Programs for Invasive Research in North American Zoos and Aquariums

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Abstract

Zoo-based research in North America is an emerging field, which has progressed from an ad hoc approach in a small number of zoos to a coordinated, integrated network of scientists with recognized research programs in approximately one half of the accredited institutions in North America. The disciplines most active in these programs—veterinary medicine and pathology, nutrition, reproductive biology, contraception, and behavior—are now becoming coordinated in zoos through Scientific Advisory Groups. Zoos with research programs generally establish either an institutional animal care and use committee or another committee to evaluate research proposals. In addition to scientific merit and experimental design, zoos evaluate proposals based on factors such as priority by conservation program/identified need; direct effect on species conservation, species type, and appropriateness; availability and location of animals; operational requirements/logistics; communication between institutions; and available funding. Euthanasia is considered only in rare circumstances. Zoo-based research has evolved into an integral component in animal management and conservation programs by providing practical information that is used to improve animal care, well-being, health, and reproduction. However, the degree to which zoos participate in invasive research varies considerably among institutions, due not only to resource limitations but also to how the term "invasive" is defined and accepted at each institution. A more standardized approach among zoological institutions for examining and approving research projects that are supported by zoo-based conservation programs would greatly facilitate the wildlife research efforts of North American zoos.

Key Words: American Zoo & Aquarium Association; conservation; IACUC; research; zoo

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Introduction

Zoos have existed in many forms for hundreds of years, primarily to provide entertainment to people and satisfy human curiosity about rare and exotic species. However, the actual methodical study of these animals to gain knowledge aimed at improving their care and assisting conservation efforts is a much more recent effort. While scientists have conducted research projects with animals in zoos for many years, it was only 15 yr ago that Dr. Kurt Benirschke (then Director of Research at the San Diego Zoo) identified "zoo research" as an emerging field and deemed it essential for maintaining wildlife species in captivity (Benirschke 1987). Although research in zoos has been documented over a prolonged period of time (e.g., publications from the Zoological Society of London), these efforts focused primarily on taxonomic evaluations and dissection of postmortem samples versus methodical approaches toward answering practical questions.

During the 1960s and 1970s, several events reflected an apparent awakening in North America regarding the plight of wildlife around the world: the 1966 passage of the Animal Welfare Act (PL 89-544), with amendments in 1970 (PL 91-579) and in 1976 (PL 94-279); and the 1973 passage of the US Endangered Species Act (PL 93-205). Resulting in part from these events, zoos began to focus on breeding and maintaining sustainable populations of endangered species, and to place greater emphasis on recruiting personnel with combined practical experience and higher level academic degrees. In addition, the number of full-time veterinarians increased from three in 1969 and 1970, to 13 in 1973 (M. K. Stoskopf, North Carolina State University, Raleigh, NC, personal communication, 2003), likely because of the definition of a major zoo (a zoo with at least one full-time veterinarian) according to the Animal Welfare Act. With this influx of professionals came interest from the academic community in collaborating with zoos on more formalized research projects and subsequently the evolution of research programs within the zoological institutions.

Many zoos and aquariums currently include research as a mandate in their mission statements or goals—even though the public and scientific communities still do not associate this image with zoological institutions. In fact, zoos offer unique opportunities to study animal biology and establish physiological databases for wildlife species in a relatively controlled environment. One of the most important reasons to conduct research within the context of wild-

life conservation is the acquisition of knowledge that will contribute to the biological database for a species (Goodrowe et al. 2000; Wildt 2000; Wildt et al. 2001). Understanding species biology will promote better animal care and daily husbandry, which in turn will lead to application of the research results through improved animal health, nutrition, reproduction, and behaviors that simulate those characteristics in the wild. In discussing the limitations of captive breeding, Snyder and colleagues (1995) emphasized the importance of professional training and research as key mandates for zoos toward meeting their goals for conservation and maintaining biodiversity. However, research can take many forms and reach across numerous disciplines. In this article, the state of zoological research programs in North American zoos and aquariums is examined along with the considerations involved in establishing and carrying out zoo-based research in this relatively new and emerging field.

