Introduction

Research in Zoos and Aquariums: Purpose, Justification, Utility, and Welfare

Michael Hutchins, Robert J. Wiese, and Brandie Smith

The subject of zoo biology can also be briefly described as thus: it embraces everything in the zoo which is biologically relevant.

Heini Hediger, *Man and Animal in the Zoo* (1969)

Zoological institutions are powerful wildlife conservation entities that work to conserve wildlife and educate and inspire millions of people about animals and their habitat each year (Gusset & Dick, 2010). Professional accredited zoos and aquariums are required to actively engage in conservation and be committed to research and scientific advancement (AZA, 2018; Barongi, Fisken, Parker, & Gusset, 2015). These activities have increased exponentially in the past few decades, and conservation, research and education rival recreation and visitor engagement in the list of zoo and aquarium priorities (Conde, Flesness, Colchero, Jones, & Scheuerlein, 2011; Conway, 1969, 2003; Field & Dickie, 2007; Hutchins & Conway, 1995; Hutchins & Smith, 2003; Konstant, 1995; Mallinson, 2003; Maple, 2016; Rabb & Saunders, 2005; Zimmerman, 2010; Zimmerman & Wilkinson, 2007).

Over the past few decades, many authors have discussed various aspects of zoo- and aquarium-based research (e.g., Anderson, Maple, & Bloomsmith, 2010; Beck, 1974; Benirshke, 1975, 1996; Chiszar, Murphy, & Smith, 1993; Hediger, 1964, 1968, 1969; Hofer, 2011; Hutchins, 2010; Hutchins, Dresser, & Wemmer, 1995; Jarvis, 1967; Kaufman & Zaremba, 1995; Lawson, Ogden, & Snyder, 2008; Lindburg, 2008;

Marlieve & Newman, 1995; Maple, 1982, 2008, 2016; McCormick-Ray, 1993; Schwartz, 2017; Wharton, 2007, 2008). The goal of this chapter is to provide a broad overview of key issues related to the history, purpose, justification, utility, and diversity of research conducted in modern zoological parks and aquariums (hereafter "zoos") today. We will also touch on a variety of important issues associated with the conduct of research in zoological institutions, including a brief exploration of the history of zoo research; advantages and disadvantages of conducting research in the zoo setting; the diversity, purpose, and utility of zoo research; administration of zoo research programs; research priority setting; zoo–university and other partnerships; animal welfare and other ethical considerations; publication of research results; and funding to sustain zoo research programs.

HISTORY OF ZOO RESEARCH

Wemmer and Thompson (1995) and Wharton (2007) both provide summaries of the history of zoo research worldwide. As the authors point out, most scientists and many zoo staff have not viewed zoos as research institutions, but a surprising amount of research is conducted in zoos and published in mainstream scientific journals and books today (see "Diversity of Research Topics" section). The presence of live animals, many of them little known to science or difficult to observe in nature, and of people seeking to gain new knowledge or experiences makes zoos a rich laboratory for scientific study.

Heini Hediger's (1969) book *Man and Animal in the Zoo* was a milestone in the history of zoo-based research. It was here that the author coined the term "zoo biology," referring to the study of wildlife and humans in the zoo setting. However, research played a prominent role in some early zoos. For example, the charter of the Zoological Society of London, established in 1826, aspired to assemble a collection of living animals that could be used for scientific research instead of just as a visitor attraction (Olney, 1980). The New York Zoological Society was established in 1895, and by 1903, William Beebe, a young curator at the Bronx Zoo, was already engaged in field expeditions to

study wildlife in nature. By the mid-twentieth century, some zoos had officially recognized research as part of their core mission. Spurred on by the extinction crisis in the 1960s and 1970s (the US Endangered Species Act was signed into law in 1972), by the 1980s and 1990s, many zoos included research as part of their mission statements and organized programs were beginning to develop, with formal research protocols and dedicated personnel.

ADVANTAGES AND DISADVANTAGES OF ZOO RESEARCH

There are many advantages and disadvantages to conducting research in zoos (Hutchins, 2001). Animal protectionists (e.g., Jamieson, 1985) are often quick to point out the disadvantages, which can be substantial when animals are maintained in inadequate social or physical environments. For example, development, behavior, physiology, and reproduction can all be modified – sometimes severely – under the conditions of captivity, especially when the environment, including size and quality of space, group composition, and dynamics and diet, does not meet an animal's basic biological or behavioral needs (Hediger, 1964, 1968, 1969; McPhee & Carlstead, 2010; Meyer-Holzapfel, 1968; Morris, 1964). This, in turn, can call into question the validity of research results (Hosey, 1997; Hutchins, 2001). In the past, inadequate environments have resulted in a wide range of problems, including, but not limited to, stereotypic behavior, inactivity, and poor physical condition, often leading to stress, disease, shortened life spans, and reproductive failure (Hediger, 1964, 1968, 1969; Meyer-Holzapfel, 1968; Morris, 1964; O'Regan & Kitchener, 2005).

