A survey of husbandry practices for Bovidae in zoos: the importance of parasite management for reintroduction programmes

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ABSTRACT

Animals from zoological institutions may be used for reintroductions. These individuals are considered healthy but they are not necessarily free of parasites, despite of the minimum husbandry standards required of zoological institutions as described in the European Association of Zoos and Aquaria (EAZA) guidelines. In this sense, parasitism has been identified as the cause of failure, or has added difficulties, in some reintroduction programmes. Here we attempt to summarize the risk of parasitism to animals originating from zoological institutions by analysing a questionnaire about parasite prevalence, sampling methods, treatment and control in three ungulates in European zoos. Completed questionnaires were received from 38 institutions (58.5% response rate). Most of the responding institutions (97%) detected the eggs of endoparasites in faeces but only one reported ectoparasites. Most institutions followed a similar preventive schedule, with ivermectin as the preferred prophylactic treatment for parasites, commonly administered in food every 6 months. The frequent use of concentrating flotation techniques as the sole method to evaluate the presence of parasite eggs in faecal samples is not recommended because it fails to detect trematode and lung-nematode infections, so it would be better to use flotation techniques together with sedimentation procedures or serological and molecular tests. Results suggest that parasite control in zoological institutions can be complicated, indicating the need to implement a specific management schedule for institutions involved in reintroduction projects.

Key-words: Cuvier's gazelle, endangered species; Mohor gazelle; parasites; reintroduction projects; scimitar-horned oryx; zoological institutions.

INTRODUCTION

The re-establishment of threatened species through reintroduction programmes using individuals bred in zoological institutions has been a well-established conservation tool for many years. Zoos and aquaria can potentially play an important role in the conservation of biodiversity through field projects and coordinated breeding programmes[1-6]. European *Ex-situ* Programmes (EEPs) intensively manage animal populations in European Association of Zoos and Aquaria (EAZA) zoological institutions and are often linked to wildlife conservation [7-9]. In spite of the considerable effort and resources invested in such programmes and

reintroduction projects, many attempts to re-establish sustainable populations have failed[10-12].The reasons for failure are varied but diseases, some of them parasitic, have played a significant role in the lack of success for a number of reintroduction attempts [e.g. fish reintroductions (Razorback sucker *Xyrauchen texanus* and Colorado pikeminnow *Ptychocheilus lucius*)[13]; reintroduction of Elk *Cervus elaphus*[14]; the Green and golden bell frog *Litoria aurea*[15]; Black rhinoceros *Diceros bicornis* and White rhinoceros *Ceratotherium simum*[16]; Wolves *Canis lupus*[17]; for a whole review[18]].

Parasitism poses a potential problem for reintroduction projects by three main routes:

1. Animals born and raised in zoological institutions encounter novel parasites on release into their ‘indigenous’ new habitats. For example, captive-bred Eastern bongo *Tragelaphus eurycerus isaaci* translocated from North America to Mount Kenya in 2004 were infected by *Theileria* spp, resulting in the death of 28% of the repatriated animals[19,20].
2. Reintroduced animals risk introducing new parasites to resident populations, resulting in greater ecological and socio-economic implications. In this sense, the reintroduction of wolves in Yellowstone has undergone the evidence of new parasites affecting wild individuals[17].
3. Stress-induced infection during translocation/reintroduction, associated with handling animals, has also been hypothesized as a reason for reintroduction failures[21,22]. Healthy animals with a subclinical parasite burden may develop clinical signs as a result of stress associated with translocation and release[23], causing poor health (and low reproduction) or death. The reintroduced population may then fail to establish.

The prevalence of several endo- and ectoparasites has previously been studied in animals housed in zoological institutions, suggesting that parasites are widespread and prevalent in captive populations. For instance, eggs of *Nematodirus* spp., *Capillaria* spp. and *Trichuris* spp. have been recovered from ruminant faeces[24], strongyle-type eggs and ascarids from carnivore faeces[25] and eggs of ascarids and strongyles from bird faeces[26]. Similarly, multiple authors have detected the presence of ectoparasites and blood parasites in mammals (flies, lice, ticks or *Babesia* spp., for example)[27,28]) and birds (e.g: mites, lice, and *Plasmodium* spp. or *Haemoproteus* spp.)[26,29] held in zoological institutions. Animal species in zoological institutions should be considered potential reservoirs for parasites, although parasite-host equilibrium is a natural and essential biotic factor[30-33]. In this sense, measures need to be taken to ensure that parasite egg shedding does not occur during reintroductions[23,34] to avoid deleterious and unpredictable consequences

on extant wild populations[17,35]. In this regard, screening animals for parasites is a standard procedure prior to any reintroduction[36].

