Francesco Maria Angelici • Lorenzo Rossi
Editors

Problematic Wildlife II

New Conservation and Management Challenges in the Human-Wildlife Interactions

Springer

Treves A, Naughton-Treves L (2005) Evaluating lethal control in the management of human–wildlife conflict. In: Woodroffe R, Thirgood S, Rabinowitz A (eds) People and wildlife, conflict or coexistence? Cambridge University Press, Cambridge, pp 86–106
UNEP: Secretariat of the Convention on Biological Diversity (2010) Pets, aquarium, and terrarium species: best practices for addressing risks to biodiversity. SCBD, Technical Series No. 48, Montreal
Vallone RP, Ross L, Lepper MR (1985) The hostile media phenomenon: biased perception and perceptions of media bias in coverage of the Beirut massacre. J Pers Soc Psychol 49:577. https://doi.org/10.1037/0022-3514.49.3.577
Van Ballenberghe V (2006) Predator control, politics, and wildlife conservation in Alaska. Alces 42:1–11
van Ham C, Genovesi P, Scalera R (2013) Invasive alien species: the urban dimension. Case studies on strengthening local action in Europe. IUCN European Union Representative Office Brussels
Van Houtan KS (2006) Conservation as virtue: a scientific and social process for conservation ethics. Conserv Biol 20:1367–1372
Vidal J (2016) 18 elephants to be flown to US zoos as drought puts pressure on Swaziland wildlife. The Guardian, 16 Feb 2016. Available via https://www.theguardian.com/environment/2016/feb/26/18-elephants-to-be-flown-us-zoos-drought-puts-pressure-on-swaziland-wildlife. Accessed 7 May 2017
Vilella-Vila M, Costa-Font J (2008) Press media reporting effects on risk perceptions and attitudes towards genetically modified (GM) food. J Socio-Econ 37:2095–2106. https://doi.org/10.1016/j.socec.2008.04.006
Vinter J (1963) Kind killing. Universities Federation for Animal Welfare, London
Wald DM, Lohr CA, Lepczyk CA et al (2016) A comparison of cat-related risk perceptions and tolerance for outdoor cats in Florida and Hawaii. Conserv Biol 30:1233–1244
Walker M, Diez-Leon M, Mason G (2014) Animal welfare science: recent publication trends and future research priorities. Int J Comp Psychol 27:80–100
Webb TJ, Raffaelli D (2008) Conversations in conservation: revealing and dealing with language differences in environmental conflicts. J Appl Ecol 45:1198–1204
Weisberg L (2017) Polar bear at SeaWorld San Diego dies after a brief, unexplained illness. Available via http://www.latimes.com/local/lanow/la-me-ln-seaworld-polar-bear-death-20170418-story.html. Accessed 20 Apr 2017
Wickins-Dražilová D (2006) Zoo animal welfare. J Agric Environ Ethics 19:27–36
Wood V, Seddon PJ, Beaven B, Heezik Y (2016) Movement and diet of domestic cats on Stewart Island/Rakiura, New Zealand. N Z J Ecol 40:186–190
Woods M, McDonald RA, Harris S (2003) Predation of wildlife by domestic cats *Felis catus* in Great Britain. Mammal Rev 33:174–188
Zamir T (2007) Ethics and the beast: an argument for speciesist liberationism. Princeton University Press, Princeton
Zoological Society of San Diego (2016) Land-based food not nutritionally sufficient for wild polar bears, according to new study. Available via https://www.sciencedaily.com/releases/2016/09/160913150503.htm. Accessed 10 Apr 2017

Chapter 14 Zoos and Conservation in the Anthropocene: Opportunities and Problems

Jan Robovský, Lubomír Melichar, and Spartaco Gippoliti

zoos are or should be one of the last bastions of organismal biology...
– Seidensticker and Forthman (1998)

Acronyms

AZA	Association of Zoos and Aquariums
BSC	Biological Species Concept
DFSC	Differential Fitness Species Concept
EAZA	European Association of Zoos and Aquaria
EDGE	Evolutionary Distinct and Globally Endangered (species)
EEP	European Endangered Species Programme
ESU	Evolutionarily Significant Unit
ISIS	International Species Information System
IUCN	International Union for Conservation of Nature
IZE	International Zoo Educators Association
MK	Mean Kinship
PSC	Phylogenetic Species Concept
RCP	Regional Collection Plan
SSC	Species Survival Commission

J. Robovský (✉)
Faculty of Science, University of South Bohemia, České Budějovice, Czechia
e-mail: robovsky@prf.jcu.cz

L. Melichar
Zoo Liberec, Liberec, Czechia
e-mail: melichar@zooliberec.cz

S. Gippoliti
Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy

F. M. Angelici, L. Rossi (eds.), *Problematic Wildlife II*,
https://doi.org/10.1007/978-3-030-42335-3_14

TAG Taxon Advisory Group
WAZA World Association of Zoos and Aquariums
ZGAP Zoological Society for the Conservation of Species and Populations
ZIMS Zoological Information Management System

14.1 Introduction

Homo sapiens is a relatively young species, with an extensive adaptive and invasive capacity (e.g. Cameron and Groves 2004; Glikson and Groves 2016), whose activities have enormous impacts on global ecosystems and species diversity. These impacts are currently referred to in the literature as 'the sixth mass extinction', 'defaunation' or 'biological annihilation' (e.g. Dirzo et al. 2014; Ceballos et al. 2015, 2017; see also Macdonald and Service 2007; Carroll and Fox 2008). Our relationship to nature and in particular species has varied greatly both spatially and temporally, according to the intentions and motivations of particular individuals, societies and populations of our species; in effect, we have been plundering natural resources too often in our history. Luckily, we also enjoy the beauty of nature in its various forms and undertake conservation actions to safeguard valuable species and landscapes. Edward O. Wilson (1987) recognizes in our species what he calls 'biophilia', which he defines as 'the innate tendency to focus on life and lifelike processes' (see also Kellert and Wilson 1993). Our relation to nature (natural resources) is complex, influenced by cultural and local conditions, and is sometimes full of paradoxes, which may depend on particular historical periods and the beliefs of that era. For example, we should be aware that many conservation actions in historic times were initiated or carried out by the nobility, out of their love of hunting (e.g. attempts to preserve aurochs, European wisent and Alpine ibex – e.g. Kowalski 1967) or by particular avid hunters (e.g. Theodore Roosevelt and Ernest Thompson Seton; for more on our hunting history and perceptions over time, see also Guthrie 2005).

Our species has also often exhibited ambitions for rearing and breeding nondomestic animals, alongside domesticated ones, for aesthetic, utilitarian and exhibition purposes. This has been well documented since antiquity (e.g. Belozerskaya 2006; Grigson 2016). The history of proto-collections and menageries intended to enrich the experience of an audience is long and fascinating (e.g. Kisling 2000; Rothfels 2002; Belozerskaya 2006). The associated animal trade was also relatively extensive. (For documentation on it since the Middle Ages, see, e.g. Rothfels 2002; Dittrich 2007; Grigson 2016.)

Travelling or stationary menageries, where the main ambition was to exhibit animals and captivate a paying public, evolved into zoos, which focused on breeding and exhibiting animals according to zoological and aesthetic standards, for example, by using Hagenbeck's concepts (e.g. Rothfels 2002; Kisling 2000) (Fig. 14.1). Zoos themselves have evolved into modern zoos spontaneously and gradually, thanks to their increasing body of knowledge on how to keep wild animals alive in captivity and their first-hand awareness of the deteriorating status of several species in the wild (e.g. Rabb 1994; Kisling 2000; Rabb 2004). For a detailed history and description of the species collections of some particular zoos over time, see, among others, Peel 1903; Schlawe 1969; Bridges 1974; Edwards 1996; Klös et al. 1994; Bell 2001; Kisling 2000; Gippoliti 2010; Blaszkiewitz 2005; Weigl 2005; Solski and Strehlow 2015; and Grigson 2016.

Fig. 14.1 The lions in Rome as an example of Hagenbeck's open zoo style. (Photo by Spartaco Gippoliti)

Modern zoos perform many crucial duties other than merely serving as a public educational institution. Specifically, their core missions are to conserve threatened species through coordinated ex situ breeding programmes, support in situ conservation projects and collaborate with research institutions to increase basic and applied knowledge on threatened fauna (see below) (Table 14.1, Fig. 14.2).

The literature on zoos, their purposes and conservation missions is extensive and complex. In this chapter, therefore, we merely summarize the basic roles of zoos and then focus on some conservation and management challenges associated with zoos (and other captive institutions) in the light of our experiences. We would also like to refer to readers, including young zookeepers, to important reviews, chapters and monographs, specifically Hediger 1942, 1969; Benirschke 1986; Frankham et al. 1986; Bostock 1993; Schonewald-Cox et al. 1983; Snyder 1995; Kisling 2000; Rothfels 2002; Miller et al. 2004; Kleiman et al. 2010; Frost 2011; Prichard et al. 2011; and Maple and Perdue 2013 and also to at least two inspiring, optimistic and highly readable bestsellers – Durrell (1976) and Goodall et al. (2010).

Table 14.1 Landmarks of zoo history, science and evolution as conservation actors

Year	Event
1752	The Tiergarten Schönbrunn in Vienna is established as the oldest zoo in the Western world
1793	The Menagerie at the Jardin des Plantes in Paris is established as the first public zoo
1826	Creation of the Zoological Society of London; the 'Menagerie' will be opened in 1828
1859	*Der Zoologische Garten* began publication, thanks to Frankfurt Zoo director Max Schmidt
1892	*A handbook of the management of animals in captivity in Lower Bengal* is authored by Ram Bramha Sanyal in Calcutta
1907	Tierpark Hagenbeck, the 'open zoo', is opened to the public near Hamburg
1932	The first international studbook for a wild animal established; *Bos bonasus*
1942	Heini Hediger published *Wilde Tiere in Gefangenschaft*, later translated in English in 1950
1946	Birth of the *International Union of Directors of Zoological Gardens* (IUDZG), currently WAZA
1959	First International Symposium on Zoo Medicine in Berlin (East) convened by Johannes Dobberstein Zoological Society of London began publishing *International Zoo Yearbook*, edited by Desmond Morris Gerald Durrell opened Jersey Zoo, now operated by the Durrell Wildlife Conservation Trust
1960	The *American Association of Zoo Veterinarians* is established
1964	*The management of wild mammals in captivity* is authored by Lee S. Crandall of the New York Zoological Society (now WCS)
1970	*Journal of Zoo and Wildlife Medicine*
1972	First World Conference on Breeding Endangered Species in Captivity is held in Jersey
1982	*Zoo Biology*
1993	*The World Zoo Conservation Strategy* launched by IUDZG
2005	*The World Zoo and Aquarium Conservation Strategy* launched by WAZA
2015	*Committing to Conservation: The World Zoo and Aquarium Conservation Strategy* produced by WAZA

14.2 Roles of Zoos

Zoos should realize their entire potential in order to fulfil conservation, education and other duties and roles to the highest standards, which are well expressed and comprehensively summarized in these experienced opinions, reviews, strategies and reports (in this case EAZA reports) and on the web pages of particular zoo and aquaria associations: van Bemmel 1971; Dathe 1978; Luoma 1988; Olney et al. 1994; Rabb 1994; Hutchins and Conway 1995; Kitchener 1997; Stepherdson et al. 1998; Conway 2003; Hutchins 2003; Mallinson 2003; Young 2003; Rabb 2004; WAZA 2005; Gippoliti and Kitchener 2007; Wirth 2007; Bowkett 2009; Gippoliti 2011; Gusset and Dick 2011a, b; Witzenberger and Hochkirch 2011; Gippoliti 2012; Conde 2013; Gusset and Dick 2013a, b; Tribe and Booth 2013; Heckel et al. 2013; Gippoliti 2014; Moss et al. 2014; Gusset and Lowry 2014; Mellor et al. 2015; Keulartz 2015; Barongi et al. 2015, Gusset and Dick 2015; Wirth 2015; Annual Report 2016a EAZA; TAG Reports 2016b EAZA; and Schwartz et al. 2017.

Fig. 14.2 The Red Panda is an example of a globally managed ex situ species. (Photo by Spartaco Gippoliti)

In summary, zoos and aquariums pursue the goals listed below, in full accordance with the United Nations *Strategic Plan for Biodiversity 2011–2020*.

14.3 Ex situ Conservation

This important conservation mission is based on scientific management focused on sufficient population size, demographic stability and retention of genetic diversity over the long term (e.g. Schonewald-Cox et al. 1983; Lacy 1995; Young and Clarke 2000; Ferrière et al. 2007; Gusset and Dick 2011b; Frankham et al. 2002; Allendorf and Luikart 2007; Mills 2007; Bertorelle et al. 2009; Witzenberger and Hochkirch 2011; Lacy 2013; Leus 2018). Input pedigree and studbook data are based on identified animals in a standard way and moreover registered in the Species360 database (formerly the International Species Information System, abbreviated as ISIS).

Species360 regularly publishes and distributes the ISIS/WAZA Studbook Library DVD. The 2011 edition comprises 1540 studbooks, including 1350 regional and 190 international studbooks, plus 292 husbandry manuals and nearly 2800 other documents (WAZA web pages, downloaded in July 2018). Currently there are 130 active international studbooks, including 159 species or subspecies, which are specified regularly in the International Zoo Yearbook (WAZA web page, downloaded in July 2018; but see also Witzenberger and Hochkirch 2011).