Fortunately, as zoos' knowledge of wildlife biology, ecology, and animal care and welfare has increased, enclosures have become larger and more naturalistic and complex (Coe & Dykstra, 2010; Hutchins, 2003; Maple, McManamon, & Stevens, 1995), and as animal managers and scientists have paid increasing attention to species-appropriate environmental enrichment (e.g., mammals: Hoy et al., 2010), including the composition of social groups and feeding strategies and

nutrition, conditions for many zoo animals have greatly improved (e.g., great apes: Hutchins et al., 1991), thus making the zoo setting even more appropriate for scientific study (Hosey, 1997; Wemmer & Thompson, 1995).

Jamieson (1985) questioned the appropriateness and utility of zoo-based research. His statements that "research that is conducted in zoos can be divided into two categories: studies in behavior and studies in anatomy and physiology" (p. 112) and that the latter are "the most common forms of zoo research" have, in recent decades, been completely disproven, and, in retrospect, were not even accurate at the time of publication. Based on this, he further concluded that the benefits of zoo-based research do not outweigh the "moral presumption against keeping animals in captivity" (Jamieson, 1995, p. 53). However, Hutchins, Smith, and Allard (2003) countered his and Regan's (1995) arguments, demonstrating how zoo and aquarium commitments to their primary missions of wildlife conservation and animal care/welfare can overcome this presumption and "provide a powerful ethical justification for accredited zoos and aquariums" (p. 964).

The advantages of zoo research are many. First, access to a wide variety of species, many of which are little known to science, can be a tremendous advantage for researchers seeking to contribute to our knowledge. For example, little is known about many aspects of the basic biology of arboreal, nocturnal, fossorial, aquatic, mountain-dwelling, or other species that are difficult or impossible to study in nature, but can be studied in the zoo setting (Hutchins, Dresser, & Wemmer, 1995). In such cases, virtually any data collected can be new to science and potentially applied to their captive management or conservation in nature.

Second, from a practical viewpoint, zoo animals are found in roughly the same location daily and are thus consistently available for study. They are also comparatively easily observed, although the advent of larger, naturalistic enclosures has, in some cases, made this more difficult. This is also true of radio-tagged animals in nature, but because they can move over long distances, they may still be difficult

to find or otherwise hard to observe during certain phases of their life cycles. For example, Hutchins (1984) studied an introduced population of free-ranging Rocky Mountain goats (*Oreamnos americanus*) for four years in Olympic National Park, Washington, but was never able to observe a birth. The species inhabits rugged, high-altitude terrain, and females typically isolate themselves during birthing, making observations difficult. However, he was able to observe and document several births at the Woodland Park Zoo in Seattle and to record early postpartum behavioral development, thus contributing to our knowledge of this species (Hutchins et al., 1987).

Animals can also be easily found and observed in laboratory settings, but in these cases, the environments – typically small, sterile cages, which may facilitate large sample sizes and experimental and control populations – are not ideal for animals, meeting only their basic biological needs. While these conditions may be appropriate for physiological studies or to experimentally test reactions to medicinal drugs, they would be, in most cases, of only limited utility to meet the goals of most contemporary zoo research. The fact that modern zoos seek to keep animals in larger, more appropriate enclosures and social groups essentially makes them intermediate between laboratory and field settings.

In zoos, animals can be more easily captured or trained in order to collect biological samples, such as feces, urine, blood, milk, glandular secretions, and hair, or to take physiometric measurements documenting growth and development though ultrasound or other methods compared with in nature (Mellen & McPhee, 2010). Captures of free-ranging wildlife, even through the use of immobilizing drugs, can be stressful and result in injury or death (e.g., La Grange, 2006). Sample collection in zoos is often done during routine health exams or from closely monitoring animals and then collecting samples noninvasively from known individuals. In some cases, such as blood or urine sample collection, animals can be trained to present themselves for the procedure, a non-stressful method for which the subject is positively rewarded (Mellen & McPhee, 2010). In some cases, using

these procedures themselves presents many opportunities for both research (Schuele, 2016) and education (Lukas et al., 1998).

