Ecological Ethics in Captivity: Balancing Values and Responsibilities in Zoo and Aquarium Research under Rapid Global Change

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Abstract

Ethical obligations to animals in conservation research and management are manifold and often conflicting. Animal welfare concerns often clash with the ethical imperative to understand and conserve a population or ecosystem through research and management intervention. The accelerating pace and impact of global environmental change, especially climate change, complicates our understanding of these obligations. One example is the blurring of the distinction between ex situ (zoo- and aquarium-based) conservation and in situ (field-based) approaches as zoos and aquariums become more active in field conservation work and as researchers and managers consider more intensive interventions in wild populations and ecosystems to meet key conservation goals. These shifts, in turn, have consequences for our traditional understanding of the ethics of wildlife research and management, including our relative weighting of animal welfare and conservation commitments across rapidly evolving ex situ and in situ contexts. Although this changing landscape in many ways supports the increased use of captive wildlife in conservation-relevant research, it raises significant ethical concerns about human intervention in populations and ecosystems, including the proper role of zoos and aquariums as centers for animal research and conservation in the coming decades. Working through these concerns requires a pragmatic approach to ethical analysis, one that is able to make trade-offs among the many goods at stake (e.g., animal welfare, species viability, and ecological integrity) as we strive to protect species from further decline and extinction in this century.

Key Words: animal welfare; climate change; conservation ethics; ex situ conservation

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Introduction

Responsibilities to wildlife in field research and conservation projects have always been complicated because ethical duties to animals, populations, and ecosystems can pull wildlife scientists and managers in different directions (Minteer and Collins 2005a, 2005b, 2008). In recent years, this situation has been made even more complex by the impacts of global change (especially climate change), which, in many quarters, has forced a reassessment of research practice and conservation policy. Scientists and managers wrestle with understanding and protecting species and ecosystems in a rapidly changing environment (Hannah 2012; Marris 2011). In parallel, conservation ethics and values are being reexamined and adapted to fit dynamic ecological and institutional contexts in which traditional models of protecting the environment are being replaced by more pragmatic and interventionist approaches less wedded to historical systems and static preservationist ideals (Camacho et al. 2010; Minteer and Collins 2012). Furthermore, as we acknowledge the history and extent of human influence and impact on ecological systems—even for the most remote parts of the planet—we are confronted with a changing vision of nature. Instead of a stark contrast between "wild" and "managed," we now encounter a continuum of systems more or less impacted by human activity, a scale of degrees and increments (rather than absolutes) of anthropogenic influence that upends many customary divisions in conservation science, policy, and ethics (see, e.g., Dudley 2011).

A case in point is the weakening division between ex situ, or zoo- and aquarium-based research and conservation, and in situ, or field-based biological research and conservation practice. Global climate change, along with other drivers of rapid environmental transformation (e.g., accelerating habitat loss and the spread of invasive species and infectious diseases), is increasingly being viewed as requiring a more proactive and intensive philosophy of conservation and ecological management (Hobbs et al. 2011). One consequence of this shift is that the conceptual and empirical boundaries separating "the field" from "the animal holding facility" are growing hazy: zoos and aquariums are becoming more engaged in field conservation programs, while preserves and natural areas are becoming more intensively managed and designed for a diverse mix of conservation and resource management

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outputs (Cole and Yung 2010; Dickie et al. 2007; Pritchard et al. 2011).

At the same time, there are new calls within conservation science and management circles to think differently about the connections between captive and wild populations. Indeed, many wildlife scientists are recognizing that captive and wild populations should be seen not as separate biological and management domains but viewed instead as linked metapopulations (e.g., Lacy 2012). They argue that the sustainability of the former requires exchange of animals and DNA from the wild, whereas the viability of the latter may require contributions from ex situ populations as well as the refinement of small-population research and management techniques (Lacy 2012; Redford et al. 2012). Such techniques, however, may only be feasible in the controlled environment of the zoo or aquarium.

The softening of the distinction between ex situ and in situ, the quickening pace of biodiversity loss, and the parallel rise of a more interventionist ecological ethic have significant implications for how we understand and make tradeoffs among values and responsibilities in conservation research and practice. These include the concerns of animal welfare and animal rights as well as species-level and ecosystem-level conservation values. Although all of these obligations remain an important part of the ethical landscape of conservation research and practice, they are being reshaped by the need to respond to rapid environmental change as well as by the research demands of a more interventionist conservation effort.