Since the exchange of animals between regions are expensive and often difficult due to logistic, legal and veterinary issues, interregional (ideally global) and coordinated population management is highly recommended (Olney et al. 1994; see also below). This approach, for example, is the goal of Global Species Management Plans, which, however, have been applied until now to only around a dozen species (e.g. Gusset and Dick 2011b).

Ex situ conservation is often exemplified using only a few species that have been saved from extinction (e.g. Conde 2013). The full list, though, is much richer. In 2013, of the 33 animal species classified as 'extinct in the wild' on the IUCN Red List, 31 are actively bred in zoos and aquariums, and 17 are managed in studbook-based breeding programmes (Gusset and Dick 2013a). Maas (2013, 2017) also enumerated the number of animal subspecies and plant species 'extinct in the wild' according to IUCN Red List of 2013 and tried to evaluate animal and plant reintroductions. Specifically, Maas (2013) noted six successful reintroductions that achieved self-sustaining populations (e.g. *Acanthobrama telavivensis, Bos bonasus, Equus przewalskii, Mustela nigripes*); eight reintroductions that met with some success, but with wild populations not (yet) self-sustaining (e.g. *Elaphurus davidianus, Gallirallus owstoni, Nectophrynoides asperginis, Thermosphaeroma thermophilum*); five attempted reintroductions with no signs of success (yet) (only one animal species – *Corvus hawaiiensis*); and 59 species that remain solely in captivity, with no reintroduction attempted (yet) (e.g. several cichlids, 3 species of *Cyprinodon* and frogs, 14 species or subspecies of *Partula, Zenaida graysoni*). Although some updates are available, we use the original and comprehensive review made by Maas (2013).

Unfortunately, captive breeding has not been successful in saving some species and subspecies, including such unique taxa as Tasmanian tiger (*Thylacinus cynocephalus*), quagga (*Equus quagga quagga*), passenger pigeon (*Ectopistes migratorius*) and pink-headed duck (*Rhodonessa caryophyllacea*). (For a list of 22 species and subspecies where the last living member died in captivity, see Maas 2013.)

Species should be held according to high standards of animal welfare, best-practice guidelines and often species-specific husbandry (e.g. Norton et al. 1995; Shepherdson et al. 1998; Yong 2003; *WAZA Code of Ethics and Animal Welfare* adopted in 2003; Maple and Perdue 2013; also Wickins-Dražilová 2006; Melfi 2009; Hill and Broom 2009; Gippoliti 2014). The *World Zoo and Aquarium Animal Welfare Strategy* recommends that zoos and aquariums should apply a simple welfare model referring to the so-called Five Domains (Gusset and Dick 2015).

14.4 In situ Conservation and Fundraising in Support of Field Conservation

Zoos support a number of in situ conservation projects and contribute to valuable research and practical conservation efforts worldwide (e.g. AZA and EAZA Conservation Databases). As in current conservation practice, an evaluation of conservation impacts is necessary; within the WAZA community, the *Project Conservation Impact Tool* is recommended (Mace et al. 2007). Such evaluations are important for improving future procedures and strategies.

Apart from the support of zoo and aquarium staff, the financial contribution of WAZA members to wildlife conservation is estimated at over 350 million US dollars every year), making zoos and aquariums the third-highest contributor to conservation worldwide after the *Nature Conservancy* and the *World Wildlife Fund* global network (Gusset and Dick 2011a). In more detail, in 2016 AZA's institutions spent approximately $216 million on more than 3409 conservation initiatives in 127 countries, and 823 species and subspecies benefitted from conservation actions (for details, see the AZA Conservation and Research Database); as of 5 April 2017, 1340 conservation projects and the activities of 165 EAZA members (51% of EAZA's members) amounting to €58.5 million have been registered in the new EAZA Conservation Database (https://www.aza.org/field-conservation; Zimmermann 2017).

14.5 Integrated Species Conservation

Ex situ and in situ conservation missions are closely related through animal transfers and by personnel, financial and other resources (see also Lacy 2010), and so the dichotomy between these two forms of species conservation is often arbitrary, as noted, for example, by Redford et al. (2013). Such interconnections have often been realized as a spontaneous progression of the conservation work of zoos and aquariums and are currently recommended by some directives (e.g. Olney et al. 1994; Mallinson 2003; Conway 2003; Hutchins 2003; Tribe and Booth 2003; Bowkett 2009; Prichard et al. 2011; Witzenberger and Hochkirch 2011; *WAZA Vision and Corporate Strategy Towards 2020;* Conde 2013; Gusset and Dick 2013b; Keulartz 2015; McGowan et al. 2017; Schwartz et al. 2017). In effect, knowledge and experience are shared, and depending on the species, some in situ projects use ex situ principles and vice versa.

This integrated approach has been well documented based on genetic exchanges of individuals between ex situ and in situ projects. Reintroductions are also an example of integrated species conservation, and it appears that in situ conservation will probably increasingly require our active interventions (e.g. translocations of many large mammals through national borders that are now fenced (Linnell et al. 2016), to preserve gene flow and metapopulation dynamics). Concerning reintroductions, there is often a fear that animals bred in captivity are less likely to survive once released than their wild counterparts (cf. Mathews et al. 2005). On balance, reintroductions of captive animals are promising (e.g. Maas 2013), although some prerelease actions such as training could be important for the survival of reintroduced animals (Menzel and Beck 2000; Reading et al. 2013). It is also relevant to such issues to consider that many reintroductions undergo a gradual process that allows a slow readaptation to 'wild' habitats.

14.6 Research and Development of Relevant Technologies

Through their living collections, zoos and aquariums have contributed much to the documentation and understanding of morphological, chromosomal, genetic, behavioural and other life-history parameters of many animal species and subspecies (e.g. Ryder and Byrd 1984; Conde 2013; Ryder and Feistner 1995; Conde 2013; Rees 2015). Such information is important as basic theoretical or applied knowledge, which is often useful in conservation management of particular taxa. Many technologies have evolved and have improved in close cooperation with zoos and aquariums, and some are put to significant use in these institutions (e.g. Ryder and Feistner 1995; Piña-Aguilar et al. 2009).

Research for evidence-based husbandry (e.g. effectiveness of husbandry practices – diets, enrichment, housing conditions, etc.) and veterinary issues are prominent research topics in zoos (see the section "Nutrition and Veterinary Issues" in this chapter and Rees 2015).

Research associated with zoos and aquariums is also often focused on socio-economic, educational, visitor and marketing issues and results that could improve future steps in these activities (e.g. Reade and Waran 1996; Majolo et al. 2005; Ballantyne et al. 2007; Moos and Esson 2013; Roe et al. 2014; Colléony et al. 2017; Skibins et al. 2017).

Scientific contributions of authors affiliated with zoos or aquariums is significant (e.g. our survey across the Web of Science – see below; WAZA web pages, downloaded in August 2018; Loh et al. 2018). Research is often conducted in collaboration with academic institutions (Fernandez and Timberlake 2008).

Our survey across the Web of Science (downloaded in August 2018) using the address search with 'zoo' as a keyword identified approx. 12,000 records that have been published since 1972, with approx. 1000 records each year during the last 3 years. Contributions are predominantly published in this sequence of top seven journals: *Journal of Zoo and Wildlife Medicine, Zoo Biology, American Journal of Primatology, PLoS ONE, Theriogenology, Journal of Wildlife Diseases* and *Veterinary Record*. Using the Web of Science categories, contributions are predominantly associated with these fields (in this sequence of top seven): veterinary sciences (35%), zoology (22%), ecology (9%), reproduction biology (5%), biodiversity conservation (5%), multidisciplinary sciences (5%) and evolutionary biology (4%). For much thorough analysis of scientific research of AZA members, see Loh et al. (2018).

As with experience gained in zoos and aquariums that become best-practice husbandry guidelines and veterinary procedures, technologies should be shared across these institutions as much as possible.

14.7 Public Relations and (Conservation) Education

Gusset and Dick (2011a) estimated that zoos and aquariums around the world receive 700 million visitors every year. Zoos and aquariums have therefore an enormous obligation to educate these visitors about taxa held at particular institutions, the general mission of zoos and aquariums, basic topics associated with biodiversity, the conservation of our planet and environmental sustainability. In the general view, zoos and aquariums have unprecedented potential to fascinate all generations through the beauty of the animal species they exhibit, to support our 'biophilia', to educate, to inspire, to encourage visitors to engage with conservation actions, to increase their environmental awareness and to enhance a basic sense of responsibility with regard to lifestyle and consumption, often in an entertaining form. Zoos and aquariums are extremely important for urban populations that have little or no contact with nature (e.g. Gippoliti 2011), which is even more important for children and young people (WAZA 2005) (Fig. 14.3). Zoo educators are organized in the IZE, which publishes the *Journal of the International Zoo Educators' Association*. Some surveys have provided compelling evidence that zoos and aquariums contribute to increasing the number of people who understand biodiversity and to increasing actions which could help to protect it (e.g. Gusset and Lowry 2014; Moss et al. 2014 and references therein).

14.7.1 Zoos as Sanctuaries

Zoos sometimes serve as sanctuaries for injured or otherwise disabled, donated or confiscated wild animals, and such animals are sometimes included in conservation programmes or education activities carried out by zoos and aquariums (Conde 2013; Cuarón 2005). What is often not realized, however, is that a modern zoo can serve as a 'repository' for confiscated animals only occasionally. This is because zoo design exhibit has evolved from a row of cages for taxonomically similar species (monkeys, large cats and so on) into habitat exhibits intended to hold together a whole social group or even several species; and so to find adequate space for a single animal often poses more than a challenge for the zoo staff. Regrettably, in some countries modern zoos goals are not well-known, and there continues to exist a call by some sections of society such as animal rights groups to transform zoos into 'sanctuaries' in which the breeding of captive animals is not allowed. Evidently, a lack of awareness of the environmental situation at the global level hinders an understanding of how zoos and other captive-breeding facilities should today be considered true 'sanctuaries of biodiversity'.

14.7.2 Deficiencies

Naturally, the fulfilment of above-mentioned duties varies around the world's zoos and aquariums for various reasons, even among accredited members of regional zoo and aquarium associations.

As the IUCN SSC Antelope Specialist Group (2015) opposes all Intentional Genetic Manipulations of antelopes for commercial or amenity purposes, with particular reference to (i) hybridization of different species, (ii) crossing of different

Fig. 14.3 Zoos are important links with wildlife, especially for children and young people. (Photo by Spartaco Gippoliti)

subspecies and (iii) selective inbreeding of a population, zoos and aquariums should re-evaluate the breeding of colour variants of animals, which are rare to non-existent in the wild. White tigers and lions may be highly appreciated by the public, but there is a risk that visitors will get a mistaken conservation message about the relevance of these animals, which are already being exploited by private organizations as 'conservation targets'. Further these colour mutations take up zoo space that is urgently needed for conservation breeding of genetically unmodified animals. EAZA (2013) took a negative position on Intentional Breeding for the Expression of Rare Recessive Alleles directly.

Concerning database (Species360) and studbook data (e.g. Witzenberger and Hochkirch 2011), the quality of the same and the associated reasonableness of population management recommendations are closely connected with the quality of the input data. While some curators and keepers are conscientious, others are not, which greatly damages the work of the conscientious colleagues and studbook keepers. Although some animals present challenges in terms of identifying individuals and relationships, zoos and aquariums should pursue registration work to the best of their abilities, giving the required time and full institutional support to their staff.

Similarly, some zoos are very cooperative in the concept of population management proposed by coordinators and/or particular species committees (e.g. in establishing bachelor groups, other measures of birth control or providing management euthanasia), but some are less active. The system should be modified such that the cooperative and altruistic institutions receive more benefits (see also below).

14.8 Conservation and Management Challenges Associated with Zoos

14.8.1 *Prioritizing of Biodiversity*

Global biodiversity is not distributed equally across the Earth's surface, and different regions with greater biodiversity face different levels of threat (Myers et al. 2000). In effect, rational conservation actions should be focused predominantly on threatened regions with exceptional concentrations of endemic species, the so-called biodiversity hotspots (Myers et al. 2000), which is an approach that has resonated well in global conservation strategies and actions. Similarly, different species face different threats and do not have the same conservation status, as conventionally evaluated under *The IUCN Red List of Threatened Species* (http://www.iucnredlist.org/about/citing). In view of limited personnel and other resources, conservation priorities could be combined with evolutionary distinction based on phylogenetic diversity, under the so-called EDGE initiative (e.g. Isaac et al. 2007). As a result, the conservation of species with lower EDGE scores should not be abandoned easily, but nor should we continue to neglect species with higher EDGE scores. The first application of EDGE criteria for mammals (Isaac et al. 2007) detected that many evolutionarily distinct and globally endangered species within the 100 highest-ranking species did not benefit from existing conservation projects or protected areas, which is alarming. Currently, the EDGE approach is available for mammals, birds, reptiles, amphibians and corals (http://www.edgeofexistence.org/index.php).

14.8.2 *Prioritizing of Collections*

Zoos are often considered 'Noah's Arks' in that they may be able to keep animal populations safe from threats that they face in the wild. Objectively they are such 'arks', but the degree to which they are depends on how 'loaded' they are.

