated to the broader scientific community. The success of the collaborations between zoos and academic institutions recently resulted in the formation of a new scientific journal (*Journal of Zoo and Aquarium Research*) first published by the European Association of Zoos and Aquariums (EAZA) in 2013. This journal joins three other scientific periodicals focused on zoo and aquarium

research, *International Zoo Yearbook* (f. 1960), *Der Zoologische Garten* (f. 1859), and *Zoo Biology* (f. 1982). Applied behavior analytic research has been published in specialized zoo journals (e.g., Bloomsmith et al. 2003; Chang et al. 1997; Forthman-Quick 1984; Holden et al. 2006), and other animal behavior and welfare-oriented journals have also accepted papers from behavior analysts and their zoo-based collaborators (Clay et al. 2009; Elmore et al. 2012; Gaalema et al. 2011; Jensen et al. 2013; Laule 1993; Lukas 1999; Marranzino 2013; Pomerantz and Terkel 2009; Savastano et al. 2003).

The *Journal of Applied Behavior Analysis* (JABA), a flagship journal for the field of behavior analysis, has published relatively few studies of animal interventions by qualified behavior analysts working in captive settings (Edwards and Poling 2011). One of the published papers (Martin et al. 2011) reported a significant reduction of feces throwing and spitting by a chimpanzee through the differential reinforcement of alternative behavior coupled with extinction of the undesired behavior. Another example published in JABA is the recent research of Dorey et al. (2009) who conducted a functional analysis of self-injury in a captive olive baboon. JABA's commitment to the "publication of reports of experimental research involving applications of the experimental analysis of behavior to problems of social importance" is a good platform for the publication of behavior analytic research that contributes to animal welfare.

Behavior Analysis and Zoo Animal Welfare

It is not enough to understand that behavior analysis can be a powerful tool in zoos and aquariums. For the connection between behavior analysis and zoos and aquariums to be reestablished, the climate must be right for integration. With the recent emergence of the animal welfare and wellness movement, zoos and aquariums are perfectly positioned to benefit from behavior analysis. Many problem behaviors are an indication of poor welfare, and behavior analysis is an important tool for improving welfare and achieving acceptable levels of psychological well-being in zoo and aquarium animals. Animal welfare has become a ubiquitous research topic in agriculture, biomedicine, and zoological collections (e.g., Dawkins 2008; Maple 2007; Maple et al. 2008; Maple and Perdue 2013; Mason and Veasey 2010; Novak and Suomi 1988). To reiterate the recommendation of Edwards and Poling (2011), animal problem behavior can be socially significant for both animals and human caregivers.

Animal welfare-oriented surveys conducted by the Humane Society of the United States (2012) have demonstrated that many people are uneasy about keeping whales in captivity primarily for entertainment, but the data also reveal that people may be willing to accept a collection of whales in captivity for the purpose of serious scientific study. Behavior analysts conducting research in marine theme parks, aquariums, and zoos that operate shows featuring trained animals can provide a scientific buffer against critics who object to living conditions for marine mammals in captivity. Performing animals spend most of their time off-stage, and these hours would be more enriching if behavior research was a priority of the performance paradigm. In a review of behavioral enrichment strategies for marine mammals, Clark (2013) identified a menu of cognitive tasks that challenge the skills of dolphins and sea lions, an improvement over more passive forms of enrichment that lead to rapid habituation (Delfour and Beyer 2012).

Clark further suggested that complex behavioral challenges could compensate for the fundamental limitations of housing marine mammals in restricted aquatic environments. The participation of highly skilled behavior analysts could lead to innovations that extend the useful life of enrichment objects and techniques and provide challenging and stimulating learning opportunities for marine mammals while simultaneously providing useful data to advance our understanding of cetacean evolution and behavior.