Research Programs in North American Zoos and Aquariums

The *American Zoo & Aquarium Association* (AZA[1]) *Research Coordinators Directory* (Thompson 2002) provides results of a survey based on inquiries regarding the status of research programs in AZA-accredited institutions. The survey was sent to 182 zoos and aquariums, of which 147 were returned. A total of 79 respondents reported having an institutional animal care and use committee (IACUC[1]), and 64 (43.5%, encompassing both large and small institutions) reported having formalized research programs. Although seemingly small, these numbers are significant when one considers that 25 yr ago, only the very large/major zoos in North America (e.g., Bronx Zoo, National Zoological Park, and San Diego Zoo) were able to support zoological research. Although the development and coordination of research programs within accredited zoos and aquariums in North America are still in an emergent phase, it is evident that zoo-based research is a growing field.

The disciplines most often emphasized in zoo-based research programs with captive populations include veterinary medicine and pathology, nutrition, reproductive biology, contraception, and behavior. These disciplines have evolved to the extent that publication of research data is widely disseminated not only throughout the more popular and respected scientific journals but also in journals dedicated almost exclusively to zoo-based research (e.g., *Journal of Zoo & Wildlife Medicine* and *Zoo Biology*).

To support the growing field of zoo-based research programs that augment conservation efforts, the AZA established the Scientific Advisory Group (SAG[1]) program in 1991 to help facilitate, support, and coordinate research within its member institutions (AZA 2002). SAGs are composed of experts in specific scientific disciplines. Group members are encouraged to spread their membership networks not only from within zoo- and aquarium-based personnel but also to include scientists in university, government, and nongovernment settings with an interest in supporting zoo-based research and conservation programs. The SAGs most directly related to research programs in North American zoos today are the Veterinary Medicine, Nutrition, Contraception, Reproductive Sciences, and Behavior SAGs (AZA 2002).

Veterinary Medicine

The role of veterinarians in zoos extends far beyond that of the daily medical care for the species in their charge. Hutchins and colleagues (1991) outlined the focus for zoo veterinarians as follows:

- Collection and analysis of necropsy data for Species Survival Plan® (SSP[1]) (i.e., managed population) species;
- Development of protocols for necropsies and disease surveys and collection of biological samples for use in research and routine health assessment;
- Collection of information on wildlife diseases and how the diseases of domestic animals can affect wildlife populations;
- Collection and analysis of data on the diseases of captive animals; and
- Development of effective methods for prevention, diagnosis, and treatment of diseases, including diseases that may affect reintroduction efforts.

The Veterinary Advisory Group (VAG[1]) was founded in 1993. Its priorities are to increase the available information database through coordinated research efforts in the following areas: (1) the incidence, distribution, and risks of disease in captive and wild populations; (2) the development and implementation of effective quarantine protocols necessary to prevent disease transmission; and (3) the development of definitive diagnostic tests to detect and monitor disease. Additional information regarding the VAG is available on the web (www.aazv.org/vagfactsheet.htm).

Nutrition

The Nutrition Advisory Group (NAG[1]) was founded in 1994 and has two primary goals: (1) to understand the biology/nutrition of nondomestic animals through the science of comparative nutrition, and (2) to establish the practice of

[1]Abbreviations used in this article: AZA, American Zoo & Aquarium Association; BAG, Behavioral Advisory Group; CAG, Contraception Advisory Group; IACUC, institutional animal care and use committee; NAG, Nutrition Advisory Group; RSAG, Reproductive Sciences Advisory Group; SAG, Scientific Advisory Group; SSP, Species Survival Plan®; TAG, Taxon Advisory Group; VAG, Veterinary Advisory Group.

zoo nutrition through diet formulation and appropriate feeding strategies for wildlife species. Information on the NAG is available on the web (www.nagonline.net/).