Current attempts to evaluate the ex situ conservation contribution of zoos have clearly shown that there is much to be improved in relation to threatened species (Conde et al. 2011; Witzenberger and Hochkirch 2011; Gippoliti 2012; Conde 2013; Conde et al. 2013; Heckel et al. 2013; Martin et al. 2014; Dawson et al. 2016; Biega et al. 2017, but see also Bowkett 2009, 2014). Specifically, Conde et al. (2013) demonstrated that only 23% (!) of terrestrial vertebrate species held in ISIS zoo are threatened, and only in Dasyuromorphia and Testudines are threatened species significantly overrepresented (i.e. the actual number of threatened species differed from the expected value, if zoo collections were taken at random). Martin et al. (2014) demonstrated that mammals and bird species held in zoos are less endemic and less threatened than their close relatives not held in zoos. On the contrary, amphibians held in zoos are equally as threatened as their close relatives not found in zoos, although ex situ institutions are not prioritizing range-restricted habitat specialists, which are species with a greater extinction risk in the future (Biega et al. 2017). Frynta et al. (2009, 2010) reported that zoos preferentially keep 'cute' species (in many vertebrate groups) and pay less attention to actual conservation needs (for species less attractive to visitors). On the other hand, reasons to why simply holding higher proportions of threatened taxa may not increase conservation impact are given in Bowkett (2014).

The major zoo and aquarium associations (e.g. EAZA, AZA) try to prioritize collections based on different criteria in the form of RCPs. Our experiences with the EAZA association, however, indicate that even some experienced colleagues are often unable to discriminate between truly threatened taxa and common taxa that have had some breeding tradition. Despite RCPs and appeals from TAG chairs, much zoo capacity often continues to be used for non-threatened taxa or stocks of unknown/mixed origin. By way of illustration, in September 2017, 1105 mouflons (*Ovis aries musimon*), a 'taxon' that was created by human's early sheep introduction in Corsica and Sardinia (cf. Gippoliti and Amori 2004), 736 Sika deer (*Cervus nippon*) of unspecified subspecies, and 987 red deer (*Cervus elaphus*) of unspecified subspecies occupied spaces in world zoos, included in Species360 Database, that could be used instead for threatened caprine or deer taxa. Some currently available, highly threatened taxa (of similar size and needs) that could occupy those enclosures include Bukhara markhor (*Capra falconeri heptneri*), West Caucasian tur (*Capra caucasica*), Transcaspian urial (*Ovis arkal*), Bukhara urial (*Ovis bochariensis*); Laristan mouflon (*Ovis laristanica*), Armenian mouflon (*Ovis gmelini*), Bactrian stag (*Cervus bactrianus),* white-lipped deer (*Cervus albirostris*), Formosan sika deer (*Cervus taioanus*) and Vietnamese sika deer (*Cervus pseudaxis*) (taxonomy follows Groves and Grubb 2011 and/or Castelló 2016).

Prioritizing is also relevant for some particular breeding lines. In case of the Przewalski horse, two main lines, A and M, are recognized, of which the A-line exhibits many morphological and genetic similarities with wild Przewalski horses (e.g. Groves 2009; Robovský 2012; Groves and Robovský in prep.). How can we explain that population management for the A-line was abandoned by the EEP (Schook et al. 2016), given that the current genomic study (Der Sarkissian et al. 2015) recognized A-line horses as virtually devoid of the admixture from domestic horses, in contrast to M-line horses, and with heterozygosity/inbreeding levels (based on genomic data) being very similar to those of M-line horses? Is it really not possible to preserve the diminishing population of A-line horses (124 animals in September 2015, though not all of these animals are housed with other A-line horses) at some target population size (approx. 100 mares, as proposed in 2008 – Yasynetska and Zharkikh 2008) alongside the M-line horses, which number over 2000? It bears keeping in mind here that A-line horses have helped to improve/standardize phenotype parameters of M-line horses throughout the captive history of the Przewalski horse (for references, see, e.g. Robovský 2012).

Making conservation actions easier by reducing or minimizing conservation options in the future is extremely risky, since concerns over the health of particular species/subspecies/line may be shaped by other motivations or targets.

Although most zoos and aquariums (at least those located in Europe and North America) should be focused on globally threatened biodiversity (Fig. 14.4 and Fig. 14.5), they should not neglect local or regional autochthonous taxa; indeed this should be desirable and inspiring, highlighting domestic environmental problems and the often overlooked local biodiversity (e.g. Gippoliti 2004; Olive and Jansen 2017). We must remember as well that some races of domesticated animals could be of conservation concern (Taberlet et al. 2008).

Some observers argue that we also need common species for 'ambassador' education and public relation purposes. This may be true, but skilful education could work well with threatened species, while the above-mentioned proportion of threatened vs. non-threatened species in zoos indicates that we already have too many non-threatened 'ambassadors'. We believe that visitors could ascribe positive values to the taxonomic diversity of a zoological collection, especially when it's presented skilfully to visitors. For excellent species-based conservation breeding and education work regarding threatened birds, see Hirschfeld et al. (2013).

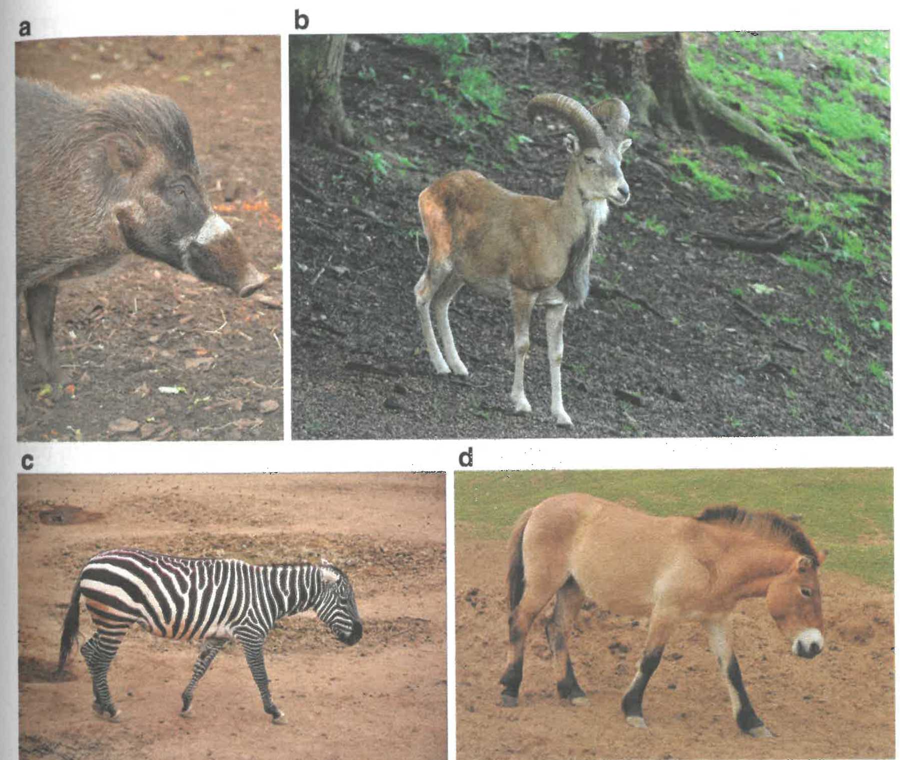

Fig. 14.4 Several mammals, which need our urgent help. (**a**) Visayan warty pig (*Sus cebifrons*), photo by Roland Wirth. (**b**) Bukhara urial (*Ovis bochariensis*), photo by Lubomír Melichar. (**c**) Half-maned zebra (*Equus quagga borensis*), photo by Lubomír Melichar. (**d**) A-line Przewalski horse (*Equus przewalskii*). (Photo by Roland Wirth)

Fig. 14.5 Two examples of birds, which need our urgent help – see the EAZA Silent Forest Campaign (https://www.silentforest.eu). (**a**) Javan Pied Starling (*Gracupica jalla*), photo by Roland Wirth. (**b**) Sumatran laughingthrush (*Garrulax bicolor*). (Photo by Roland Wirth)

Another issue is the preservation of species diversity in zoos (cf. Peš and Vogeltanz 2010; Lupták 2015; Matschei 2017; Santore 2017), especially of threatened taxa. That diversity has often diminished, due to several factors, which include the loss of interest in some species, veterinary and other logistic limitations in attempts to refresh currently low stocks and homogenization of zoos potentially due to perceived visitor preferences, as usually declared, etc. (e.g. Wirth 2011; Matschei 2017), but also availability of species and prioritization of managed species. Any attempt either to keep the current diversity of threatened taxa in zoos or obtain and breed new threatened taxa should therefore be supported and commended by the zoo and conservation community and visitors. Specialized facilities, which are closed to the public, are often required for this mission. In this context, it should be noted that generally some facilities used for successful breeding of threatened species need not always meet 'optimal welfare/aesthetic criteria' from the human perspective but should at best be exclusively for the needs of particular species (cf. Heckel et al. 2013).

14.8.3 *Taxonomic Instability*

We are living through a revolution in the biological sciences, thanks to new evolutionary concepts, statistical and molecular phylogenetics methods and both old and new data sets. For many biologists/zoologists/taxonomists and conservationists, the traditional view on species and the parameters that define species (i.e. BSC – biological species concept) in taxonomy and management practice seems to be untenable. (For further reading, see Behie and Oxenham 2015; Groves et al. 2017;

Gippoliti et al. 2018; Gippoliti and Groves 2020, this volume and references therein).

This is at times considered negatively (e.g. Garnett and Christidis 2017; for overview, see also replies and papers citing this comment). To allay these fears of instability, however, we can now access a large body of data that often fully suffice for qualified conservation and management actions. Similarly, the current taxonomic instability (e.g. in larger mammals) is often exaggerated with regard to its impact on conservation and simplified as a conflict between BSC and PSC (phylogenetic species concept) or between 'lumpers' and 'splitters'. Under both (or any other) species concepts, taxonomic opinions are often very similar (e.g. compare Grubb 2005 and Groves and Grubb 2011 in case of ungulates). Predominantly we do have the same entity but of different evolutionary and conservation values. Although we consider PSC highly suitable, not merely because it minimizes the risk that some unique populations would be neglected, we should be open to different opinions as much as possible in order to preserve current species diversity (e.g. Hazevoet 1996).

In summary, taxonomic instability does not hamper conservation, because conservation actions can be assessed, often quite easily, under different taxonomic concepts and approaches – for example, Swayne's hartebeest is a (very) distinct and endangered hartebeest taxon that could be classified as separate subspecies of *Alcelaphus buselaphus* under BSC or separate species under PSC; irrelevant which species concept is closer to biological/evolutionary reality, it is no doubt that its existence is widely accepted by scientific and conservation communities and it deserves our full attention and adequate conservation actions. As some IUCN species specialist groups, however, insist on the BSC, a sensitive approach would require that assessments be done at the subspecies level, or at least the level of subspecies that are recognized as evolutionary distinct (ESU), or at the level of separate species under PSC when data are available. Such an approach is sometimes more difficult to be adopted with lesser charismatic creatures, such as rodents. Yet zoos should lead the way, attracting attention towards little-known overlooked lineages or taxa that are suffering decline, even in our own backyard, such as the subterranean members of genera *Spalax* and *Nannospalax* in Central Europe or the little known populations subsumed under *Castor fiber* in Europe and Central Asia (Gippoliti and Amori 2007; Csorba et al. 2015).

14.8.4 *Precautionary Principle in Management*

Frankham et al. (2012) advocated a DFSC, differential fitness species concept, to be applied to fragmented populations with some diagnosable differences, under which populations are considered the same species unless there are signs of outbreeding depression or fixed chromosomal differences. Other authors assert that successful (e.g. fertile) interbreeding under human control gives no indication of species status (for references, see Groves and Robovský 2011; Groves et al. 2017). Some zoos seem to consider DFSC sensible (e.g. the current mixing of different subspecies of dama gazelle (*Nanger dama*) is underway in some institutions, as proposed in Senn et al. 2014; for a critique, see Schreiber et al. 2018). The precautionary principle should be applied here, since 'Once they have been mixed up they can never be unscrambled' (Groves 1995). In practice, when the 'lumping' of some separate stocks is unavoidable, we should proceed carefully, step by step, that is, not lumping the mass, but at first only in a few institutions and insisting on a detailed documentation of somatic, reproductive and other parameters of the lumped stock.

Concerning the taxonomic status of animals in zoo and aquarium collection, zoos should also try (1) to accumulate morphological and genetic data on their captive populations and priority should be given to threatened taxa; (2) to check historical data on the origin of their stocks, and if unavailable or incomplete, genetic/morphological comparisons should be used and priority should be given to populations used for reintroductions; (3) concerning potential reintroductions and new imports, animals should be mixed only within the same evolutionary significant unit/taxon under the precautionary principle (cf. van Bemmel 1971; Dathe 1978); and (4) in general, our conservation steps should minimize potential harm/regrets and maximize potential benefits/options, as measured by reproductive fitness and adaptive evolutionary processes.

Concerning reintroductions, they should also follow species (morphological) adaptations and their historical distribution (when available), habitat and diet preferences. This is because some endangered species had/have lived or live in suboptimal-marginal habitat due to destructive human activities, e.g. European bison; these species are called 'refugee species' (e.g. Cromsigt et al. 2012; Kerley et al. 2012).