Behavior analytic methods and technology are particularly well suited for application to zoos and aquariums. Single-subject designs are ideal for zoos and aquariums, which often house a small number of each species in their collection. In addition, the behavior analytic approach that focuses on not only antecedent-behavior-consequence relationships, but also on motivating operations and discriminative stimuli, means that zoos and aquariums stand to benefit from training protocols that take all of the above-mentioned environmental relationships into account. For example, the full potential of training based on positive reinforcement could be greatly strengthened by the behavior analytic approach, including the use of preference assessments to determine a hierarchy of reinforcers (e.g., Fisher et al. 1992), the use of functional analyses to identify environmental variables maintaining behavior (e.g., Iwata et al. 1982/1994; Martin et al. 2011), the manipulation of motivating operations and discriminative stimuli, the analysis of treatments, and the reliance on stringent data collection methods. Behavior analysts are specifically trained to recognize ratio strain, the role of response effort, and the necessity for contiguity and contingency when delivering a reinforcer following a behavior. In addition, behavior analysts recognize the importance of programming for generalization and discrimination, whichever is most appropriate for the desired treatment goal.

Stereotypic behavior, social aggression, self-injurious behavior, and coprophagia have all been treated with behavior management techniques based on operant conditioning and the basic principles of learning (Blooms Smith et al. 2007; Clay et al. 2008; Laule 1993; Martin et al. 2011). Behavioral therapies are often the preferred method of behavior change, obviating the need for risky pharmaceutical intervention. To clarify, some (if not many) non-behavior analytic trainers have demonstrated their effectiveness in applying operant conditioning-based training methods, but behavior analysts have a scientific understanding of the principles of behavior that can be used to maximize treatment efficacy.

Expanding the Network of Behavior Analysis

Although zoo and aquarium curators, keepers, and veterinarians have discovered the value of applying operant conditioning procedures to provide safe, noninvasive medical, and management interventions, without a formal education in behavior analysis, they cannot be expected to recognize the full potential of behavior analysis as a science and practice. These practitioners have been content to use their own training personnel to train others and to utilize affiliated societies such as International Marine Animal Training Association (IMATA) and Animal Behavior Management Alliance (ABMA) for the expertise needed to manage the health and welfare of animals or to train them for wildlife shows. Among such affiliations, information is often disseminated through newsletters, workshops, and trade conferences with little emphasis on refereed journal publications, systematic replication, or technological innovation. Representatives of ABMA have acknowledged in a core value statement that operant conditioning is their

most effective training tool (AMBA n.d.); however, the scientific foundation underlying operant conditioning is not mentioned as an essential feature of the technology. Although the expertise and achievements of elite trainers cannot be underestimated, reconnecting behavior analysts with academic credentials to curators, keepers, trainers, and veterinarians will demonstrate how animal behavior can be modified to affect optimal well-being and welfare. In addition, reconnecting behavior analysts with zoos and aquariums will allow the full potential of the science and practice of behavior analysis to be unleashed to the benefit of the animals, the staff, and the visiting public.

One way to achieve the goal of expanding the network of behavior analysis is through the formation of management teams composed of both behavior analytic scientists and caregivers. Although the overall climate is right for the collaboration between behavior analysis and zoos and aquariums, it is possible that with change, there may come resistance from a subset of current employees. To mitigate the likelihood of staff resistance, behavior analysts should enter new settings with humility and tact while actively facilitating cross-disciplinary collaboration, cooperation, and cohesion in the workplace. Sharing authorships on publications and conference presentations is an excellent way to build a trusting partnership.

A Current Working Model in San Francisco

A new operating model for activating research partnerships, at both master's and doctoral levels in psychology and biology, is currently evolving at the San Francisco Zoo in conjunction with nearby collaborating universities. The San Francisco Zoo paradigm builds on the success of Professor Hal Markowitz (Markowitz 1978, 1982, 2011). In San Francisco, we are confirming, once again, that it is feasible to set up an animal behavior research program with a zoo-university partnership as the foundation of research and practice (Maple and Bocian 2013). In this case, the newly appointed chief scientist at the zoo, Dr. Jason Watters, is a full-time employee with an earned doctorate and a joint appointment in local and regional academic departments. The research department is the catalyst for the zoo's innovative wildlife wellness initiative. The initial subjects selected for observation and experimentation include polar bears, lowland gorillas, Nile hippopotamus, giant anteaters, and Asian one-horned rhinoceros. These species are high priorities for behavior analysis and environmental interventions aimed at advancing welfare and wellness. For example, the stereotypic rubbing of a rhino's horn is an ideal target for a functional analysis and function-based treatment evaluation. The success of treatment would be apparent in the horn's growth and recovery to its normal size and shape.