Research priorities that have been identified for the NAG include the following:

1. With respect to nutrition, assessing healthy animals, establishing normal reference values, and assessing the debilitated animal and/or populations, both in the field and in captivity;
2. Investigating deficiencies, toxicities, and requirements for vitamins; and
3. Understanding whether the nutrition provided to animals is adequate by determining the nutrient composition of foods, including foods consumed in the wild and foods that are fed to nondomestic animals in zoological institutions.

Reproduction

Species survival is critically dependent on reproduction, therefore formulating comprehensive reproductive studies and databases is fundamental to conserving species and populations. There has been increasing interest in developing a broader, more integrated approach toward understanding, monitoring, enhancing, and/or controlling reproduction. The Reproductive Sciences Advisory Group (RSAG[1]) was formed in 2001 to address these growing concerns and to advocate integrative research and cooperative multidisciplinary studies that can more efficiently address wildlife management problems and effective reproduction. For most species, there is a lack of a fundamental knowledge regarding basic reproductive processes and factors (e.g., environmental, behavioral, and nutritional) that affect reproduction. The RSAG therefore promotes and encourages research efforts that will add to this database and enhance understanding of natural reproductive processes in wildlife species. Further information on the RSAG is available on the web (www.omahazoo.com/repro/home.htm).

On this basis, the long-term goals of the RSAG are to

- Develop mechanisms to communicate and educate people regarding the importance of integrating appropriate disciplines and technologies in the reproductive sciences;
- Develop a collaborative network of people who are interested in supporting studies of reproductive sciences for wildlife species; and
- Liaise with species' conservation management programs to identify and prioritize research needs and provide advice on appropriate technology availability and utilization.

Contraception

Over the last 3 decades, zoological institutions have become much more effective in breeding endangered species. Because of this success, zoos require contraception to overcome space limitations, maintain social groups, and assist genetic management of populations. To this end, the Contraception Advisory Group (CAG[1]) was formed in 1989 to accumulate, analyze, and disseminate data on the development of effective contraception methods for captive wildlife and on contraceptive reversibility. Based on the results of research studies conducted in this discipline, recommendations are formulated for the use of appropriate contraceptive methods for wildlife species maintained in zoological institutions. A compilation of these recommendations and of specific CAG research efforts is available on the Saint Louis Zoo website (www.stlzoo.org/content.asp?page_name = contraception).

Behavior

Established in 1993, the Behavioral Advisory Group (BAG[1]) was created to assist in promoting, conducting, analyzing, and applying the results of husbandry surveys and behavioral studies to improve the management, reproduction, and well-being of zoo animals. Specifically, the goals of the BAG are to

1. Assist AZA members in handling animal management problems with a behavioral or husbandry basis by recommending and helping in the coordination of specific behavioral and husbandry research;
2. Develop new, simplified, and standardized techniques for incorporating behavioral information into husbandry surveys, and for analyzing and applying the results to solve management and reproductive problems;
3. Develop new techniques for evaluating the adaptation of individual animals to zoo conditions;
4. Develop simplified techniques for recording and analyzing animal behavior that can be used under multiple environmental conditions in different zoos; and
5. Promote the use of ethological and psychological research on zoo animals for their contribution to basic biological knowledge.

Additional information on the BAG and on the existence and development of behavioral ethograms for zoo animals is available on the web (www.ethograms.org). Collectively, it is obvious that research efforts in these disciplines are aimed at providing practical information that can be used as tools for developing and implementing improved animal care and management strategies and conservation efforts for wildlife species.

Defining Invasive Research

Compared with laboratory and farm animal research, in which "invasive" is generally used to mean "involving entry

into the body" (Webster 1985), the question of what defines invasive research leads to many different answers and varies extensively among zoological institutions. Invasive research in North American zoos and aquariums can be defined in one of several ways: (1) very broadly, from anything that alters the daily husbandry/management practices for an animal or group (e.g., collection of fecal samples, changes in temperature, lighting, diet, housing, and exhibit composition; (2) more restrictively, to include procedures that can cause stress or distress (e.g., increased human presence, remote biopsy, introduction of objects or scents not part of the exhibit furniture, and voluntary semen collection or venipuncture); or (3) specifically, to include those procedures that require animal manipulation/restraint or anesthesia (e.g., manual restraint for administration of drugs/medication, venipuncture, or ultrasonography; anesthesia for elective procedures including tissue biopsy, surgical manipulation, artificial insemination, and semen collection).