14.9 Other Management Issues

Modern zoos manage current stock based on population management (summarized in the EAZA region as *Population Management Manual* – EAZA 2015), scientific principles and data, in order to maximize genetic variability over the long-term perspective (for references, see above). Additionally, all animals are managed in order to maximize the welfare of particular animals (see above), also using various enrichment methods (Stepherdson et al. 1998; Young 2003; Mason and Rushen 2006; Shyne 2006; Hoy et al. 2010; Jonas et al. 2018). These principles are often meaningful, and some associated tools are very sophisticated, but in some cases, there may be room for common sense.

Concerning welfare and enrichment, the effectiveness of the principles should be enforced when life-history parameters (e.g. sociality, group size, diet) and associated adaptations are considered. For example, breeding within a group (of the suitable size and composition) is the best welfare enrichment for species that do live in groups; breeding should be an essential part of animals' lives in zoos, at least as a source of natural welfare/enrichment. Similarly, enrichment should be designed to meet species-specific requirements (Law and Kitchener 2002; Mason 2010) and could be highly effective when applied with common sense. In some institutions, felids and other carnivores are fed predominantly on pellets or commercially prepared diets, sometimes offered through more or less sophisticated enrichment techniques; but the most basic type of enrichment should utilize the long-lasting processing of food, by providing whole or partial carcasses that include feathers/skin, hairs and bones (e.g. cf. McPhee 2002; Bashaw et al. 2003; Skibiel et al. 2007). Similarly, the food can be scattered or hidden across the entire enclosure, and feeding schedules can be randomized (Jonas et al. 2018).

Inbreeding is another important topic in population management (e.g. Schonewald-Cox et al. 1983; Hedrick and Kalinowski 2000; Frankham et al. 2002; Holt et al. 2003; Koeninger Ryan et al. 2003; Charpentier et al. 2007). Many pages have been written about inbreeding, but our impression is that much evidence, thorough meta-analyses and a consideration of the biology and history of particular species or groups are still needed, since some results regarding the avoidance of inbreeding, inbreeding depression, etc., are often unexpected or vary according to particular species and/or life-history parameters (e.g. social and reproductive system) (e.g. Smith 1979; Schonewald-Cox et al. 1983; Hedrick 2000; Charpentier et al. 2007; Holland et al. 2007; Olson et al. 2012; Ibáñez et al. 2011, 2013; Bichet et al. 2014; Ellegren and Galtier 2016). Additionally, some captive stocks continue to prosper despite numerically limited founder stock. This may be due to previous exposure to inbreeding; bottlenecks in the history of the species caused by natural processes and/or by chance – inbreeding could fix negative but also positive allelic combinations, which could be of adaptive significance; differences between detected inbreeding values based on studbook vs. genomic data; or a relatively short time, from an evolutionary perspective, for an effect to have been felt (e.g. Kalinowski et al. 1999; Charpentier et al. 2007; Tokarska et al. 2011; Holland et al. 2007; Der Sarkissian et al. 2015; Moreno et al. 2015). In the case of European bison (*Bos bonasus*), the average inbreeding level in lowland bison is almost 50%, yet no signs of inbreeding depression have been observed. In contrast, inbreeding effects have been noticed in the lowland-Caucasian line, which has a much lower average inbreeding level (28%) (Todarska et al. 2011).

Some observers believe in 'genetic rescue' for stocks/populations or species with limited genetic diversity parameters, yet often propose to undertake outbreeding with different ESUs or species, which is more risky. All these cases require a proper consideration of historic (or prehistoric) genetic diversity; of the history of the species (some species or subspecies have been derived by isolating some segment of the paternal line, with the result that they include only some genetic variants); and of other evolutionary factors (cf. Weeks et al. 2011). For example, the observed genetic depletion in Amur tigers likely reflects a founder history via Central Asia that predates human-induced bottlenecks (Driscoll et al. 2009). In any case, sensitive conservation actions should rigorously evaluate the pros and cons of 'rescue', taking account as well of proposals published to obtain all possible feedback, evidence and arguments (e.g. Weeks et al. 2011; Hoban et al. 2013; Gippoliti et al. 2017). These actions could, moreover, deploy varying conservation approach criteria, as was done, for example, by Moodley et al. (2017) for black rhinoceroses (see also Elemental Conservation Units – Wood and Gross 2008).

The care of zoos and aquariums devoted to particular specimens is highly complex. In effect, many species prosper well under our management (e.g. Tidière et al. 2016). Concerning limited capacities of ex situ institutions, coordinators of some breeding programmes are trying to slow the growth of prospering populations. There are several basic options, which could be combined skilfully, such as separation of the sexes (ideally only for a short time; breeding every 2 years is often sufficient), having offspring remain with parents as long as possible, management euthanasia (breed and cull strategy) and contraception or castration (e.g. Gippoliti 2014; Penfold et al. 2014). Again, we tend to recommend that the natural processes and biology of particular species be considered. It is known, for example, that some species or groups (e.g. suids, rhinoceroses) are sensitive to not being allowed to breed at a young age, and the current practice, the results of which are unfortunately too seldom published (see point 'Publication of Interesting Observation and Experiences'), indicates that reproduction in a 'switch-on, switch-off' regime, as requested by coordinators using contraception, does not always work correctly (cf. Penfold et al. 2014). Stopping the breeding for the whole or majority of a population is risky, as it could reduce the reproductive success of some animals. For example, wild pig species such as the endangered Visayan warty pig *Sus cebifrons* have evolved to produce many offspring at regular intervals (most of which will not survive to adulthood in the wild), and captive management, to 'avoid this surplus' through temporarily preventing mating or temporary contraception, can render females permanently infertile within 3 years (Przybylska 2014; cf. Leus 2018).

We tend to encourage coordinators and keepers to apply 'clever' tools for population management that accord with the biology of managed species (cf. Norton et al. 1995; Leus 2018). Although the breed and cull strategy is controversial for many observers, we should be aware of its similarity and optimality from the biological perspective for the majority of species, when consideration is made of their natural mortalities owing to many factors (e.g. predation, stochastic catastrophes or harsh environmental conditions) for particular age cohorts. Considering welfare and other biological factors, animals managed under the breed and cull strategy could experience most natural behaviours, such as reproduction, care of offspring and existence within a normal social structure with all age cohorts.

It should be also mentioned that although some institutions, curators and keepers accept this strategy, they put it into practice under the assumption that the coordinator is working carefully with the population and also taking other actions to allow the population an acceptable growth rate (cf. Powell and Ardaiolo 2016). Otherwise, the repeated application of the breed and cull strategy by each cooperating institution could demotivate the institutions, curators and keepers in the future. And, as stated above, these very cooperative institutions should benefit from their altruistic (and difficult, especially from the public relation point of view) actions, e.g. by being recommended for breeding programmes in the future, obtaining animals with a higher ranking in population and a higher influence in species (e.g. EEP) commissions, etc.

14.10 Hidden Risk of the Mean Kinship Criterion?

Several approaches and criteria are used in managing captive populations to retain as much genetic variability as possible (e.g. Schonewald-Cox et al. 1983; Lacy 1995; Frankham et al. 2002; Allendorf and Luikart 2007; Witzenberger and Hochkirch 2011). The traditional approach has tried to minimize reproduction between closely related individuals based on studbook data and associated inbreeding coefficients, but currently the use of MK is considered to be a better management that should be preferred (e.g. EAZA Population Management Manual – EAZA 2015). According to the same document, breeding priority should be given to individuals with low mean kinships, which is an approach that could equalize the genetic influence of particular individuals within the population. The low mean kinship could mean two different breeding histories of the particular individual: (1) the individual has not yet had any breeding opportunity, yet could indeed have such an opportunity to reproduce, and (2) the individual has had breeding opportunities but has failed due to factors that could include poor somatic and reproduction parameters, unusual or even pathological behaviour of genetic or environmental-ontogenetic origin or previous husbandry. In effect, the support/prioritization of animals under the second variant could deteriorate a managed population over the long term (cf. Frankham et al. 1986; Massaro et al. 2013; Chargé et al. 2014). The potential negative effect of MK under this variant could be minimized by the proactive communication of the coordinator with particular keepers and between keepers before animals are exchanged. Transferring animals in suboptimal condition due to health, somatic or other parameters is considered an unethical conduct.

14.11 Nutrition and Veterinary Issues

A lot of energy, budget and personal capacities are devoted to these important issues, which exhibit a relatively good publication production (see, e.g. *Journal of Zoo and Wildlife Medicine*). As with the management issues mentioned above, the nutrition of zoo animals should reflect the biology and nutrition of particular species (cf. Clauss et al. 2009; Junge et al. 2009 Hatt et al. 2011; Clauss et al. 2013). When the seasonal availability of some parts of a diet (e.g. fruits), the daily intake and the nutritional quality of the diet in the wild are considered, some species are evidently overfed, with regard to the amount or to the nutritional quality of the daily intake (e.g. lemurs – Junge et al. 2009). This overfeeding has a significant effect on the health, longevity and reproduction of such animals (e.g. Junge et al. 2009). Considering that zoos must avoid domestication and provide relevant educational experiences to visitors, there is ample opportunity for greater collaboration between nutritionists and caretakers to increase foraging time and encourage species-typical behaviours without overfeeding the animals. To this end, particular relevance may be assigned to natural browsing of berries and older natural fruit varieties whose consumption can elicit the most appropriate feeding behaviour without compromising the general health of the concerned animals. Currently, cultivated fruits and vegetables with much higher level of sugar and lower level of fiber are often replaced by vegetables with a well-balanced content of sugar and fiber (e.g. Junge et al. 2009).

We must confess that the extensiveness of this field is beyond our scope. We therefore refer interested readers to the series *Fowler's Zoo and Wild Animal Medicine Current Therapy*, *Comparative Animal Nutrition and Metabolism* (Cheeke and Dierenfeld 2010), *Wild mammals in captivity* (Kleiman et al. 2010), publications by Prof. Marcus Clauss and materials associated with the EAZA Nutrition Group and Veterinary Committee, AZA Nutrition and Veterinary Advisory Group.

14.12 Collaboration with Other Sectors of Society

Although some zoo associations are quite restrictive in relation to working with private animal holders, when it comes to the prioritizing of collections, recommended meta-population approaches, limited space and other capacities, zoos should cooperate more with other organizations or responsible private holders that are both sensitive to conservation issues and trustworthy, in order to achieve greater population viability of particular threatened species. Organizations focused on in situ conservation, which have been increasingly supported by zoos providing funds and professional training (see above), could also recommend the establishment of some ex situ management for particular species. It should be mentioned that division between in situ and ex situ conservation is often arbitrary, as the two forms are often closely connected and use very similar tools, as could be demonstrated, for example, in the case of kakapo (*Strigops habroptilus* – Powlesland et al. 2006), the Iberian lynx (*Lynx pardinus*) (e.g. Vargas et al. 2009), Tasmanian devil (*Sarcophilus harrisii* – McCallum 2008), Western Derby's eland (*Taurotragus derbianus derbianus* – Derbianus Conservation: www.derbianus.com), the giant sable antelope (*Hippotragus niger variani* – Pinto et al. 2016) and many ZGAP projects (Wirth 2007). Synergies among various subjects could increase the effectiveness of conservation projects, and so such collaborative efforts can only be recommended.

14.13 Education and Popularization

Excellent educational and popularization work can highlight the conservation mission of a particular zoo, ideally with a regional or global perspective, and popularize each and every species held in a particular zoo, especially threatened species which are seemingly considered 'normal', 'dull' or 'less attractive' (cf. Gerald Durrell). Durrell's propagation of Rodrigues fruit bat *Pteropus rodricensis* and pink pigeon *Nesoenas mayeri* are exemplary cases of talented popularization and educational work (Durrell 1979). Excellent educational work should not shy away from an explanation of potentially controversial and ethically complicated issues under the responsible breeding management (Norton et al. 1995) such as management euthanasia, the breed and cull strategy, the feeding of carnivores with euthanized zoo animals, the significance of bachelor groups and the exchange of favourite specimens under population managements across zoos. Institutions with such agenda should win our recognition, as they allow other institution scopes for explanations, discussions and following (also Gippoliti 2014). In any case, a truthful media presentation is more valuable than populism, since it can help us to realize the best management steps in the future. We should recognize that there may be different degrees of difficulty according to prevalent cultural attitudes at regional or national levels. At present, at least in some countries, increasing attention is being paid to welfare issues and the detriment caused by other zoo activities (Maynard 2017). Zoo resources, like natural resources, are finite. Increasing the attention paid to welfare-related arguments poses the very real danger that zoos could be diverted from work on other scientific or conservation issues.

14.14 Publication of Interesting Observation and Experiences

Zoos breed a huge number of species, and the obtained knowledge and experiences are the source of a vast amount of information on all possible biological parameters (see above and Fig. 14.6). This information is often published and currently also uploaded into the ISIS – now the Species360 – ZIMS database (e.g. Schwartz et al. 2017). All zoos should be encouraged to publish interesting observations, basic biological parameters of kept animals and the observed effects of husbandry changes. Even rare observations are valuable, as when they are combined with an understanding of typical behaviour, they can give a richer picture of individual motivations and relationships (cf. Fischhoff et al. 2010). Additionally, even short and technical (descriptive) studies help provide a better understanding of the biology of particular species, which could have great importance for species-specific management and conservation actions. Publication of documented husbandry experiences minimizes duplications of activities and provides a potential for improvements to husbandry or conservation actions (e.g. Barongi et al. 2015). The category Management of Captive Animals is included in the very interesting Conservation Evidence website (conservationevidence.com) (Andrew Bowkett, pers. comm.).