The age, sex, and genealogy of individual zoo animals and their reproductive histories are often known, which is a tremendous advantage for certain kinds of research (Schwartz, 2017). Under field conditions, this information is often unknown or difficult to come by unless animals can be marked or otherwise identified for long periods of time.

There are disadvantages to zoo-based research as well. Although one goal of modern zoo animal management is to give animals opportunities to express as large a portion of their natural behavioral repertoires as possible (Hutchins, 2003; McPhee & Carlstead, 2010), captive animals are kept in environments that may resemble, but do not replicate exactly the natural habitats the species frequents in nature. It is important to note, however, that conditions in nature can vary greatly as well (e.g., elephants: Hutchins, 2006a), making it difficult to account for such variability when designing zoo management programs.

In many cases, research opportunities are limited by practical animal management or exhibition needs (Hutchins, 1988; Kleiman, 1996). For example, conspicuous marking to identify individual animals may be prohibited by zoo management, as it detracts from the visitor experience. Furthermore, in order to prevent unwanted reproduction, males are sometimes isolated from females when the latter are in reproductive condition, thus limiting some research opportunities. In addition, not surprisingly, predators and prey are not kept together in the same enclosures, thus limiting the expression of predator and anti-predator behavior. Similarly, group composition or history may not be what it is in nature, as, for example, in African elephants, where herds normally consist of several generations of related females (Poole & Moss, 2008). Although this is changing (Hutchins,Smith, & Keele, 2008), given limited availability, zoos typically have had to form elephant groups from unrelated animals. This could alter social behavior, but elephants have also shown the ability to integrate into these groups and form attachments to unrelated individuals.

One obvious disadvantage of zoo-based research is small sample size, which can make it difficult to draw statistically significant conclusions (Kuhar, 2006; Plowman, 2008). This is especially true of rare or endangered animals that are seldom exhibited in zoos or may be present in limited numbers. That being said, this disadvantage can sometimes be overcome through cooperative studies that extend over several institutions, thus greatly expanding the number of subjects involved (Kleiman, 1996). For example, a study investigating the impact of dominance status on ovarian activity in female African elephants utilized 33 subjects housed at 14 different facilities across North America (Freeman, Schulte, & Brown, 2010).

It should also be noted, however, that when little or nothing is known about a species, even studies based on small sample sizes can make important contributions. Consider, for example, Ogden, Olson, and Miner, (1991) study of a single pair of golden monkeys at Seattle's Woodland Park Zoo and Portland's Washington Park Zoo. Another example is Plair, Reinhart, and Roth, (2012) study of neonatal behavioral milestones and growth in two Sumatran rhino calves born at the Cincinnati Zoo. Virtually nothing was known about these species' reproductive biology, behavior, or development at the time, so these studies made contributions of scientific significance.

Another possible disadvantage is the lack of trained personnel (Anderson et al., 2010). In order to conduct and publish valid scientific research, zoos must have trained scientists on staff or otherwise develop cooperative relationships with academic institutions or nongovernmental organization partners that possess this expertise (Fernandez & Timberlake, 2008; Hutchins, 1988; Kleiman, 1996). This is not to say that zoo staff, including keepers and curators, and volunteers cannot be trained to contribute to scientific research – they certainly can (Hutchins, 1988; Kleiman, 1980; Whitham & Wielebnowski, 2009) – but supervision by trained scientists with necessary skills, such as study design, statistics, interobserver reliability, and publication, is critical for long-term success.

Unlike university research laboratories, where controlled experimental studies are possible, zoos seldom conduct manipulative experiments on their animals, preferring instead to rely on naturalistic observations (which may include quantitative methods) to collect data. While this may be a disadvantage for determining causal relationships between variables, it is still contributing to our overall knowledge of a species' basic biology and behavior. In addition, it is far superior to and more efficient than relying on simple trial and error, which is what zoos did in the past (Hutchins, 2001). It should be noted that field studies seldom provide opportunities for manipulative experimental studies either. That being said, some manipulations may be possible, which provide the conditions of natural "experiments." This can involve before-and-after studies of subjects under different conditions. For example, Meller, Croney, and Shepherdson (2007) studied the effects of rubberized flooring on elephant behavior at the Oregon Zoo. The authors took advantage of changes that were occurring in indoor elephant holding at the institution, first collecting baseline data when the animals were on traditional concrete floors and then when the rubberized floors were installed. They found increases in locomotion and normal sleep behavior (standing vs. recumbent) and decreased discomfort behaviors on the rubberized floor when compared with the concrete floor, suggesting the new flooring was a welcome addition. Studies on diet are also a common way to get before-and-after comparisons in the zoo environment (see Chapter 10, this volume).