A good example of this trend is the Amphibian Ark Project (AArk), a global consortium of zoos, aquariums, universities, and conservation organizations that has organized itself around the goal of slowing global amphibian declines and extinctions, which by all accounts have reached historic levels over the last several decades (Collins and Crump 2009; Gewin 2008; Zippel et al. 2011). Zoos and aquariums in the AArk serve as conservation way stations for amphibian populations facing possible extinction because of the combined forces of habitat loss, infectious disease, and climate change. But they also function as centers of research into the drivers of population decline, the possibilities of disease mitigation, and the prospect of selecting for biological resistance to a lethal amphibian pathogen (Woodhams et al. 2011). With the mission of rescuing, housing, and breeding hundreds of amphibian species to return them eventually to native localities, the AArk is emerging as a hybrid or "pan situ" approach to biodiversity protection, a project that integrates (and blurs the borders between) ex situ and in situ conservation (Dickie et al. 2007; Gewin 2008).

In addition, the breeding and research activities within the AArk evoke questions of animal welfare and conservation ethics, including the tensions between and within these commitments. Amphibian research can be invasive and even lethal to individual animals, raising significant and familiar welfare and rights-based concerns in zoo and aquarium research. Moreover, infectious disease research, a significant part of the AArk research portfolio, carries the risk of an infected host or the pathogen itself infecting other animals in a captive-breeding facility or even escaping into local populations. In fact, just such a case occurred when the often-lethal pathogen the amphibian chytrid fungus moved from a common species in a captive-breeding facility to an endangered species. When the latter was introduced into Mallorca to establish a population in the wild, subsequent research revealed that animals were infected by the pathogen from the breeding facility before transfer (Walker et al. 2008). Still, it is clear that many amphibian species will experience further declines or go extinct in the wild if dramatic measures such as the AArk are not pursued until a sustainable recovery and conservation strategy is developed.

In what follows, we examine the ethical and policy-level aspects of research and conservation activities that involve captive wildlife in zoos and aquariums, focusing on some of the implications of accelerating biodiversity decline and rapid environmental change. As we will see, the most pressing ethical issues surrounding zoo- and aquarium-based wildlife in this era of rapid global change are not best described as traditional animal rights versus conservation dilemmas but instead concern what we believe are far more complicated and broad-ranging debates within conservation ethics and practice. These debates include devising an ethically justified research and recovery strategy for wildlife across evolving in situ and ex situ conservation contexts that may require a more interventionist approach to biodiversity management. Zoo and aquarium researchers in a time of rapid global change must find creative ways to integrate and steer the expanding biodiversity research efforts of their facilities. In doing so, they will need to provide the ethical justification and scientific guidance for responding to the plight of those globally endangered species that can benefit from controlled and often intensive analysis in ex situ centers.

Debating the Moral Standing of Animals and the Environment

Ethicists and environmental advocates have often found themselves deeply divided over the moral status of and duties owed to nonhuman animals—a division that has existed despite the common effort among environmental and animal philosophers to expand societal thinking beyond a narrow anthropocentrism (e.g., Callicott 1980; Regan 2004; Sagoff 1984; Singer 1975). The dispute is usually attributed to different framings of moral considerability and significance. Animal welfare and animal rights approaches prioritize the interests or rights of individual animals, whereas environmental ethics typically embraces a more holistic view that focuses on the viability of populations and species and especially the maintenance of ecological and evolutionary processes. The difference between these two views can be philosophically quite stark. For example, animal-centered ethicists such as Peter Singer believe that it makes little sense to talk about nonsentient entities such as species, systems, or processes as having their own "interests" or a good of their

own (as environmental ethicists often describe them), although they can be of value to sentient beings and thus objects of indirect moral concern.

In the view of ecocentric ethicists such as J. Baird Callicott and Holmes Rolston, however, an ethics of the environment is incomplete if it does not accord direct moral status to species and ecosystems and the evolutionary and ecological processes that produced and maintain them. Most environmental ethicists are sensitive to animal welfare considerations and are certainly aware that many threats to populations, species, and ecosystems impact animal welfare either directly or indirectly. Typically, however, they advocate focusing moral concern and societal action on such ends as the protection of endangered species and the preservation of wilderness rather than reducing the pain and suffering (or promoting the rights or dignity) of wild animals. Domestic animals are even further outside the traditional ambit of environmental ethicists; indeed, their comparative lack of wildness and autonomy has for some suggested a lower moral status as "artifacts" of human technology rather than moral subjects (see, e.g., Katz 1991).

It is important to point out here that although "animal rights" is often used as a blanket term for ethical and advocacy positions defending the humane treatment or rights of animals, philosophers and others often make an important distinction between animal rights and animal welfare arguments. The former is generally seen as a nonconsequentialist view of an animal's moral status (i.e., a view on which the covered class of individuals is entitled to fair treatment following ascriptions of moral personhood or inherent worth similar to the logic of entitlement we ideally accord individual human persons). Alternatively, the welfare position is traditionally rooted in consequentialist moral reasoning whereby the impacts of decisions and actions affecting the interests or good of the animal are weighed against other goods (including the interests and preferences of humans), and decisions are made based on an assessment of the aggregate good of a particular action, all things being equal. What this means is that, although in many cases both animal rights and animal welfare philosophies will justify similar policy and practical outcomes, in some instances the welfare position may be more accommodating to animal harms when these are offset by the net benefits produced by a particular action or rule. It bears emphasizing, however, that calculations of these benefits and harms must be fair and consistent; they cannot give arbitrary weight to human preferences simply because they are anthropocentric in nature, and all interests—including those of the animal—must be considered.