The established zoo journals, *Zoo Biology*, *Journal of Zoo and Wildlife Medicine*, *International Zoo Yearbook* and the new *Journal of Zoo and Aquarium Research* increase the opportunities to publish results, as the reviewing process is accommodated to the specifics of zoo work and available sample sizes. Unfortunately, some established zoo journals have not been longer published – *Der Zoologische Garten*, *Dodo*, *Milu* or *Bongo*. Time limitations, a crowded agenda and 'professional blindness' often limit the prolific scientific contribution that zoos could make.

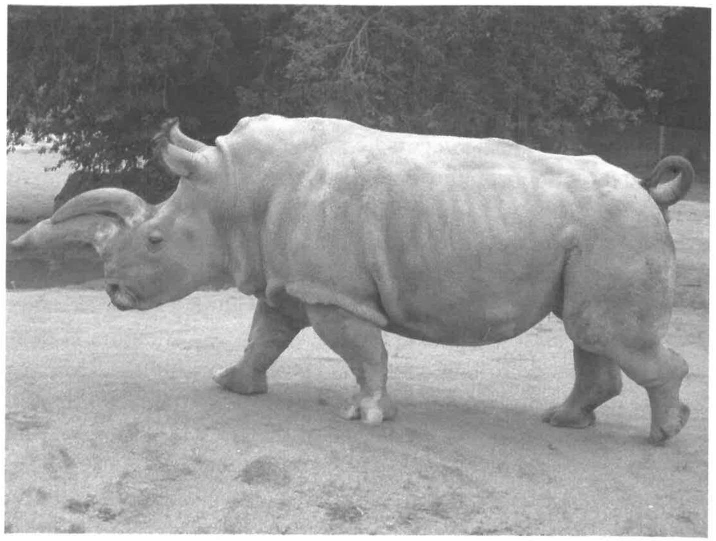

Fig. 14.6 The Nile rhinoceros (*Ceratotherium cottoni*) belongs to a taxon well-documented by zoo staff (especially at Dvůr Králové Zoo) – see references in the unique Rhino Resource Center (http://www.rhinoresourcecenter.com/). (Photo by Jan Robovský)

14.15 Collection of Material

Corpses of animals held in zoos and aquariums have been sources of valuable morphological comparisons since the early histories of zoos. Details of the anatomy of extinct or nearly extinct species are often known, thanks only to the opportunities offered by scientifically managed zoos in the 1800s (Owen 1868; Garrod 1878; Owen 1868; Beddard and Treves 1887). Even the external morphology of a multitude of mammal species is being studied in zoos, an opportunity that was exploited fully by the great zoologist Reginald Innes Pocock in London (Gippoliti et al. 2017). Kitchener (2002) and Gippoliti and Kitchener (2007) comprehensively reviewed the importance of zoo specimens stored in collections (see also Randi 2007). Unfortunately, material of great importance has often been irretrievably lost (e.g. Groves 1982).

Since some (captivity-induced) morphological changes have been described for zoo animals (e.g. O'Regan and Kitchener 2005, references therein, and also de Beaux 1923; Hilzheimer 1937; Kleinschmidt 1950; Angst 1967; Angst and Storch 1967; Rausch 1967; Velzen 1967; Klimov and Orlov 1982; Dathe 1984; Heráň 1988; Volf 1995; Duckler and Binder 1997; Spasskaya and Orlov 1999; Spasskaya 2000; Spasskaya and Kůs 2003; Wisely et al. 2005; Stuermer and Wetzel 2006; Spasskaya 2007; Clauss et al. 2007; Kaiser et al. 2009; Zordan et al. 2012; Edwards et al. 2013; Hartstone-Rose et al. 2014; Saragusty et al. 2014; Taylor et al. 2016; but see also Guay et al. 2011), zoo animals could be, after their demises, the source of

much valuable data to allow a calibration of previous and current forms of husbandry (e.g. Kitchener 2002; Kitchener and MacDonald 2004; Taylor et al. 2016). In the case of captivity-induced morphological changes, it would be worth knowing which factors are responsible, whether they are inherited or obtained via ontogeny (and how often), and whether they are reversible or not, as in domestic animals (e.g. Hemmer 1990; Groves 1989, 1999; Kruska 2005; O'Regan and Kitchener 2005; Dobney and Larson 2006; Saragusty et al. 2014; see also Frankham et al. 1986). We should encourage museums, zoos and aquariums to collaborate more intensively in collecting valuable zoo animals (cf. Kitchener 1997; Gippoliti and Kitchener 2007), which should be recommended by zoo staff based on the significance of particular specimens for the global population, being representatives of some particular breeding line and/or of interest based on origin (wild, wild-born, captive) and on some specific features (known age and husbandry, veterinary procedures, standard or atypical somatic parameters). Zoos should be aware that the quality of any comparison depends strongly on representativeness and sample size; our survey of somatic parameters of the Przewalski horses (Groves and Robovský, in prep.) across worldwide collections showed that only the Scientific Museum of the Biosphere Reserve 'Askania Nova' Reserve and National Museum Praha (via Prague Zoo) have stored the representative skeletal material of this species that allowed us to compare captive lines and generations (Robovský et al. 2014).

New technologies encourage the collection of tissue cultures, gametes, embryos or tissue samples of dead or live animals, under the so-called BioBank or Frozen Zoo initiative, which could be used for many scientific and conservation goals, including artificial insemination and cloning (e.g. Holt et al. 2003; Clarke 2009; Piña-Aguilar et al. 2009). Biomaterial banks could be the source of much interesting information, such as taxonomic identity, purity, genetic diversity, paternity of particular specimens, etc. (e.g. Randi 2007; Witzenberger and Hochkirch 2011; Fienieg and Galbusera 2013). Currently, EAZA tends to concentrate the biomaterial in a network of laboratories (i.e. EAZA Biobank – Hvilsom et al. 2016). Nonetheless, all zoos and aquariums could be encouraged to collect biomaterial at their facilities or in collaboration with natural history museums, since storage is easy and inexpensive (e.g. blood/tissue samples stored in tubes with pure ethanol, hairs stored in paper envelopes, both ideally stored in cold conditions).

14.16 Zoo Design Trends

Considerable funding has been directed in recent decades towards the building of new zoo sections or even whole new zoos (e.g. Salzert 2010). The development of a true 'zoo design' industry does not facilitate a critical review of the successes and failures achieved in this field. The title chosen for the proceedings of one of the most recent meetings on zoo design *Innovation or Replication* (Plowman and Tonge 2005) identifies one of the current issues. Although zoos are often currently distancing themselves from their history, today as in the past, zoos have often copied each other's design styles, often with results that get worse over the years (Hancocks 2001). Incidentally, the relevance of (often huge) budgets devoted, for example, to very costly rock artwork design is probably one of the factors leading to an increasing commercialization of zoo operations, which is a factor that may have negative consequences for their overall conservation mission. Many 'outsiders' of the zoo world are led to think that a good zoo where animals are kept well requires millions of euros. This is simply untrue, as shown by several zoos that achieved considerable importance in the zoo world for their innovative yet low-cost design and conservation mission without having millions to spend (Jersey Zoo, La Torbiera Zoological Park in Piedmont, Due La Fontaine in the Loira, Pilsen Zoo and others). Often, these designs fully exploit the potential of the local landscape and wise use of plantings. One general concern is that some modern-style exhibits pay excessive attention to aesthetic elements, while neglecting important key factors that are functionally relevant to animal welfare, such as space, shade, soil texture, vertical climbing apparatus for arboreal animals, etc. (Gippoliti 2006).

14.17 Conclusion

In conclusion, we hope that zoos will continue to pursue their important conservation missions: to be *fully loaded* arks of *threatened biodiversity*, managed based on biologically sensible principles and in close cooperation with other (including private) individuals and organizations that are sensitive to conservation issues and trustworthy. Our management goals should focus on preserving particular threatened species or evolutionary lineages based on a (meta-) population approach (i.e. breeding should take priority over restrictions and often hypothetical fears associated, e.g. with inbreeding, disease, etc.). Critics want zoos to stop breeding as they regard zoos as prisons. This idea is gaining traction and must be countered by responsible breeding plans throughout the world. The key is improved habitats that encourage animals to thrive. In the end, the public will support zoos if the animals are perceived as being at the centre of zoo mission. Our steps should be taken as well in the spirit of Ulie S. Seal who said, 'Strategies and priorities should maximize options while minimizing regrets for species conservation', and of Gerald Durrell who said, 'In conservation, the motto should always be "never say die"'.

Acknowledgements JR is deeply indebted to many keepers, curators and zoo directors and other colleagues from zoos and universities for sharing their knowledge and experience. Additional thanks go to Luděk Čulík (Dvůr Králové Zoo), Lubomír Melichar (Liberec Zoo), the late Peter Lupták (Bojnice Zoo), Jan Vašák (Jihlava Zoo), Jan Pluháček (Ostrava Zoo), Tomáš Peš (Plzeň Zoo), the late Zdeněk Veselovský (Praha Zoo) and Evžen Kůs (Praha Zoo) for the formation of his deeper insight in the zoo world and to Colin Groves*, Wolfgang Frey, Roland Wirth, Jens-Ove Heckel, Arnd Schreiber, Eulalia Moreno, Noam Werner, Klaus Rudloff, Christian Kern, Luboš and Luděk for their inspiring enthusiasm, conservation missions and always pleasant meetings!

SG wishes to thank those colleagues who have played a long-standing role in the development of his scientific and conservation interests: Pier Lorenzo Florio, Fabio Cassola, Ermanno Bronzini, Jean-Marc Lernould, John Oates, Ken Kawata, the late Nicholas Gould and Lothar Schlawe. Several friends have shared their interest and concern over zoos, including Francesco Rocca, Michele Capasso, Mauro Picone, Antonio Rosati, Andreina D'Alessandro, Corradino Guacci, Harry Salomon and the late Roberto Busacchi.

Our sincere thanks belong to all previous and current zoo staff for their enthusiastic and conservation-oriented missions.

We would like to express our gratitude to Roland Wirth and two referees – Terry Maple and Andrew Bowkett – for their critical review and very valuable suggestions which greatly improved the final version of the manuscript, to Roland Wirth for the beautiful photos and to Anton Baer and Andrew Bowkett for language editing. *We dedicate this chapter to the memory of our highly regarded friend Colin Peter Groves, who passed away on 30 November 2017.

References

Allendorf FW, Luikart G (2007) Conservation and the genetics of populations. Blackwell Publishing, Oxford

Angst R (1967) Beitrag zum Formwandel des Craniums der Ponginen. Z Morph Anthrop 58(2):109–151

Angst R, Storch G (1967) Bemerkungen über den Schädel des Gorilla Abraham aus dem Frankfurter Zoologischen Garten. Nat Mus 97(10):417–420

Ballantynea R, Packera J, Hughesa K et al (2007) Conservation learning in wildlife tourism settings: lessons from research in zoos and aquariums. Environ Educ Res 13(3):367–383

Barongi R, Fisken FA, Parker M, Gusset M (eds) (2015) Committing to conservation: the world zoo and aquarium conservation strategy. WAZA Executive Office, Gland

Bashaw MJ, Bloomsmith MA, Marr MJ et al (2003) To hunt or not to hunt? A feeding enrichment experiment with captive large felids. Zoo Biol 22(2):189–198

Beddard FE, Treves F (1887) On the anatomy of the Sondaic rhinoceros. Trans Zool Soc Lond 12:183–198

Behie AM, Oxenham MF (eds) (2015) Taxonomic tapestries. The threads of evolutionary, behavioural and conservation research. ANU Press, Canberra

Bell CE (ed) (2001) Encyclopedia of the world's zoos. Fitzroy Dearborn, London/Chicago

Belozerskaya M (2006) The Medici giraffe. And other tales of exotic animals and power. Little, Brown and Company, New York/Boston/London

Benirschke K (ed) (1986) Primates. The road to self-sustaining populations. Springer-Verlag, New York/Berlin/Heidelberg/London/Paris/Tokyo

Bertorelle G, Bruford MW, Hauffe HC et al (eds) (2009) Population genetics for animal conservation. Cambridge University Press, Cambridge/New York/Melbourne/Madrid/Cape Town/Singapore/Sao Paulo

Bichet C, Penn DJ, Moodley Y et al (2014) Females tend to prefer genetically similar mates in an island population of house sparrows. BMC Evol Biol 14(1):47

Biega A, Greenberg DA, Mooers AO et al (2017) Global representation of threatened amphibians ex situ is bolstered by non-traditional institutions, but gaps remain. Anim Conserv 20(2):113–119

Blaszkiewitz B (2005) 50 Jahre Tierpark Berlin. Berliner Tierpark-Buch 44:1–348

Bostock SSC (1993) Zoos and animal rights. The ethics of keeping animals. Routledge, London/New York