Responses from research coordinators in North American zoos and aquariums indicate that invasive research generally is defined as those circumstances in which an animal's habitat or husbandry routine is altered or when physiological data are being collected for a prolonged time; invasive research generally does not include procedures necessary for routine veterinary care or diagnoses. Some institutions train their animals to participate voluntarily in invasive procedures using operant conditioning techniques (e.g., marine mammals, elephants, and rhinos trained for venipuncture and ultrasonography; primates and felids trained to accept injections or allow venipuncture; various mammal and avian species trained to participate in manual semen collection). Although these procedures are invasive, the training for and implementation of the behaviors may come to be considered standard animal management practice (vs. research protocol) once a behavior has been established because the animal's participation is reward based and voluntary (T. Roth, Cincinnati Zoo, personal communication, 2003; J. Rupp, H. Reed, Point Defiance Zoo & Aquarium, personal communication, 2003).

Overall, zoos tend to take a conservative approach when examining and approving research projects, and they require their animal care committees to evaluate procedures that alter animal management in any way. The submittal and evaluation procedures vary widely among institutions. Although a research project may receive endorsement from an AZA species- or taxon-based management group, zoo administrators may still choose not to undertake a project based on their own definition of invasive. This element of subjectivity can lead to inconsistent participation for priority projects, even among accredited institutions. A more standardized approach among zoological institutions toward examining and supporting research projects that are supported by zoo-based conservation programs (if the infrastructure and resources are in place) would greatly facilitate the wildlife research efforts of North American zoos and aquariums.

Developing an IACUC or Similar Institutional Committee

Although research projects can receive broad endorsement in concept from both funding organizations and conservation programs, individual research projects within zoos and aquariums are still approved at the institutional level, with each facility maintaining the responsibility for deciding what types and level of research they can and will support. Because zoological institutions have similar missions and interests in spite of their limited personnel, financial, and animal resources, the very nature of research programs in these facilities is one of joint participation working toward the common goals of species and habitat conservation. Due to this collaborative nature, research proposals from a wide variety of disciplines may be submitted for consideration.

The review procedures for approval vary considerably among institutions and can proceed either through a formal IACUC or through another type of scientific review committee (depending on whether the institution is registered as a formal research facility). At minimum, the veterinarian, curator(s), research staff, and/or individual responsible for conservation and science generally are involved in the review of research proposals. The scientific review committee also can include one or more representatives of the animal care staff, a non-animal user within the institution (e.g., public relations or education staff member), and a layperson not formally affiliated with the zoo or aquarium.

Although the number of institutions that have animal care and use committees is still small, there is a growing interest in developing research programs in North American zoos and aquariums. For this reason, the AZA's Research Coordinator's Group has devised guidelines for the development of research programs and the formation of an IACUC, which are formulated after guidelines provided in the US AWA (www.aphis.usda.gov/ac).

Although curators and animal care staff can evaluate the usefulness of a proposal to the institution's collection and mission and its conservation-based application, the expertise of these individuals may not always extend into scientific research. It is essential for institutions that do not have extensive depth of expertise within their own staff to have available resources/expertise to assist with the evaluation of research proposals from an experimental design and scientific merit perspective. Under these circumstances, zoos often develop relationships with local universities or governmental agencies that can provide additional resources and expertise for evaluating and strengthening proposals. This approach also allows for subsequent development of collaborative research efforts and partnerships that ultimately benefit conservation efforts.

Considerations for Zoo-based Research

In addition to scientific merit and experimental design, numerous other factors affect the approval and successful

implementation of research in zoos. These factors include but are not limited to the following: priority by conservation program/identified need; direct impact on species conservation, type, and appropriateness; number of animals to be used; availability and location of animals; level of invasiveness; operational requirements/logistics; communication between institutions; and available funding.