Not surprisingly, these different approaches to moral consideration have often produced sharp disagreements at the level of practice, especially in wildlife management and biological field research. For example, animal rights proponents regularly condemn wildlife research and management practices that inflict harm or even mortality upon individual animals, such as the lethal control of invasive species, the culling of overabundant native wildlife, and the use of invasive field research techniques; practices that have for decades been widely accepted among wildlife and natural resource managers (e.g., Gustin 2003; Smith 2007). Controversial cases such as the reduction of irruptive whitetail deer populations threatening forest health in New England (Dizard 1999), amphibian toe clipping in capture–mark–recapture field studies (May 2004), the hot branding of sea lions for identification in marine research projects (Minteer and Collins 2008), and the culling of black-throated blue warblers for an ecological field experiment (Vucetich and Nelson 2007) illustrate the ethical conflicts characterizing much of the environmental/conservation ethics and animal welfare/rights debate in wildlife field research.

Despite attempts by some ethicists and scientists to find common ground between animal- and environmental-centered values at either the philosophic or pragmatic level (e.g., Jamieson 1998; Minteer and Collins 2008; Minteer 2012; Perry and Perry 2008; Varner 1998), many observers believe that the gulf separating ethically individualistic, animal-centered commitments and conservationists' more holistic commitment to promoting the viability of populations and communities is simply too wide to bridge, even in cases where animal-centered and biodiversity-centered advocates have common cause (Hutchins 2008; Meffe 2008).

This division has recently been reinforced by public stances taken by wildlife conservation organizations such as The Wildlife Society (TWS), which in 2011 released a position statement on animal rights and conservation that underscored what the organization described as the incompatibility between these two ethical and policy orientations (http://wildlife.org/policy/position-statements). Animal-centered views perceived as more moderate in nature, such as the commitment to the humane treatment of animals in research and management (i.e., a weaker animal welfare position) are ostensibly accepted by TWS, although the organization's position here probably still falls short of what animal welfare ethicists such as Singer would argue is demanded by a principled concern for animal well-being in research and management contexts.

The Ethical Complexity of Zoo and Aquarium Conservation

The practice of keeping animals in zoos and aquariums is one of the more intriguing areas of conflict within the animal ethics–conservation ethics debate. The presumption that the keeping of animals in captivity in zoos and aquariums is morally acceptable has long been questioned by animal rights–oriented philosophers who believe that such facilities by definition diminish animals' liberty and dignity as beings possessing inherent worth (e.g., Jamieson 1985, 1995; Regan 1995). Such critiques either implicitly or explicitly evoke the unpleasant history (from both the contemporary welfare and wildlife conservation perspective) of zoos as wildlife menageries designed primarily for public titillation and entertainment, including notorious cases of animal

abuse and the exploitation of captive wildlife for profit. Zoo advocates, however, argue that modern zoos and aquariums have a vital societal mission to educate zoo visitors regarding the necessity of wildlife conservation and the dilemma of global biodiversity decline and that they contribute (and could contribute even more) significantly to fundraising efforts to support conservation projects in the field (e.g., Christie 2007; Hutchins et al. 1995; Zimmerman 2010).

This broad ethical debate over zoos and aquariums in society and the various trade-offs it evokes regarding animal welfare, conservation, scientific research, and entertainment have been complicated by particular high profile cases, such as the keeping of elephants or large carnivores in zoos (Clubb and Mason 2003; Wemmer and Christen 2008) and whales or dolphins (cetaceans) in aquariums and marine parks (Bekoff 2002; Grimm 2011; Kirby 2012). Among other issues, these cases often reveal disagreements among scientists about conditions for housing some of the more charismatic, large, and popular animals in zoos away from in-range conditions as well as differences in assessments of species-specific welfare impacts and requirements across a range of taxa (Hosey et al. 2011). They also exemplify the welfare–entertainment–education–conservation nexus that forms much of the normative and ethical discourse around zoos in modern society (Hancocks 2001; Hanson 2002).

Zoos and aquariums therefore raise a number of ethical issues, from the basic question of the moral acceptability of keeping animals in captivity to more specific arguments and debates over practices such as captive (conservation) breeding, zoo-based research, wild animal acquisition, habitat enrichment, and the commercialization of wildlife (see, e.g., Davis 1997; Kreger and Hutchins 2010; Norton et al. 1995). Clearly, these practices provoke a set of complicated questions about our responsibilities to captive animals and the conservation of species and habitats in the wild.