Bowkett AE (2009) Recent captive-breeding proposals and the return of the Ark Concept to global species conservation. Conserv Biol 23(3):773–776

Bowkett AE (2014) *Ex situ* conservation planning is more complicated than prioritizing the keeping of threatened species in zoos. Anim Conserv 17(2):101–103

Bridges W (1974) Gathering of animals. An unconventional history of the New York Zoological Society. Harper & Row Publishers, New York/Evanston/San Francisco/London

Cameron DW, Groves CP (2004) Bones, stones and molecules. "Out of Africa" and human origins. Elservier Academic Press, Amsterdam/Tokyo
Carroll SC, Fox CW (eds) (2008) Conservation biology. Evolution in action. Oxford University Press, New York
Castelló JR (2016) Bovids of the world. Antelopes, gazelles, cattle, goats, sheep, and relatives. Princeton University Press, Princeton
Ceballos G, Ehrlich PR, Barnosky AD et al (2015) Accelerated modern human–induced species losses: entering the sixth mass extinction. Sci Adv 1(5):e1400253
Ceballos G, Ehrlich PR, Dirzo R (2017) Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. PNAS 114(30):e6089–E6096
Chargé R, Sorci G, Sain Jalme M et al (2014) Does recognized genetic management in supportive breeding prevent genetic changes in life-history traits? Evol Appl 7(5):521–532
Charpentier MJE, Widdig A, Alberts SC (2007) Inbreeding depression in non-human primates: a historical review of methods used and empirical data. Am J Primatol 69(12):1370–1386
Cheeke PR, Dierenfeld ES (2010) Comparative animal nutrition and metabolism. CABI, Oxfordshire
Clarke AG (2009) The Frozen Ark Project: the role of zoos and aquariums in preserving the genetic material of threatened animals. Int Zoo Yearb 43:222–230
Clauss M, Franz-Odendaal TA, Brasch J et al (2007) Tooth wear in captive giraffes (*Giraffa camelopardalis*): Mesowear analysis classifies free-ranging specimens as browsers but captive ones as grazers. J Zoo Wildlife Med 38(3):433–445
Clauss M, Wilkins T, Harley A et al (2009) Diet composition, food intake, body condition, and fecal consistency in captive tapirs (*Tapirus* spp.) in UK collections. Zoo Biol 28(4):279–291
Clauss M, Kohlschein G-M, Peemöller A et al (2013) Short-term digestible energy intake in captive moose (*Alces alces*) on different diets. Zoo Biol 32(5):484–489
Colléony A, Clayton S, Couvet D et al (2017) Human preferences for species conservation: animal charisma trumps endangered status. Biol Conserv 206:263–269
Conde DA (2013) Role of zoological gardens. In: MacLeod, Archibald JD, Levin P (eds) Grzimek's animal life encyclopedia, Gale Research Inc., Detroit, pp 207–215
Conde DA, Flesness N, Colchero F et al (2011) An emerging role of zoos to conserve biodiversity. Science 331(6023):1390–1391
Conde DA, Colchero F, Gusset M et al (2013) Zoos through the lens of the IUCN red list: a global metapopulation approach to support conservation breeding programs. PLoS ONE 8(12):e80311
Conway (2003) The role of zoos in the 21st century. Int Zoo Yearb 38(1):7–13
Cromsigt JPGM, Kerley GIH, Kowalczyk R (2012) The difficulty of using species distribution modelling for the conservation of refugee species – the example of European bison. Divers Distrib 18(12):1253–1257
Csorba G, Krivek G, Sendula T, Homonnay ZG, Hegyeli Z, Sugár S, Farkas J, Stojnić N, Németh A (2015) How scientific researches can change conservation priorities? A review of decade-long research of blind mole-rats (Rodentia: Spalacinae) in the Carpathian Basin. Therya 6(1):103–121
Cuarón AD (2005) Further role of zoos in conservation: monitoring wildlife use and the dilemma of receiving donated and confiscated animals. Zoo Biol 24(2):115–124
Dathe H (1978) The meaning and value of breeds representing pure subspecies in zoological gardens. Zool Garten N F 48(2/3):164–166
Dathe H (1984) Zur Akzeleration bei Zootieren. Zool Garten NF Jena 54(6):369–376
Dawson J, Patel F, Griffiths RA, Young RP (2016) Assessing the global zoo response to the amphibian crisis through 20-year trends in captive collections. Conserv Biol 30(1):82–91
De Beaux O (1923) A proposito di un cranio di *Theropithecus* ♀. Giornale Morfologia Uomo e Primati 4:24–29
Der Sarkissian C, Ermini L, Schubert M et al (2015) Evolutionary genomics and conservation of the endangered Przewalski's horse. Curr Biol 25(19):2577–2583
Dirzo R, You HS, Galetti M et al (2014) Defaunation in the Anthropocene. Science 345(6195):401–406

Dittrich L (2007) Der Import von Wildtieren nach Europa - Einfuhren von der fruhen Neuzeit bis zur Mitte des 20. Jahrhunderts. In: Pechlander H et al (eds) Tiere unterwegs: Historisches und Aktuelles über Tiererwerb und Tiertransporte. Braumuller, Wien, pp 1–64
Dobney K, Larson G (2006) Genetics and animal domestication: new windows on an elusive process. J Zool 269(2):261–271
Driscoll CA, Yamaguchi N, Bar-Gal GK et al (2009) Mitochondrial phylogeography illuminates the origin of the extinct Caspian tiger and its relationship to the Amur tiger. PLoS ONE 4(1):e4125
Duckler GL, Binder WJ (1997) Previously undescribed features in the temporalis and masseteric musculature of several large felids raised in captivity. Zoo Biol 16(2):187–191
Durrell G (1976) The stationary ark. HarperCollins Publishers Ltd, London
Durrell G (1979) Golden bats and pink pigeons. Collins, Fontana
EAZA (2013) EAZA position on intentional breeding for the expression of rare recessive alleles. EAZA, Amsterdam
EAZA (2015) EAZA population manual. http://www.eaza.net/assets/Uploads/Governing-documents/201510-EAZA-Population-Management-Manual-V1.05-Council-approved-20131401.pdf. Accessed 22 Sept 2017
EAZA (2016a) Annual report 2016. EAZA, Amsterdam
EAZA (2016b) TAG reports 2016. EAZA, Amsterdam
Edwards J (1996) London zoo from old photographs 1852–1914. Edward Charles, London
Edwards CTT, Rasmussen GSA, Riordan P et al (2013) Non-adaptive phenotypic evolution of the endangered carnivore *Lycaon pictus*. PLoS ONE 8(9):e73856
Ellegren H, Galtier N (2016) Determinants of genetic diversity. Nat Rev Genet 17(7):422–433
Fernandez EJ, Timberlake W (2008) Mutual benefits of research collaborations between zoos and academic institutions. Zoo Biol 27(6):470–487
Ferriere R, Dieckmann U, Couvet D (eds) (2007) Evolutionary conservation biology. Cambridge University Press, Cambridge
Fienieg ES, Galbusera P (2013) The use and integration of molecular DNA information in conservation breeding programmes: a review. J Zoo Aquarium Res 1(2):44–51
Fischhoff IR, Sundaresan SR, Larkin HM et al (2010) A rare fight in female plains zebra. J Ethol 28:201–205
Frankham R, Hemmer H, Ryder OA et al (1986) Selection in captive populations. Zoo Biol 5:127–138
Frankham R, Ballou JD, Briscoe DA (2002) Introduction to conservation genetics. Cambridge University Press, Cambridge
Frankham R, Ballou JD, Dudash MR et al (2012) Implications of different species concepts for conserving biodiversity. Biol Conserv 152:25–31
Frost W (ed) (2011) Zoos and tourism. Conservation, education, entertainment? Channel View Publications, Bristol/Buffalo/Toronto
Frynta D, Marešová J, Landová E et al (2009) Are animals in zoos rather conspicuous than endangered? In: Columbus AM, Kuznetsov L (eds) Endangered species: new research. Nova Science Publishers, New York, pp 299–341
Frynta D, Lišková S, Bültmann S, Burda H (2010) Being attractive brings advantages: the case of parrot species in captivity. PLoS ONE 5(9):e12568
Garnett ST, Christidis L (2017) Taxonomy anarchy hampers conservation. Nature 546(7656):25–27
Garrod AH (1878) On some points in the visceral anatomy of the rhinoceros of the Sunderbunds (*Rhinoceros sondaicus*). Proc Zool Soc Lond 1877:707–711
Gippoliti S (2004) The role of captive breeding in the conservation of the European mammal diversity. Hystrix Ital J Mamm 15(1):35–53
Gippoliti S (2006) Applied primatology in zoos: history and prospects in the field of wildlife conservation, public awareness and animal welfare. Primate Rep 73:57–71
Gippoliti S (2010) La giungla di Villa Borghese. I cento anni del Giardino Zoologico di Roma, Belvedere/Latina

Gippoliti S (2011) Zoos and conservation in the XXI century: overlooked meeting points between ecology and social sciences? Museologia Scientifica nuova serie 5(1–2):168–176
Gippoliti S (2012) Ex situ conservation programmes in European zoological gardens: can we afford to lose them? Biodivers Conserv 21(6):1359–1364
Gippoliti S (2014) Bioethics in the zoo from an Italian perspective. Museologia Scientifica nuova serie 8:9–12
Gippoliti S, Amori G (2004) Mediterranean island mammals: are they a priority for biodiversity conservation? Biogeographia 25:135–144
Gippoliti S, Amori G (2007) Beyond threatened species and reintroduction: establishing priorities for conservation and breeding programmes for European rodents in zoos. Int Zoo Yearb 41:194–202
Gippoliti S, Groves CP (2020) Cryptic problematic species and troublesome taxonomists: a tale of the Apennine bear and the Nile white rhinoceros. In Angelici F.A., Rossi L. (eds) Problematic Wildlife II) – new conservation and management challenge in the human-wildlife interactions. Springer Chasm.
Gippoliti S, Kitchener A (2007) The Italian zoological gardens and their role in mammal systematic studies, conservation biology and museum collections. Hystrix Ital J Mamm 18(2):173–184
Gippoliti S, Di Francesco T, Robovský J (2017) On the shoulders of giants: Reginald Innes Pocock and integrative mammal research in museums and zoos. Mammalia 82:529–539
Gippoliti S, Cotterill FPD, Zinner D, Groves CP (2018) Impacts of taxonomic inertia for the conservation of African ungulate diversity: an overview. Biol Rev 93:115–130
Glikson AY, Groves C (2016) Climate, fire and human evolution. The deep time dimensions of the Anthropocene. Springer, Cham/Heidelberg/New York/Dordrecht/London
Goodall J, Maynard T, Hudson G (2010) Hope for animals and their world (how endangered species are being rescued from the brink). Icon Books, New York/London
Grigson C (2016) Menagerie. The history of exotic animals in England 1100–1837. Oxford University Press, Oxford
Groves C (1982) The skulls of Asian rhinoceroses: wild and captive. Zoo Biol 1(3):251–261
Groves CP (1989) Feral mammals of the Mediterranean islands: documents of early domestication. In: Clutton-Brock J (ed) The walking larder. Unwin-Hyman, London, pp 46–58
Groves CP (1995) Microtaxonomy and its implications for captive breeding. In: Gansloßer U (ed) Research and captive propagation. Filander Verlag, Fürth, pp 24–28
Groves C (1999) The advantages and disadvantages of being domesticated. Perspect Human Biol 4(1):1–12
Groves CP (2009) The A-line Przewalski horse. News Biosphere Reserve "Askania Nova" 11:97–103
Groves CP, Grubb P (2011) Ungulate taxonomy. The Johns Hopkins University Press, Baltimore
Groves C, Robovský J (2011) African rhinos and elephants: biodiversity and its preservation. Pachyderm 50:69–71
Groves CP, Cotterill FPD, Gippoliti S et al (2017) Species definitions and conservation: a review and case studies from African mammals. Conserv Genet 18:1247–1256
Grubb P (2005) Order Artiodactyla. In: Wilson DE, Reeder DAM (eds) Mammal species of the world. The Johns Hopkins University Press, Baltimore, pp 637–722
Guay PJ, Parrott M, Selwood L (2011) Captive breeding does not alter brain volume in a marsupial over a few generations. Zoo Biol 30:1–5
Gusset M, Dick G (2011a) The global reach of zoos and aquariums in visitor numbers and conservation expenditures. Zoo Biol 30(5):566–569
Gusset M, Dick G (2011b) Towards sustainable population management. WAZA Mag 12:1–44
Gusset M, Dick G (2013a) Fighting extinction. WAZA Mag 13:1–41
Gusset M, Dick G (2013b) Towards integrated species conservation. WAZA Mag 14:1–45
Gusset M, Lowry R (2014) Towards effective enviromental education. WAZA Mag 15:1–48
Gusset M, Dick G (2015) Towards positive animal welfare. WAZA Mag 16:1–44
Guthrie RD (2005) The nature of paleolithic art. The University of Chicago Press, Chicago