Although many of these considerations are institutionally based, the priorities and needs for a species or taxon are established by coordinated management/conservation programs. Within the AZA, management/conservation programs are based on single species (SSPs), groups of species within a taxon (Taxon Advisory Groups; TAGs[1]), and species/habitats relating to geographic areas (Conservation Action Partnerships). The SSP and TAG programs are responsible for directing population management programs within accredited zoos and aquariums and for establishing management, research, and conservation priorities. SSPs initially were developed as cooperative programs for managing reproduction in captive animal populations to maintain genetically diverse, demographically stable, healthy, self-sustaining populations. Since then, SSPs have evolved to become more holistic programs, which encompass multidisciplinary approaches to species conservation both in zoos and in the wild and include efforts aimed at captive husbandry and reproduction, physiological research, education, fund raising, field projects and reintroduction (AZA 2002). The TAG programs are responsible for recommendations to AZA institutions regarding similar groups of animals (taxa) in the form of a Regional Collection Plan. These taxon-based Regional Collection Plans include recommendations regarding which species should be maintained in zoos and aquariums and how much space should be allocated to each species. The TAGs also are required to develop prioritized 3-yr action plans for conservation, education, and research projects, which specifically link efforts in zoos and aquariums to efforts in native ranges (AZA 2002).

Justification and Rationale

The majority of North American zoos report that approved projects must be conservation oriented with direct, practical applications. Very few institutions will consider proposals that are purely academic. However, zoos may support academic-based projects if they can be conducted opportunistically and/or completely noninvasively using little or none of the institutions resources. This general policy does not rule out studies that provide basic information on animal physiology, nutrition, behavior or manifestation of diseases, and veterinary care. Rather, these projects must be designed to answer specific questions related to animal care or well-being. It should be recognized that adding basic physiological information to a database of knowledge for any given species will undoubtedly add to the ability to care for and contribute to the conservation of the species in question.

One common theme within AZA SAG and zoo-based research programs is that research of any type should meet specific conservation or animal management objectives. During the early phases of research in zoos, scientists generally approached research with wildlife species in a "shotgun" type of approach, which likely was driven by availability of animals and the willingness of institutions to participate in "research." However, it has become apparent that effective application of research findings to wildlife conservation will best be achieved by a coordinated, methodical approach that addresses the prioritized needs established by the SSP and TAG programs. Zoo-based scientists and research programs should align their interests and research efforts with the priorities or needs of identified species through a multidisciplinary approach (Thompson 1993; Wildt et al. 2001). Projects with clear conservation benefits, practical/applied implications, and alignment with institutional conservation focus areas are those that will receive approval and support from SSPs, TAGs, and individual institutions.

At times the species in question may not be available for extensive research studies. For example, in the development of reproductive technologies for wildlife species, the trend with mammals has been to use closely related domestic animals as model species—working either in parallel for comparative purposes, or simply using the model first to develop basic information and then adapting it to the species of interest. Certain risks are associated with this approach because what is true for the model system may not always be true for the wildlife species (e.g., cat and cheetah, Wildt et al. 2001; domestic dog and red wolf, Goodrowe et al. 2001). However, an appropriate domestic model system can provide a starting point for the species in question, and administrators of the SSP and TAG programs recognize the value of this approach.

Logistics for the Institution

Each zoological institution is unique in its setting, exhibits, and physical facilities, and in how animal management programs are implemented. Therefore, each facility will consider numerous logistical and practical factors before approving a research project that includes but is not limited to the following factors: staff time and expertise, exhibit composition, holding facilities, tractability of the animals, available methods for animal restraint, effects of restraint on animal well-being, permits for translocation of biological specimens, government regulations, cost of the project, and proximity of the investigator (nearby or on site). Because zoos and aquariums are public facilities with recreation or entertainment as part of their mission, these institutions also must take into account the effect of animals being off exhibit and the public perception regarding research. To accommodate these factors, institutions often provide educational opportunities to teach the public about the ongoing scientific efforts at their institution.