DIVERSITY OF RESEARCH TOPICS AND QUESTIONS: UTILITY AND PURPOSES

Several authors have attempted to summarize the scope of research in modern zoos and aquariums (Anderson, Keiling, & Maple, 2008; Finlay, James, & Maple, 1986; Hardy, 1996a, 1996b; Hutchins, Paul, & Bowdoin, 1996; Kaufman & Zaremba, 1995; Kleiman, 1992; Maple & Bashaw, 2010; Maple & Finlay, 1989; Melfi, 2007; Stoinski, Lukas, & Maple, 1998; Wemmer, Rodden, & Pickett, 1997). The diversity of

topics studied in the modern zoo is mind-boggling. In this section, we review some of those topics and provide a few examples and justifications based on their utility. This is in no way a comprehensive overview, as we have left out numerous topics in the interest of brevity.

Research is often categorized according to its goals. "Applied" research is focused on problem-solving. For example, any research aimed at improving zoo animal management or husbandry would be classified as applied research. In contrast, "basic" or "pure" research is intended to improve our understanding of the natural world, irrespective of its possible practical application (Hutchins, 2001; Thompson, 1993).

Most zoo-based research is applied. However, basic research is conducted as well. For example, elucidating why Caribbean flamingos (*Phoenicopterus ruber*) tend to stand on one leg (Anderson & Williams, 2010) is a basic research question, with little or no immediate practical application to animal management or conservation, but that could have theoretical or scientific significance. Another example was the discovery by the National Aquarium in Baltimore and Baltimore Zoo that toxic alkaloids in the skin of poison dart frogs (Dendrobatidae) are not present in captive-bred individuals and have a dietary origin (Daly et al., 1994). Still another would be handedness (laterality) in primates (e.g., ring-tailed lemurs: Hosey, Hill, & Lherbier, 2012). That being said, it is important to realize that pure research conducted today may have practical value in the future, even though its usefulness may not be immediately evident (Hutchins, 2001; Hutchins & Thompson, 2008; Thompson, 1993).

Anatomy and Physiology

Zoos can be valuable collaborators to assist with studies of the basic anatomy and physiology of animals little known to science. Living animals make it possible to study a wide variety of topics, including blood chemistry and characteristics, which are essential for establishing "normal" health parameters. This, in turn, can help veterinarians determine when an animal is ill or in poor condition. For example,

Ange-van Heugten, Verstegen, Ferket, Stoskopf, and van Heugten, (2008) studied blood serum chemistry concentrations of 30 captive wooly monkeys (*Lagothrix lagotricha*) housed at two European institutions as a means of establishing normal parameters to monitor health. Common causes of death in this species are pregnancy and hypertension, thus making these data useful for health evaluation. Similarly, Abbondanza, Power, Dickson, Brown, and Oftedal, (2013) were able to investigate variation in milk composition of three lactating female Asian elephants (*Elephas maximus*) from birth to the calf's third year of age and to determine changes that occur over time. Such studies would be difficult, if not impossible to conduct on free-ranging elephants.

All living animals will someday also die, and animals are often valuable from a scientific perspective even after their deaths (Hutchins, 2003). While anatomical studies are not typically conducted by zoos themselves, zoos are often a source for animal carcasses/skeletons for museum study collections or university anatomists who wish to better understand the anatomical structures of various species that may be little known to science (Hutchins, 1990).

Animal Welfare

The issue of how to assess animal welfare – or the well-being of individual animals – housed in zoos is a hot scientific topic and one that is in its early stages of development. There are, in fact, many different philosophies and scientific approaches to the study of animal welfare, recently summarized by Barber (2009), Fraser (2009), Hill and Broom (2009), and Veasey (2017). This will undoubtedly be an important and controversial topic of investigation for the coming decades.

Behavior

Behavioral research is a common focus of zoo research and many authors have discussed its role and utility (Eisenberg & Kleiman, 1977; Forthman & Ogden, 1992; Hediger, 1968; Hosey, 1997; Kleiman, 1992; Lindburg, 2010; Melfi, 2005; Moran & Sorensen, 1984). Behavioral research not only improves our understanding of a species' basic behavioral biology, but also helps to improve care and husbandry