Perhaps one of the strongest conservation-based arguments supporting housing animals in zoos and aquariums today is that these facilities provide the ability to create "captive assurance populations" through ex situ breeding, with the goal of reintroducing some individuals back into the wild to restore or expand lost or declining populations (Beck et al. 1994; Reid and Zippel 2008). This technique, described earlier in our discussion of the AArk, has produced some notable conservation successes in recent decades, including the recovery of (among other species) the Arabian oryx, the black-footed ferret, and the California condor. On the other hand, many animal rights–oriented critics of conservation breeding and the reintroduction efforts of zoos, such as the advocacy organization People for the Ethical Treatment of Animals (PETA), argue that captive breeding efforts are biased toward the breeding of "cute" animals of value to the public (rather than breeding for conservation purposes) and that such practices create surplus animals that are subsequently transferred to inferior facilities and exploited (www.peta.org/about/why-peta/zoos.aspx). PETA questions as well the broader goal of releasing captive-born and raised animals to the wild, pointing out the inherent difficulties surrounding reintroductions, including the risks they pose to the reintroduced animals and other wildlife in situ. Although these sorts of challenges have also been noted by wildlife biologists and biodiversity scientists, many advocates of conservation breeding and reintroduction programs have argued that further research and improved biological assessment and monitoring efforts can improve the likelihood of success for the release or reintroduction of captive animals to the wild (Earnhardt 2010; Fa et al. 2011).

The data suggest that zoos and aquariums are playing an increasingly significant role in field conservation programs and partnerships. In its 2010 Annual Report on Conservation Science, the Association of Zoos and Aquariums (AZA) lists zoos engaged in more than 1,970 conservation projects (i.e., activities undertaken to benefit in situ wildlife populations) in over 100 countries (www.aza.org/annual-report-on-conservation-and-science/). The AZA coordinates taxon advisory groups and species survival plans to manage conservation breeding, develop in situ and ex situ conservation strategies, and establish management, research, and conservation priorities (www.aza.org/). These experts (which include biologists, veterinarians, reproductive physiologists, and animal behaviorists, among other researchers) also contribute to the development of taxon-specific animal care manuals that provide guidance for animal care based on current science and best practices in animal management (www.aza.org/animal-care-manuals).

As part of their expanding efforts in field conservation, ex situ wildlife facilities are also becoming more significant players in biodiversity research. As Wharton (2007) notes, systematic, zoo-based research on reproduction, behavior, genetics, and other biological dimensions has made many important contributions to the improvement of animal husbandry practice over the past three decades. Moreover, ex situ animal research conducted to inform field conservation is seen as a growing priority for zoos and aquariums, especially in light of worrying trends in global biodiversity decline and the widely acknowledged potential of the extensive zoo and aquarium network to carry out studies that can provide conservation-relevant knowledge for field projects (WAZA 2005; MacDonald and Hofer 2011).

Applied research in zoological institutions (i.e., research motivated by the goal of improving conservation and/or veterinary science) is not the only research contribution of zoos and aquariums, however. Basic research on captive wildlife is also conducted throughout the system and is highly valued by many wildlife scientists, both within and outside of zoological institutions. At Zoo Atlanta, for example, researchers are presently conducting a number of studies designed to inform our understanding of wildlife biology, including the biomechanics of sidewinding locomotion in snakes, social behavior and acoustic communication in giant pandas, and taxonomic and phylogenetic studies of frogs, among other taxa (J. Mendelson, Zoo Atlanta, personal communication, 2012). Such research is often impossible to conduct in the wild, and thus captive populations can hold great value as specimens for basic scientific study.

Although not every zoo and aquarium has the capacity to conduct extensive animal research (focused on either veterinary/animal care or conservation purposes), the larger and better-equipped facilities such as the Bronx Zoo, the San Diego Zoo, Zoo Atlanta, the Monterey Bay Aquarium, and the St. Louis Zoo have become active wildlife and conservation research centers in addition to being popular educational and entertainment facilities. For all these reasons, zoos, aquariums, and other ex situ facilities (e.g., botanic gardens) are being championed by organizations such as the World Association of Zoos and Aquariums as potential models of "integrated conservation" given their ability to participate in a wide range of conservation activities, from ex situ research, education, and breeding of threatened species to field projects in support of animals in the wild to serving (in the case of the AArk) as temporary conservation rescue centers to protect animals threatened by rapid environmental change (WAZA 2005; Zippel et al. 2011). Whether these facilities can develop successful reintroduction programs that will lead to the ultimate recovery of populations they are holding temporarily (such as the AArk program) or whether these "temporary" efforts become de facto and permanent ex situ "solutions" to particular wildlife conservation problems in the field, however, remains to be seen.