If programs such as the San Francisco Zoo's sponsored wellness initiative proliferate, they may serve as sparks to expand the scope of behavior analysis and may persuade psychology departments to hire behavior analysts with animal expertise once again. Within the ABAI, there already exists an animal behavior special interest group, and it provides a formal connecting point within the association. Some of the professionals in this group have carried out research in zoos (e.g., Fernandez et al. 2009), and others have worked as consulting applied behavior analysts with both exotic and domesticated species. There are other notable examples of behavior analysts working with exotic and domesticated species, including a student group at the University of North Texas, the Organization for Reinforcement Contingencies with Animals

(ORCA), that host an annual meeting to discuss and evaluate progress in the art and science of animal training. Alligood (2013), reviewing the history of training and enrichment programs at Disney's Animal Kingdom (DAK), acknowledged that zoos and aquariums represent golden opportunities for applications of behavior analysis.

The case has been made that behavior analysts in universities, institutes, and private practice who have an interest in expanding their intellectual footprint should negotiate structured partnerships with zoos and aquariums. These partnerships will be successful if zoo and aquarium directors reach out to deans, department chairs, and individual faculty at nearby universities and vice versa. Zoos and aquariums worldwide are committing human and financial resources to improve animal welfare, and professional behavior analysts can leverage these investments to generate interest and participation. The impressive growth of behavior analysis throughout the world (Marr 2006) indicates that there are many global opportunities to connect with aquariums and zoos that are also in a continuing period of expansion and unprecedented popularity. There are more than 1,000 zoos and aquariums worldwide, with rapid growth in Asia. Partnerships with behavior analysts will be particularly important for the world's newest aquariums given their propensity for acquiring marine mammals including whales, which are among the most difficult species to habituate to the limitations of captivity. The science and practice of behavior analysis can contribute immensely to the improving standards and practices of zoos and aquariums in developing nations (Agoramoorthy 2010).

Training to achieve the goals of optimal wellness and welfare, facilitate daily exercise and behavioral stimulation, and provide for a less-invasive protocol of medical monitoring and intervention (e.g., Goymann et al. 1999) has always been associated with environmental enrichment and innovative exhibit and facility design (Augustine and Baumer 2012; Baker 1997; Bashaw et al. 2003; Bloomsmith et al. 1988; Coe 2003; Maple and Finlay 1987; Markowitz 1978, 1979; Mellen and Sevenich MacPhee 2001; Shepherdson et al. 1998). Hancocks (2001) argued that zoos and aquariums have not instituted comprehensive change and have failed to significantly advance animal welfare in even the best institutions. This generalization is too harsh, as zoos and aquariums throughout the world are on a trajectory that is rapidly producing better practices and standards in animal management and superior facilities for a variety of species (Norton et al. 1995).

Applied behavior analysis is one of the tools that facilitates the use of innovative exhibit and helps to define useful behavioral concepts such as "contrafreeloading" (Kinzley 2009; McGowan et al. 2010; Meehan and Mench 2007; Sommerfeld et al. 2006), whereby animals prefer to work for food rather than have it available *ad lib*. Zoo and aquarium animals have to be trained to experience the environmental opportunities provided by innovations such as exhibit rotation, computerized feeding devices, and elevated, tubular pathways that generate movement and promote exploration beyond the primary exhibit (Maple and Perdue 2013; Markowitz 1973, 2011; Markowitz and Aday 1998).