Opportunistic research approaches (e.g., collection of

tissues at necropsy) reflect the collaborative spirit of SSPs and provide excellent opportunities to gain significant amounts of information over an extended period of time. Such research requires coordination, communication, and preparedness on the part of the researcher to ensure that all aspects of the process are in place at each institution of interest before the event. The necropsy protocols developed by the elephant, cheetah, and rhinoceros SSPs (www.aza.org) are excellent examples of this approach and have led to enhanced understanding of species' biology shared across multiple disciplines. It should be noted that physiological research generally is not conducted with marine fishes due to the limited numbers of animals, the low to nonexistent fecundity rates of these species, and the difficulties in maintaining these species in captive environments. Unfortunately, it is just this type of situation that would benefit most from a methodical research approach to allow establishment of a database of physiological norms and animal management requirements toward improving veterinary care and animal husbandry.

Research Staff and Collaboration

Because of the numerous animal-related and logistical challenges associated with conducting research in a zoological and aquarium setting, combined with a need to develop more extensive biological databases for wildlife species, there is an increasing need for trained scientists to conduct research with captive wildlife. Experience and skill of the researcher are considered when research projects are examined; therefore, it is important for individuals to have sufficient training or expertise with zoo animal research and to be cognizant of how to apply rigorous scientific methods to situations that can be restrictive. For example, because zoos and aquariums generally do not hold large numbers of any particular species, research projects typically must be conducted at numerous facilities to ensure adequate sample size and allow definitive conclusions. This necessity places an increased burden on the researcher to communicate with numerous facilities effectively to ensure consistency in the project and to solve any problems that might arise. Although the number of animals used in studies with rare or endangered species may seem small, the sample sizes from species held in zoos often comprise a much larger proportion of a total world population and may in fact be more representative of the entire population, compared with typical laboratory or domestic animal models. For example, during a single breeding season with the red wolf, investigators were able to perform semen processing and cryopreservation studies on 15 males, which represented 20% of the entire captive population of males for this species held in zoos (K.L.G., unpublished data, 2003).

Often, researchers from outside the zoo community are not as well versed in the restrictions of working with captive wildlife in zoos or in the communications with various zoo staff necessary to ensure project success. Therefore, establishing strong collaboration between zoo-based researchers and other scientists will allow maximizing the amount of information that can be obtained from a particular project. In this type of collaborative endeavor, zoo scientists can provide direction and advice to external scientists on the prioritization of research needs, potential logistical and regulatory challenges, and insight into the specific animals/facilities. Alternatively, external researchers can provide tools and technology not available to zoo-based scientists as well as different perspectives on research questions, using their strong foundation in basic science and applying it to wildlife species.

Research Involving Euthanasia

Most zoos and aquariums do not participate in research or accept proposals that involve euthanasia. Some institutions will examine this type of proposal on a case-by-case basis and will weigh the benefits to wildlife conservation compared with taking an animal's life. Because zoos and aquariums are public institutions, they also must examine these types of proposals from an education and public relations perspective and must take these factors into account before project approval. Projects of this type usually are limited to opportunistic circumstances and/or with species that produce extremely large numbers of offspring that cannot feasibly be raised to the adult stage (e.g., freshwater fishes, amphibians, invertebrates).

Conclusion

Zoo-based research programs in North America have developed extensively since the late 1970s from ad hoc efforts to well-coordinated networks. A significant stigma that has been overcome is the stereotypical researcher isolated from the rest of the institution "doing bad things" to animals in the zoo's collection. Zoo-based research and scientists have become an integral component in zoos and aquariums and in conservation programs as a result of individual scientists and the coordinated SAGs working with animal managers, determining the needs and priorities of animal/population management programs, and providing useful information that is incorporated to improve animal care, well-being, and reproduction. With increased funding, acceptance, coordinated networks, and growing numbers of trained scientists, it is evident that zoo-based research offers tremendous potential in continuing to assist wildlife conservation.

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