For many wildlife biologists and conservationists, then, breeding and conservation-oriented research on captive wildlife are seen as essential activities that should not be halted on the basis of animal welfare and animal rights objections. The ethical imperative to save threatened species from further decline and extinction in the wild has for them a priority over concerns regarding individual animal welfare. Humane treatment of animals (both ex situ and in the field), however, remains a clear ethical obligation of zoo-based scientists and professionals as well as field researchers. It is an obligation formalized in the ethical codes of the major professional and scientific societies, such as the AZA and the Society for Conservation Biology.

Yet not everyone is convinced that this reinvigorated conservation justification for keeping animals in captivity is a compelling rationale for such facilities. For example, some critics have argued in the past that actual conservation-relevant research conducted in or by zoos and aquariums is, in fact, a relatively minor part of their mission and that it cannot justify keeping animals in captivity (see, e.g., Jamieson 1995). Such criticisms are, however, slowly losing their bite as we witness the more recent growth of zoo-based research for conservation purposes (Stanley Price and Fa 2007). Still, it is true that much of the research conducted by zoos today remains focused on animal husbandry rather than conservation of animals in the wild (Fa et al. 2011).

This situation may be changing, however. Indeed, research on captive wildlife in zoos and aquariums (including that driven by conservation concerns) is predicted to continue to grow in significance in the coming decades. Perhaps the most obvious reason for this is access. As mentioned above, scientists in ex situ facilities have the ability to carry out potentially high-impact research projects on captive animals that may be too costly, risky, or logistically impossible to perform on small, wild populations in situ (Barbosa 2009). This research can be valuable for improving animal husbandry in zoos and aquariums, but it can also be useful for augmenting field conservation projects because biological data from captive animals is incorporated in the planning and implementation of field interventions (Wharton 2007). Data collected from animals drawn from populations that only exist in small numbers in the wild are particularly valuable; therefore, captive populations afford important opportunities to collect data on rare species in a controlled and safe environment.

To the degree that research on zoo and aquarium wildlife is used to inform and improve efforts to conserve and manage vulnerable wildlife populations in the field, it may be defended as an ethically justified activity according to the more holistic obligation to promote species viability and ecosystem health—even if it includes techniques that disrupt or harm captive wildlife in the process. Yet, these activities could still be challenged by more animal rights–based arguments that claim that such harms, including the fundamental loss of freedom and the degradation of an animal subject's dignity associated with captivity, can never be offset by the production of beneficial biological consequences at the population or species level (i.e., "good consequences" in the aggregate cannot justify the violation of the moral duty to respect the worth of the individual animal).

For an animal welfare proponent willing to take a more pragmatic position, however, unavoidable harms or disvalues in zoo and aquarium research projects that directly lead to the promotion of the good of the species in the wild may be viewed as ethically tolerable in light of the collective benefit for sentient animals. This view could follow from the utilitarian principle to evaluate an action based on its consequences for all sentient beings impacted by the action or from a more integrated ethical system in which both animal welfare and conservation ethics are operant in moral decision making (see, e.g., Minteer and Collins 2005a, 2005b). Indeed, we suspect that most informed animal welfare supporters also see the value of wildlife conservation and landscape protection (or at least are not opposed to these activities). Therefore, they should not dismiss the real population, species, and ecosystem benefits of research on captive wildlife, especially in a time of global change.

The ethical evaluation of research on captive wildlife, however, can become even more complicated, especially if one holds the foundational view that it is wrong to place animals in captivity in the first place. Research undertaken primarily to improve animal care in ex situ facilities, for example, would appear to be a morally justifiable activity, especially if it produces results than can help zoo managers enrich habitats and improve the health and well-being of wildlife in their care. That is, the research would seem to produce a positive value that deserves to be weighed against any disvalue produced by harming or stressing an animal during the research process. And yet, this research could still be seen as morally unacceptable even if it improves the welfare

of captive animals because it destroys the animal's freedom or treats them as a "mere means" to some anthropocentric end. Therefore, according to this abolitionist position, zoo and aquarium wildlife research conducted under the banner of improving animal care or husbandry makes the mistake of assuming that keeping animals in zoos and aquariums is itself defensible, a stance that many arguing from a strong animal rights framework flatly reject (e.g., Jamieson 1985, 1995; Regan 1995).

But what about the case where research on captive wildlife is demonstrated to be necessary to obtain information relevant to the conservation and management of threatened populations in the wild? In such situations, strong ethical objections to the keeping of animals in ex situ facilities, to interfering in their lives, and so forth arguably have comparatively less normative force. To reject this claim, one would have to argue that the well-being of captive animals is and should be a completely separate moral issue from the welfare of wild populations—a position that, as mentioned earlier, is difficult to hold in our increasingly integrated conservation environment. This does not entail the rejection of animal welfare considerations in research design and conduct; these remain compelling at all stages of the research process. But it provides a powerful and morally relevant consideration for undertaking that research rather than ruling it out on moral grounds.