Pedagogy Is Alive and Well in the Zoo

Universities that partner with local or regional zoos and aquariums will be providing their students with new and exciting opportunities to interact with exotic wildlife and to

confront the challenge of protecting and preserving the natural world. There is still much to learn from studies of zoo animal behavior and of many species that have not yet been studied by psychologists. Zoos and aquariums worldwide house more than 6,000 species, and the estimated number of zoo animals in the world is more than 750,000 specimens. Shaped to participate in experimental studies, rare animals, such as the giant panda, have yielded remarkable information about their learning capacity (Perdue et al. 2009; Tarou et al. 2004) and sensory abilities (e.g., color vision; Kelling et al. 2006). In addition, familiar animals like the African elephant have been studied in new ways that have led to a greater understanding of their unique ability to detect infrasonic calling by conspecifics (Payne et al. 1986). Research by Georgia Tech graduate students conducted at Zoo Atlanta generated important new data on the ability of lowland gorillas to recognize numbers and sums of numbers (Anderson et al. 2005). Other studies have been probing the neuroscience that underlies the ability of reptiles to learn (e.g., Almlil and Burghardt 2006; Emer and Grace 2011; Holtzman et al. 1999).

Modern zoos and aquariums represent an opportunity to observe and study whole organisms, many of them living in social groups. Indeed, both graduate and undergraduate coursework in herpetology, ichthyology, mammalogy, and ornithology can be revitalized in cooperation with zoos and aquariums that maintain diverse collections of increasingly rare wildlife. In Atlanta, a relationship between the zoo and Georgia State University was developed specifically to provide students with more contact with ornithology, mammalogy, and herpetology specialists because these resources were unavailable on the university campus (Dwight Lawson, personal communication). Working with living social animals may provide an important perspective for students of psychology who are otherwise left to contemplate broad theories, models, and hypotheses based on the narrow standard of *Homo sapiens*. The biodiversity represented in the world's zoos and aquariums is a new and exciting frontier for the science and practice of behavior analysis as well as an opportunity to significantly advance the science of animal welfare.

One of the advantages of a zoo-aquarium-university partnership is the opportunity to offer courses and laboratory experiences focused on a diverse population of captive wildlife. For 30 years, the senior author's graduate research group enjoyed this advantage in partnership with Atlanta's zoo while he served as a member of the psychology faculty at Emory University and the Georgia Institute of Technology. Similarly, M.J. Marr's Experimental Analysis of Behavior Lab enjoyed a long and successful educational partnership with Zoo Atlanta and continues to earn a reputation as the most enjoyable and valuable laboratory course on the Georgia Tech campus (Lukas et al. 1998). Marr's students not only acquired skills in systematic observation and behavior shaping, but also came to understand and practice the principles and methods of applied behavior analysis. Zoos and aquariums represent an opportunity to operate higher-quality animal labs with a greater diversity of species available for study at lower cost and risk than traditional university-housed animal research labs.

Conclusion

Consistent with Skinner's (1987) observation that behavior analysis should address the world's most pressing problems, the plight of the world's wildlife is a significant social

issue that cannot be ignored. Both conservation and animal welfare are generating controversy and passionate debate on campuses and in the public media. Behavior analysis applied to greater effect in zoos and aquariums promises to improve the lives of monkeys and apes, big cats, cetaceans, and a diversity of other creatures, and it surely provides a major justification for keeping animals in captivity, namely, the need for greater understanding of their propensities and capabilities. The timing is right for strengthening the relationship between zoos and aquariums and practicing behavior analysts.

This review has outlined the following: (1) the benefits of expanding the role of behavior analysis in zoos and aquariums, (2) suggestions on how to accomplish this goal, (3) the role for behavior analysis in the current welfare oriented *zeitgeist*, and (4) current working models that can be expanded. The experiences described in this review could be easily duplicated if zoos/aquariums and universities were unified in the pursuit of strengthening the animal welfare agenda through collaboration with the field of behavior analysis. Animals benefitting from training and monitoring by skilled behavior analysts and their collaborators tend to be more active, thereby enriching and enlightening educational experiences for zoo and aquarium visitors alike (Anderson et al. 2008). Behavior analysts, students, animals in zoos and aquariums, as well as the zoo and aquarium institutions themselves stand to benefit from interdisciplinary collaborations. We should be eager to facilitate the evolution and dissemination of behavior analysis, while expanding employment opportunities for behavior analysts at the master's and doctoral level in zoos and aquariums throughout the world.

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