Hancocks D (2001) A different nature. The paradoxical world of zoos and their uncertain future. California University Press, Berkeley
Hartstone-Rose A, Selvey H, Villari JR et al (2014) The three-dimensional morphological effects of captivity. PLoS ONE 9(11):e113437
Hatt JM, Müller DWH, Bingaman L et al (2011). Life expectancy in zoo mammals: what a zoo veterinarian should know. AAZV conference, Kansas City, Missouri, USA, October 2011, p 181–183
Hazevoet CJ (1996) Conservation and species lists: taxonomic neglect promotes the extinction of endemic birds, as exemplified by taxa from eastern Atlantic islands. Bird Conserv Int 6:181–196
Heckel J-O, Holland J, Richardson DM, Wirth R (2013) Has the Ark gone off course? WAZA News 4:4–7
Hediger H (1942) Wildtiere in Gefangenschaft. Benno Schwabe & Co., Basel
Hediger H (1969) Man and animal in the zoo. Routledge & Kegan Paul, London
Hedrick PW, Kalinowski ST (2000) Inbreeding depression in conservation biology. Annu Rev Ecol Syst 31:139–162
Hemmer H (1990) Domestication: the decline of environmental appreciation. Cambridge University Press, New York
Heráň I (1988) Comments on anomalies in the frame of *foramen occipitale magnum* in the lion, *Panthera leo* (Linné, 1758). Gazella 15:97–101
Hill SP, Broom DM (2009) Measuring zoo animal welfare: theory and practice. Zoo Biol 28(6):531–544
Hilzheimer M (1937) Domestikationsmerkmale am Schädel des Gorilla Bobby. Z Säugetierkd 12:89–96
Hirschfeld E, Swash A, Still R (2013) The world's rarest birds. Princeton University Press, Princeton
Hoban S, Arntzen JW, Bertorelle G et al (2013) Conservation genetic resources for effective species survival (ConGRESS): bridging the divide between conservation research and practice. J Nat Conserv 21(6):433–437
Holand O, Askim KR, Roed KH et al (2007) No evidence of inbreeding avoidance in a polygynous ungulate: the reindeer (*Rangifer tarandus*). Biol Lett 3(1):36–39
Holt WV, Pickard AR, Rodger JC, Wildt DE (2003) Reproductive science and integrated conservation. Cambridge University Press, Cambridge/New York/Melbourne/Madrid/Cape Town/Singapore/Sao Paulo
Hoy JM, Murray PJ, Tribe A (2010) Thirty years later: enrichment practices for captive mammals. Zoo Biol 29(3):303–316
Hutchins M (2003) Zoo and aquarium animal management and conservation: current trends and future challenges. Int Zoo Yearb 38(1):14–28
Hutchins M, Conway WG (1995) Beyond Noah's Ark: the evolving role of modern zoological parks and aquariums in field conservation. Int Zoo Yearb 34(1):117–130
Hvilsom C, Pereboom Z, Schad K (2016) Banking on our future. Zooquaria 94:34
Ibánez B, Moreno E, Barbosa A (2011) No inbreeding effects on body size in two captive endangered gazelles. Mamm Biol 76(6):748–754
Ibánez B, Moreno E, Barbosa A (2013) Parity, but not inbreeding, affects juvenile mortality in two captive endangered gazelles. Anim Conserv 16(1):108–117
Isaac NJB, Turvey ST, Collen B et al (2007) Mammals on the EDGE: conservation priorities based on threat and phylogeny. PLoS ONE 2(3):e296
IUCN SSC Antelope Specialist Group (2015). IUCN SSC Antelope Specialist Group position statement on the intentional genetic manipulation of antelopes. Ver. 1.0
Jonas CS, Timbrell LL, Young F et al (2018) Management of captive animals: global evidence for the effect of selected interventions. University of Cambridge, Cambridge
Junge RE, Williams CV, Campbell J (2009) Nutrition and behavior of lemurs. Vet Clin North Am Exot Anim Pract 12(2):339–348

Kaiser TM, Brasch J, Castell JC et al (2009) Tooth wear in captive wild ruminant species differs from that of free-ranging conspecifics. Mamm Biol 74:425–437
Kalinowski ST, Hedrick PW, Miller PS (1999) No inbreeding depression observed in Mexican and Red wolf captive breeding programs. Conserv Biol 13(6):1371–1377
Kellert SR, Wilson EO (eds) (1993) The biophilia hypothesis. Sherawater Book, Shearwater
Kerley GIH, Kowalczyk R, Cromsigt JPGM (2012) Conservation implications of the refugee species concept and the European bison: king of the forest or refugee in a marginal habitat? Ecography 35(6):519–529
Keulartz J (2015) Captivity for conservation? Zoos at a crossroads. J Agric Environ Ethics 28(2):335–351
Kisling VN Jr (ed) (2000) Zoo and aquarium history. Ancient animal collections to zoological gardens. CRC Press, Boca Raton/London/New York/Washington D.C
Kitchener AC (1997) The role of museums and zoos in conservation biology. Int Zoo Yearb 35(1):325–336
Kitchener AC (2002) Using mammal collections. Biol Curator 22:24–27
Kitchener A, MacDonald A (2004, Sept) The longevity legacy. The problem of old mammals in zoos. In: Hiddinga B (ed) EAZA conference, Kolmarden, pp 132–137
Kleiman DG, Thompson KV, Baer CK (eds) (2010) Wild mammals in captivity. University of Chicago Press, Chicago/London
Kleinschmidt A (1950) Anatomische Beobachtungen an Fetthaube, Schädel und Wirbelsäule des Gorilla "Bobby". Zool Anz 145:380–405
Klimov VV, Orlov VN (1982) Sovremennoe sostoânie i problemy sochraneniâ lošadi Prževalskogo (*Equus przewalskii*) (present status and problems of conservation of *Equus przewalskii*). Zoologičeskij Žurnal 61(12):1862–1869
Klös H-G, Frädrich H, Klös U (1994) Dier Arche Noah an der Spree. 150 Jahre Zoologischer Garte Berlin. Eine tiergärtnerische Kulturgeschichte von 1844 bis 1994. FAB Verlag, Berlin
Koeninger Ryan K, Lacy RC, Margulis SW (2003) Impacts of inbreeding on components of reproductive success. In: Holt WV, Pickard AR, Rodger JC, Wildt DE (eds) Reproductive science and integrated conservation. Cambridge University Press, Cambridge, pp 82–96
Kowalski K (1967) The Pleistocene extinction of mammals in Europe. In: Martin PS, Wright HE (eds) Pleistocene extinctions. The search for a cause. Yale University Press, New Haven/London, pp 349–364
Kruska DC (2005) On the evolutionary significance of encephalization in some Eutherian mammals: effects of adaptive radiation, domestication, and feralization. Brain Behav Evol 65(2):73–108
Lacy RC (1995) Clarification of genetic terms and their use in the management of captive populations. Zoo Biol 14(6):565–578
Lacy R (2010) Re-thinking ex situ vs. in situ species conservation. Proceedings of 65th Annual WAZA Conference:25–28
Lacy RC (2013) Achieving true sustainability of zoo populations. Zoo Biol 32(1):19–26
Law G, Kitchener A (2002) Simple enrichment techniques for bears, bats and elephants – untried and untested. Int Zoo News 49(1):4–12
Leus K (2018) Ex-situ conservation of wild pigs and peccaries: roles, status, management successes and challenges. In: Melletti M, Meijaard E (eds) Ecology, conservation and management of wild pigs and peccaries. Cambridge University Press, New York, pp 420–436
Linnell JDC, Trouwborst A, Boitani L et al (2016) Border security fencing and wildlife: the end of the transboundary paradigm in Eurasia? PLoS Biol 14(6):e1002483
Loh T-L, Larson ER, David SR et al (2018) Quantifying the contribution of zoos and aquariums to peer-reviewed scientific research. Facets 3:287–299
Luoma JR (1988) A crowded ark, the role of zoos in wildlife conservation. Houghton Mifflin Co., Boston
Lupták P (2015) Zoo Bojnice: Slovenská archa biodiverzity. Zoo Bojnice, Bojnice

Maas PHJ (2013) Last stand in captivity or cultivation: successes and failures. In: TSEW (2017). The sixth extinction. Available via http://www.petermaas.nl/extinct. Accessed 22 Sept 2017
Maas PHJ (2017) Globally extinct mammals. In: TSEW (2017). The sixth extinction. Available via http://www.petermaas.nl/extinct. Accessed 22 Sept 2017
Macdonald DW, Service K (eds) (2007) Key topics in conservation biology. Blackwell Publishing, Malden/Oxford/Victoria
Mace GM, Balmford A, Leader-Williams N et al (2007) Measuring conservation success: assessing zoos' contribution. In: Zimmermann A, Hatchwell M, Dickie LA, West C (eds) Zoos in the 21st century: catalysts for conservation? Cambridge University Press, Cambridge, pp 322–342
Majolo B, Schino G, Troisi A (2005) Towards thirty years of ethological research on the Japanese Macaque (*Macaca fuscata*) colony of the Rome zoo. J Anthropol Sci 83:43–60
Mallinson JJC (2003) A sustainable future for zoos and their role in wildlife conservation. Hum Dimens Wildl 8(1):59–63
Maple TL, Perdue BM (2013) Zoo animal welfare. Springer, Heidelberg/New York/Dordrecht/London
Martin TE, Lurbiecki H, Joy JB et al (2014) Mammal and bird species held in zoos are less endemic and less threatened than their close relatives not held in zoos. Anim Conserv 17(2):89–96
Mason GJ (2010) Species differences in responses to captivity: stress, welfare and the comparative method. Trends Ecol Evol 25(12):713–721
Mason G, Rushen J (eds) (2006) Stereotypic animal behaviour. Fundamentals and applications to welfare, 2nd edn. CABI, Wallingford/Cambridge
Massaro M, Sainudiin R, Merton D et al (2013) Human-assisted spread of a maladaptive behavior in a critically endangered bird. PLoS ONE 8(12):e79066
Mathews F, Orros M, McLaren G et al (2005) Keeping fit on the ark: assessing the suitability of captive-bred animals for release. Biol Conserv 121(4):569–577
Matschei C (2017) Seltene Tiere im Zoo: Säugetiere. Schüling Verlag, Münster
Maynard L (2017) Media framing of zoos and aquaria: from conservation to animal rights, environmental communication. J Environ Comm. 12(2):177–190
McCallum H (2008) Tasmanian devil facial tumour disease: lessons for conservation biology. Trends Ecol Evol 23(11):631–637
McGowan PJK, Traylor-Holzer K, Leus K (2017) IUCN guidelines for determining when and how ex situ management should be used in species conservation. Conserv Lett 10(3):361–366
McPhee ME (2002) Intact carcasses as enrichment for large felids: effects on on- and off-exhibit. Zoo Biol 21(1):37–47
Melfi (2009) There are big gaps in our knowledge, and thus approach, to zoo animal welfare: a case for evidence-based zoo animal management. Zoo Biol 28(6):574–588
Mellor DJ, Hunt S, Gusset M (eds) (2015) Caring for wildlife: the world zoo and aquarium animal welfare strategy. WAZA Executive Office, Gland
Menzel CR, Beck BB (2000) Homing and detour behavior in Golden lion Tamarin social groups. In: Boinski S, Garber PA (eds) On the move: how and why animals travel in groups. Chicago University Press, Chicago, pp 299–326
Miller B, Conway W, Reading RP et al (2004) Evaluating the conservation mission of zoos, aquariums, botanical gardens, and natural history museums. Conserv Biol 18(1):1–8
Mills LS (2007) Conservation of wildlife populations. Demography, genetics, and management. Blackwell Publishing, Malden/Oxford/Victoria
Moodley Y, Russo IRM, Dalton DL et al (2017) Extinctions, genetic erosion and conservation options for the black rhinoceros (*Diceros bicornis*). Sci Rep 7:41417
Moreno E, Pérez-González J, Carranza J, Moya-Larano J (2015) Better fitness in captive Cuvier's gazelle despite inbreeding increase: evidence of purging? PLoS ONE 10(12):e0145111
Moss A, Esson M (2013) The educational claims of zoos: where do we go from here? Zoo Biol 32(1):13–18
Moss A, Jensen E, Gusset M (2014) A global evaluation of biodiversity literacy in zoo and aquarium visitors. WAZA executive office, Gland