We should underscore that this conclusion does not hold for poorly designed or weakly motivated research projects that promise to shed little new scientific light on wildlife biology and behavior relevant to conservation or that appear to essentially reproduce studies already performed on either captive or wild animals in the field (Minteer and Collins 2008). Determining the conservation value of the proposed research and its scientific necessity is thus a critical activity bearing on the welfare and conservation of animals across in situ and field settings. Yet it is an analysis that necessarily contains a measure of uncertainty that can complicate evaluations and proposed trade-offs among animal welfare, scientific discovery, and the potential for the research to produce results with a direct application to the conservation, management, or recovery of populations in the wild (Parris et al. 2010).

Improved husbandry and conservation value in the field are not the only potential benefits of zoo and aquarium research for wildlife, however. As Lewis (2007) notes, research on captive animals in ex situ facilities may also yield results that can pay dividends in the form of improved animal welfare in field research projects. This is especially true in the case of zoos and aquariums with extensive veterinary departments with the capacity to develop equipment and protocols that minimize research impacts on wildlife in field studies. Such projects might include research on novel, less-invasive animal marking and sampling techniques, the development of safer forms of darting and the use of anesthesia, and the creation of new breeding techniques for recovering particular wild animal populations (Lewis 2007). Although it is not always entirely clear which interventions should be considered invasive in the animal research context or what exactly constitutes harm in these analyses (see, e.g., Goodrowe 2003; Parris et al. 2010; Pauli et al. 2010), it does seem to be the case that wildlife researchers in both ex situ and field study environments are increasingly adopting non-invasive sampling and study techniques for wildlife research, signifying, perhaps, a growing sensitivity to animal welfare in field biology and conservation (Robbins 2009).

If ex situ research on animals can lead to the development of less-invasive technologies and research protocols, then some of the welfare concerns raised by the manipulation or harm of zoo and aquarium animals in the research process that produces these technologies may be offset, at least to a degree and at the aggregate (i.e., population, species, and ecosystem) level, by the net welfare benefits of adopting these less-invasive tools and techniques in biological field research. It is important to note once again, however, that this judgment will likely still not satisfy strict animal rightists who typically resist such attempts at "value balancing" (see e.g., Regan 2004). Furthermore, and as mentioned above, acceptance of animal harms in such research should hold only as long as the research in question is judged to be scientifically sound and well-designed (i.e., as long as it does not run afoul of the "reduction, refinement, and replacement" directives of the use of animals in the life sciences, which are designed to minimize the impact of research activities on animal welfare and screen out research designs that are not ethically justified, scientifically necessary, or efficient (Russell and Burch 1959).

Rapid Global Change and the Evolving Ethics of Ex Situ Research

It is clear that ex situ facilities such as zoos and aquariums will continue to increase in importance as centers of scientific research and conservation action in the 21st century (Conde et al. 2011; Conway 2011; Fa et al. 2011). The forces of global environmental change, including climate change, accelerating habitat loss, and the spread of infectious diseases and invasive species, along with the synergies among these and other threats, are currently exerting great pressure on wild species and ecosystems. This pressure is expected to only increase in the coming decades (Rands et al. 2010; Stokstad 2010; Thomas et al. 2004). These dynamics have suggested to many zoo scientists and conservationists an expanding role for many zoos and aquariums in wildlife protection. They can function as safe havens for the more vulnerable species threatened in the wild, as research institutions seeking to understand the impact of global environmental change on wildlife, and as active players in the increasingly intensive process of wildlife conservation in situ, including population management and veterinary care (Conway 2011). As Swaisgood (2007) points out, with the requirement of more intensive managerial interventions in the field because of human encroachment, habitat modification, and other changes, many of the issues central to zoo

research and conservation (including animal welfare, the impacts of human disturbance on wildlife, and the consequences of the introduction of animals into novel environments) are increasingly drawing the interest of wildlife researchers and managers in natural areas and in situ conservation projects.

All of these conditions speak to the necessity of wildlife research in zoos and aquariums for informing conservation science under conditions of rapid environmental change, including (most notably) research on the effects of climate change on animal health (MacDonald and Hofer 2011). For example, aquariums can simulate climate change impacts such as shifts in temperature and salinity, the effects of which can be studied on fish growth, breeding, and behavior (Barbosa 2009). Such research could contribute to our understanding of the stresses exerted by global change on wildlife and consequently inform and improve conservation and management efforts in situ.

Another line of research in the domain of global change biology (and wildlife adaptation to environment change) includes studies of captive animals' responses to pathogens and emergent diseases, such as the work undertaken as part of the aforementioned AArk (Woodhams et al. 2011). Notably, these investigations could allow scientists to gain a better grasp of the consequences of temperature variations and disease transmission for the health of wild populations before any effects take hold (Barbosa 2009). The AArk example illustrates the kind of ethical balancing that needs to be performed for claims surrounding animal and species-level welfare and the health and historic integrity of ecosystems. For many amphibian species, AArk is a place of last resort. Once the amphibian chytrid enters an ecosystem, at least some susceptible species will not be able to return to their native habitats without an intervention strategy such as selective breeding for infectious-disease tolerance. An alternative tactic is managed relocation (i.e., the translocation of populations from their native habitat to novel environments that may be well outside their historic range) (e.g., Schwartz et al. 2012). Both approaches, however, involve ethical decisions that balance the welfare of individual frogs and salamanders against that of populations and species as well as the historic integrity of ecosystems (i.e., the particular mix of species and communities that have evolved in these systems over time) (Winston et al. in press).

Health- and disease-oriented wildlife research in zoos and aquariums may not only be targeted at wildlife conservation. The public health community, for example, may also have a significant role to play in zoo research in the near term. Epidemiologists and others have noted the value of zoo collections for biosurveillance (i.e., as biological monitoring stations that can be studied to understand and plan for the emergence of future infectious diseases posing public health risks) (McNamara 2007). This proposal raises two further interesting ethical questions regarding the evaluation of zoo- and aquarium-based research under global change: (1) the acceptability of wildlife health research motivated by improving field conservation of the species and (2) wildlife health research that enlists captive wildlife as "sentinels" (McNamara 2007) to provide an early warning system for infectious diseases that might impact human welfare. Both research projects could be pursued under the banner of "wildlife, health, and climate change," yet each would differ in its underlying ethical justification. One program would likely be more species-centered or nonanthropocentric (wildlife health research for conservation purposes), whereas the other would presumably be defended on more anthropocentric grounds, given the focus on safeguarding public health. This philosophic division, however, is not always that well defined, especially if wildlife health research in zoos and aquariums has benefits for both in situ conservation and more human-centered interests (e.g., the provision of ecosystem services). Still, the different research foci would be expected to evoke some differences in ethical analysis regarding their implications for animal welfare, conservation, and human welfare ethics.

For a swelling number of cases, then, scientific study and refinement of conservation breeding techniques, wildlife health research, and so forth will likely be necessary to save focal species in the wild under dynamic and perhaps unprecedented environmental conditions (Gascon et al. 2007). Ethical objections to conservation breeding or to the impacts of high-priority conservation research on captive wildlife motivated by animal welfare and rights concerns will, we believe, become less compelling as the need for captive assurance populations increases (because of the impacts of global change). These ethical objections will also weaken as we see the rise of additional partnerships between ex situ and field conservation organizations and facilities and especially as the former become more directly engaged in recovery and reintroduction efforts that benefit animals in the wild. It is one thing to evaluate captive-breeding programs designed to provide a steady supply of charismatic animals for zoo display. These have rightly drawn the ire of animal advocacy organizations as discussed earlier. It is another thing to assess those activities with the goal of recovering wildlife populations threatened in the field because of accelerating environmental change.

This does not mean that the ethical challenges of recognizing and promoting animal welfare concerns in ex situ research and conservation will or should be swept aside but rather that the more significant (and often more demanding) ethical questions, at least in our view, will take place on the species conservation side of the ethical ledger. These challenges will include the task of accommodating a philosophy of scientific and managerial interventionism in wildlife populations and ecological systems as rapidly emerging threats to species viability and ecosystem health move wildlife researchers and biodiversity managers into a more aggressive and preemptive role in conservation science and practice (Hobbs et al. 2011; Minteer and Collins 2012). The risks attached to this shift include creating further ecological disruption by intervening in biological populations and systems, and a more philosophic consequence—the transgression of venerable preservationist ideals that have long inspired and

motivated the efforts of conservationists and ecologists to study and protect species and ecosystems.

For example, ethical dilemmas surrounding the translocation of wildlife populations from native habitats to new environments, including temporary relocations to ex situ facilities such as zoos and aquariums, raise a set of difficult technical, philosophic, and ethical questions for conservation scientists and wildlife biologists (Minteer and Collins 2010). Beyond the animal welfare or animal rights concerns about handling and moving animals that may experience considerable stress (or even mortality) during this process, such practices will also have implications for (1) the original source ecosystems (i.e., the community-level impacts of removing individuals from populations stressed by climate change), (2) the temporary ex situ facility that houses the animals (including shifts in resources and collection space as well as risks of disease transmission) (e.g., Greenwood et al. 2012), and (3) the native species present in the eventual "recipient" ecosystems once the wildlife are introduced (Ricciardi and Simberloff 2009).