Myers N, Mittermeier RA, Mittermeier CG et al (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858
Norton BG, Hutchins M, Stevens EF, Maple TL (eds) (1995) Ethics on the ark: zoos, animal welfare, and wildlife conservation. Smithsonian Institution Press, Washington DC
O'Regan HJ, Kitchener AC (2005) The effects of captivity on the morphology of captive, domesticated and feral mammals. Mammal Rev 35(3–4):215–230
Olive A, Jansen K (2017) The role of accredited zoos in the recovery process for species at risk in Canada. Can Geogr 61(3):319–333
Olney PJS, Mace GM, Feistner ATC (1994) Creative conservation. Interactive management of wild and captive animals. Springer Science+Business Media, Dordrecht
Olson LE, Blumstein DT, Pollinger JR, Wayne RK (2012) No evidence of inbreeding avoidance despite demonstrated survival costs in a polygynous rodent. Mol Ecol 21(3):562–571
Owen R (1868) Comparative anatomy and physiology of vertebrates 3. Mammals. Longmans Green, London
Peel CVA (1903) The zoological gardens of Europe. Their history and chief features. Bloomsbury, London
Penfold LM, Powell D, Traylor-Holzer K et al (2014) "Use it or lose it": characterization, implications, and mitigation of female infertility in captive wildlife. Zoo Biol 33(1):20–28
Peš T, Vogeltanz J (2010) The garden full of treasures. List of species in zoological and botanical gardens of the town Pilsen. Zoologická a botanická zahrada města Plzně and Městské knihy s. r. o, Plzeň
Pina-Aguilar RE, Lopez-Saucedo J, Sheffield R et al (2009) Revival of extinct species using nuclear transfer: hope for the mammoth, true for the Pyrenean ibex, but is it time for "conservation cloning"? Cloning Stem Cells 11(3):341–346
Pinto PV, Beja P, Ferrand N et al (2016) Hybridization following population collapse in a critically endangered antelope. Sci Rep 6:18788
Plowman AB, Tonge SJ (eds) (2005) Innovation or replication? Proceedings of the 6th international symposium on zoo design. Whitley Wildlife Conservation Trust, Paignton
Powell DM, Ardaiolo M (2016) Survey of U.S. zoo and aquarium animal care staff attitudes regarding humane euthanasia for population management. Zoo Biol 35:187–200
Powlesland RG, Merton DV, Cockrem JF (2006) A parrot apart: the natural history of the kakapo (*Strigops habroptilus*), and the context of its conservation management. Notornis 53(1):3–26
Pritchard DJ, Fa JE, Sara Oldfield S et al (2011) Bring the captive closer to the wild: redefining the role of *ex situ* conservation. Oryx 46(1):18–23
Przybylska L (2014) EEP Visayan warty pig studbook *Sus cebifrons negrinus*. Poznań Zoo, Poznań
Rabb GB (1994) The changing roles of zoological parks in conserving biological diversity. Am Zool 34(1):159–164
Rabb GB (2004) The evolution of zoos from menageries to centers of conservation and caring. Curator (Mus J) 47(3):237–246
Randi E (2007) Museum theriological collections for the study of genetic diversity. Hystrix Ital J Mamm 18(2):157–171
Rausch RL (1967) Comparative development of the canine teeth in wild and captive black bears, *Ursus americanus* Pallas. Can J Zool 45(4):465–471
Reade LS, Waran NIL (1996) The modem zoo: how do people perceive zoo animals? Appl Anim Behav Sci 47(1–2):109–118
Reading RP, Miller B, Shepherdson D (2013) The value of enrichment to reintroduction success. Zoo Biol 32(3):332–341
Redford KH, Jensen DB, Breheny JJ (2013) The long overdue death of the Ex situ and In situ dichotomy in species conservation. WAZA Mag 14:19–22
Rees PA (2015) Studying captive animals. A workbook of methods in behavior, welfare and ecology. Wiley, Chichester
Robovský J (2012) Muss die A-Linie des Przewalski-Pferdes Teil einer wissenschaftlich fundierten Erhaltungsstrategie der Art werden? ZGAP Mitt 28(2):23–28

Robovský J, Novotná A, Čulík L et al (2014) Revised catalogue of wild equids in the collection of the National Museum, Prague, and several other collections in the Czech Republic (Perissodactyla: Equidae). Lynx 45:97–138
Roe K, McConney A, Mansfield CF (2014) The role of zoos in modern society – a comparison of zoos' reported priorities and what visitors believe they should be. Anthrozoös 27(4):529–541
Rothfels N (2002) Savages and beasts. The birth of modern zoo. The Johns Hopkins University Press, Baltimore/London
Ryder OA, Byrd ML (1984) One medicine. A tribute to Kurt Benirschke from his students and colleagues. Springer-Verlag, Berlin/Heidelberg/New York/Tokyo
Ryder OA, Feistner ATC (1995) Research in zoos: a growth area in conservation. Biodivers Conserv 4(6):671–677
Salzert W (2010) Was macht Tiergarten attraktiv? Ein kleines Einmaleins des Zoogehegeplanung. Schüling Verlag, Münster
Saragusty J, Shavit-Meyrav A, Yamaguchi N et al (2014) Comparative skull analysis suggests species-specific captivity-related malformation in lions (*Panthera leo*). PLoS ONE 9:e94527
Sartore J (2017) National Geographic the photo ark: one man's quest to document the world's animals. National Geographic
Schlawe L (1969) Die für die Zeit vom 1. August 1844 bis 31. Mai 1888 nachweisbaren Thiere im zoologischen Garten zu Berlin - Amphibia - Reptilia - Aves - Mammalia. Selbstverlag, Berlin
Schonewald-Cox CM, Chambers SM, MacBryde B, Thomas WL (1983) Genetics and conservation. A reference for managing wild animals and plant populations. The Benjamin/Cummings Publishing Company Inc., London/Amsterdam/Don Mills/Ontario/Sydney/Toronto
Schook MW, Powell DM, Zimmermann W (2016) Wild equid captive breeding and management. In: Ransom JI, Kaczensky P (eds) Wild equids. Ecology, management, and conservation. The Johns Hopkins University Press, Baltimore, pp 149–163
Schreiber A, Moreno E, Groves C, Robovský J (2018) Systematics and the management units of the dama gazelle *Nanger dama*. Gnusletter 35(1):8–12
Schwartz KR, Parsons ECM, Rockwood L, Wood TC (2017) Integrating *in-situ* and *ex-situ* data management processes for biodiversity conservation. Front Ecol Evol 5(120):1–7
Seidensticker J, Forthman DL (1998) Evolution, ecology, and enrichment. Basic considerations for wild animals in zoos. In: Mellen JD, Hutchins M (eds) Second nature. Environmental enrichment for captive animals. Smithsonian Institution Press, Washington/London, pp 15–29
Senn H, Banfield L, Wacher T et al (2014) Splitting or lumping? A conservation dilemma exemplified by the critically endangered Dama Gazelle (*Nanger dama*). PLoS ONE 9(6):e98693
Shyne A (2006) Meta-analytic review of the effects of enrichment on stereotypic behavior in zoo mammals. Zoo Biol 25(4):317–337
Skibiel AL, Trevino HS, Naugher K (2007) Comparison of several types of enrichment for captive felids. Zoo Biol 26(5):371–381
Skibins JC, Dunstan E, Pahlow K (2017) Exploring the influence of charismatic characteristics on flagship outcomes in zoo visitors. Hum Dimens Wildl 22(2):157–171
Smith RH (1979) On selection for inbreeding in polygynous animals. Heredity 43(2):205–211
Snyder NFR (1995) A much improved conservation role for zoos. Zoo Biol 14(1):36–38
Solski L, Strehlow H (2015) 150 Jahre ZOO Breslau/150 lat ZOO Wrocław. Zoo Wrocław, Wrocław
Spasskaya N (2000) Revision of the osteological material of the Przewalski horses (*Equus przewalskii* Poljakov, 1881) in museums in Czech Republic. Gazella 27:71–96
Spasskaya N (2007) Investigation of the kiang (*Equus kiang*, Equidae) skull from Ladakh, India. Erforsch biol Ress Mongolei (Halle/Saale) 10:227–230
Spasskaya N, Kůs E (2003) The exterior´ peculiarities of Przewalski horse. Gazella 30:79–99
Spasskaya N, Orlov VN (1999) Patterns of cranial variability in Przewalski's horses of different lines of breeding. Vestn Zool Suppl 11:196–201
Stepherdson DJ, Mellen JD, Hutchins M (eds) (1998) Second nature. Environmental enrichment for captive animals. Smithsonian Institution Press, Washington/London

Stuermer IW, Wetzel W (2006) Early experience and domestication affect auditory discrimination learning, open field behaviour and brain size in wild Mongolian gerbils and domesticated laboratory gerbils (*Meriones unguiculatus* forma *domestica*). Behav Brain Res 173(1):11–21
Taberlet P, Valentini A, Rezaei HR et al (2008) Are cattle, sheep, and goats endangered species? Mol Ecol 17(1):275–284
Taylor LA, Müller DWH, Schwitzer C et al (2016) Comparative analyses of tooth wear in free-ranging and captive wild equids. Equine Vet J 48(2):240–245
Tidiere M, Gaillard J-M, Berger V et al (2016) Comparative analyses of longevity and senescence reveal variable survival benefits of living in zoos across mammals. Sci Rep 6:36361
Tokarska M, Pertoldi C, Kowalczyk R et al (2011) Genetic status of the European bison *Bison bonasus* after extinction in the wild and subsequent recovery. Mammal Rev 41(2):151–162
Tribe A, Booth R (2003) Assessing the role of zoos in wildlife conservation. Hum Dimens Wildl 8(1):65–74
Van Bemmel ACV (1971) Keeping and breeding of pure subspecies in zoos and National Parks. Zool Garten N F 40(3):160–162
Van Velzen SKT (1967) Does captivity influence the morphogenesis of the animal skull and teeth? Ned Tijdschr Tandheelkd 74(4):17–42
Vargas A, Breitenmoser C, Breitenmoser U (2009) Iberian Lynx Ex situ conservation: an interdisciplinary approach. Fundación Biodiversidad and IUCN Cat Specialist Group, Madrid
Volf J (1995) Variabilität, Plastizität und Selektion der Przewalskipferde, *Equus przewalskii* Poljakov, 1881. Zool Gart 65(5):284–292
WAZA (2005) Building a future for wildlife - the world zoo and aquarium conservation strategy. World Zoo and Aquarium Association, Bern
Weeks AR, Sgro CM, Young AG et al (2011) Assessing the benefits and risks of translocations in changing environments: a genetic perspective. Evol Appl 4(6):709–725
Weigl R (2005) Longevity of mammals in captivity: from the living collections of the world. A list of mammalian longevity in captivity. Kleine Senckenberg-Reihe 48:1–215
Wickins-Dražilová D (2006) Zoo animal welfare. J Agric Environ Ethics 19:27–36
Wilson EO (1987) Biophilia. Harvard University Press, Cambridge, MA, London
Wirth R (2007) 25 Jahre ZGAP. Eine ZGAP-Geburtstagsbetrachtung. ZGAP Mitt 23(1):1–8
Wirth R (2011) Biobenzin, Problemwölfe und Tigerbabys in Zoos – wie mit falschen Arumenten der Niedergang der biologischen Vielfalt beschleunigt wird. ZGAP Mitt 1:2–6
Wirth R (2015) Sind Zoos und Erhaltungszucht noch im Einklang? ZGAP Mitt 31(1):2–5
Wisely SM, Santymire RM, Livieri TM et al (2005) Environment influences morphology and development for *in situ* and *ex situ* populations of the black-footed ferret (*Mustela nigripes*). Anim Conserv 8(3):321–328
Witzenberger KA, Hochkirch A (2011) Ex situ conservation genetics: a review of molecular studies on the genetic consequences of captive breeding programmes for endangered animal species. Biodivers Conserv 20:1843–1861
Wood CC, Gross MR (2008) Elemental conservation units: communicating extinction risk without dictating targets for protection. Conserv Biol 22(1):36–47
Yasynetska NI, Zharkikh TL (2008) Hellabrunn symposiums on the a-line Przewalski horse. News Biosphere Reserve 'Askania Nova' 10:208–216
Young RJ (2003) Environmental enrichment for captive animals. Blackwell Science Ltd, Oxford
Young AG, Clarke GM (eds) (2000) Genetics, demography and viability of fragmented populations. Cambridge University Press, Cambridge
Zimmermann M (2017) EAZA conservation database report. Available via www.eaza.net. Accessed 22 Sept 2017
Zordan M, Deem SL, Sanchez CR (2012) Focal palatine erosion in captive and free-living cheetahs (*Acinonyx jubatus*) and other felid species. Zoo Biol 31(2):181–188

Chapter 15
Problematic Animals in the Zoo: The Issue of Charismatic Megafauna

Geoff Hosey, Vicky Melfi, and Samantha J. Ward

15.1 Introduction

Animals in zoos can be regarded as problematic for a number of reasons. Firstly, they indicate something to us about deep-seated problems in our relationship with the natural world, about human population growth and encroachment on natural habitats and about hunting and poaching and anthropogenic climate change. So for animals of some species which are threatened in the wild, being in a zoo might be their best prospect for survival; indeed for some, which are already extinct in the wild such as the scimitar-horned oryx *(Oryx dammah)*, Père David's deer *(Elaphurus davidianus)* and the Wyoming toad *(Anaxyrus baxteri)*, this is their only prospect of survival. This might make them problematic animals in another sense; how do we ensure the most successful and appropriate management and best welfare for these species, given that they have not evolved to live in a captive environment and in some cases we are deficient in information about their biology in the wild? Addressing these husbandry issues can be done through systematic research and an evidence-based approach (Melfi 2009), but much of this effort is directed at a small selection of large-bodied popular animals, the so-called charismatic megafauna, to the neglect of smaller, less popularly appealing species, thus rendering some species 'problematic' for this reason. Finally, for some people there are no reasons which can justify keeping any animals in zoos, or at least no

G. Hosey (✉)
University of Bolton, Bolton, UK
e-mail: gh2@bolton.ac.uk

V. Melfi
Hartpury University, Gloucester, UK

S. J. Ward
School of Animal Rural and Environmental Sciences, Nottingham Trent University, Nottingham, UK

F. M. Angelici, L. Rossi (eds.), *Problematic Wildlife II*,
https://doi.org/10.1007/978-3-030-42335-3_15