Another example is the practice of ecological engineering for species conservation in the wild, which can involve the significant modification (and even invention) of habitat to improve field conservation efforts. Along these lines, Shoo et al. (2011) have proposed considering and testing a number of interventionist approaches to the conservation of amphibian populations threatened by climate change. These include activities such as the manipulation of water levels and canopy cover at breeding sites as well as the creation of new wetland habitat able to support populations under variable rainfall scenarios. The investigators suggest employing an adaptive management protocol to experimentally determine whether and to what extent such manipulations are effective in the field.

Such conservation challenges and others like them ultimately compel us to rethink our responsibilities to safeguard declining species and promote ecosystem integrity and health in an increasingly dynamic environment. We believe that this analysis will also require a reassessment of wildlife research priorities and protocols (including the relative significance of animal welfare concerns in research and conservation) for some time to come.

Conclusions

The ethical terrain of zoo and aquarium research and conservation is experiencing its own rapid and unpredictable shifts that mirror the accelerating pace of environmental and societal change outside these facilities. What is required, we believe, is a more concentrated engagement with a range of ethical and pragmatic considerations in the appraisal of animal research under these conditions. The growing vulnerability of many species to the often lethal combination of climate change, habitat degradation, emerging infectious diseases, and related threats has created a sense of urgency within the biodiversity science community. We need to respond with research agendas that can help to understand and predict the impact of these forces on the viability of populations and species in the wild and to inform actions and policies designed to conserve these populations and species.

Part of this ethical appraisal will require asking some hard questions of zoos and aquariums regarding their priorities and abilities to assume this more demanding position in conservation science, especially because some observers have suggested a need for greater planning and research capacity in these facilities (Anderson et al. 2010; Hutchins and Thompson 2008). Zoological institutions are idiosyncratic entities, and thus there is often a great deal of variability in how particular zoos and aquariums interpret their conservation mission (J. Mendelson, Zoo Atlanta, personal communication, 2012). The divide between mission and practice can produce significant challenges for these institutions as they take on a more aggressive conservation role. For example, and as mentioned above, many would argue that it is critical for zoos and aquariums to avoid becoming the final stop for species threatened in the wild. Instead, they should be true partners in what we have called an integrated, pan situ conservation management strategy across captive, wild, and semiwild contexts. The development by zoos and aquariums of more explicit reintroduction plans in such cases would therefore help ensure that their conservation ethic remains compatible with that of the wider community, which generally favors the maintenance of wild populations (i.e., in situ conservation) whenever possible.

One implication of this move by zoos and aquariums toward a more expanded research and conservation mission is that it will likely affect other zoo programs that have long dominated the culture and activities of zoo keeping. The display of exotic animals for public entertainment, for example, may be impacted as zoos and aquariums attempt to carve out more space for research and conservation activities, both in their facilities and in their budgets. On this point, Conway (2011) proposes that zoos will need to commit to creating more "conservation relevant zoo space" as they make wildlife preservation (and not simply entertainment and exhibition) their primary public goal. Yet such a shift in mission and programs could undercut public support for zoos, especially to the extent that the traditional displays of charismatic wildlife are reduced to accommodate a stronger conservation and research agenda.

An increased emphasis on climate change and its biodiversity impacts, too, could pose a challenge to zoos and aquariums wary of promulgating a negative or doom-and-gloom message to their visitors. Although some facilities are embracing this challenge and making climate change a part of their conservation education programming, some zoos and aquariums are struggling to incorporate this message within their more traditional educational and entertainment aims. For example, the Georgia Aquarium has apparently assured visitors that they will not be subjected to material about "global warming," a concession, according to the aquarium's vice president for education and training to the conservative political leanings of many of the facility's

guests (Kaufman 2012). This example speaks to the larger challenge of moving zoos and aquariums into a stronger position of global leadership in conservation education, research, and practice under global change and other major threats to habitat and population viability in the coming decades.

Animal rights and welfare concerns will continue to be relevant to the evaluation of research and conservation activities under global change, but ultimately a more sophisticated and candid analysis of the trade-offs and the multiple imperatives of conservation-driven research on captive populations is required. Our understanding of these responsibilities—and especially the requirement of balancing animal well-being in practice in wildlife management and conservation policy—must evolve along with rapid climate change, extensive habitat fragmentation and destruction, and related forces threatening the distribution and abundance of wildlife around the globe. Unavoidable animal welfare impacts produced as a result of high-priority and well-designed conservation research and conservation activities involving captive animals will in many cases have to be tolerated to understand the consequences of rapid environmental change for vulnerable wildlife populations in the field. It will allow recovery and promote the good of vulnerable species in the wild more effectively under increasingly demanding biological conditions. Inevitably, these changes will continue to blur the boundaries of in situ and ex situ conservation programs as a range of management activities are adopted across more or less managed ecological systems increasingly influenced by human activities.

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