The Scimitar-horned oryx *Oryx dammah* (Extinct in the Wild), the Mohor gazelle *Nanger dama mhor* (Critically Endangered) and the Cuvier's gazelle *Gazella cuvieri* (Vulnerable) are threatened ungulates listed in the International Union for Conservation of Nature (IUCN) Red List[37], and they are managed in zoos through EEPs. At 31 December 2012, 54 institutions participated in the management of 417 [133.284 (♂♂.♀♀)] Scimitar-horned oryx, 12 institutions held 193 (87.106) Mohor gazelle and six institutions had 186 (74.112) Cuvier's gazelle. Reintroductions/translocations are recommended by international bodies and range-states authorities (e.g. IUCN) as appropriate tools for the conservation of these three species. A number of reintroduction projects have been carried out since the 1980s in Senegal (Scimitar-horned oryx and Mohor gazelle), Tunisia (Scimitar-horned oryx, Mohor gazelle and Cuvier's gazelle) and Morocco (Scimitar-horned oryx and Mohor gazelle)[38-41]. At the time of writing, ongoing projects include reintroduction of the Scimitar-horned oryx[42] and Cuvier's gazelle in Tunisia[43]. While some of the projects seem to have succeeded[41,44], others have failed and parasites have been identified as the likely cause for lack of success in some cases[45,46]. Some studies have assessed parasitism in bovidae in zoological institutions which provide the source animals for reintroduction or translocation conservation actions (Scimitar-horned oryx in two Belgian zoos[24] and Cuvier's and Mohor gazelle at one Spanish institution[47-50]) or other taxa and projects[51]. This information is crucial to minimize the risk of reintroducing animals with contagious diseases[52] and to provide prophylactic treatment to the selected founder stock for reintroductions[53].

In this paper, we review the methods used for the detection of parasitism affecting Scimitar-horned oryx, Mohor gazelle and Cuvier's gazelle in several EAZA member institutions. Unless otherwise stated, in this study endoparasites refer to those whose eggs are detected in faeces, which includes gastrointestinal and respiratory parasites. We also review the EAZA institutions' management practices and their time schedules. The research addresses questions related to prevalence, sampling methods, treatment and parasite control, which are relevant in designing reintroduction programmes.

MATERIALS AND METHODS

In July 2010, a modified version of the questionnaire by Isaza et al[54] was sent to 65 EAZA-member zoological institutions holding any of the three study species (i.e. Scimitar-horned oryx, Mohor gazelle and Cuvier's gazelle). Questions were asked on the presence of ectoparasites, blood parasites and other endoparasites that shed eggs in the faeces for animals housed in those institutions, as well as their husbandry and veterinary practices for detection and control of parasites. Responses were received from 38 institutions (58.5%) between August 2010 and July 2011. Not all institutions answered every question, so responses were relativized to the number of answers received to each specific question rather than to the total number of institutions answering the questionnaire. Sample size for each question is provided in the Tables 2 and 3. Some institutions had two host species and, in all these cases, responses reported for both species were always the same. Zoological institutions are treated as the sample unit and prevalence of each item category was defined as the percentage of institutions reporting a given answer in the questionnaire. Confidence limits (CI) of 95% were calculated.

RESULTS

Thirty-eight completed questionnaires were received from 12 European countries and Israel (Table 1). Most housed Scimitar-horned oryx (86.8%), while Mohor and Cuvier's gazelles were present at nine (23.7%) and four (10.5%) institutions, respectively. Most institutions considered the control of endoparasites that shed eggs in the faeces and blood parasites (79%; CI = ± 13) as well as the control of ectoparasites (82%; CI = ± 12) to be important for the health of the host species; however, only 66% ($n = 25$) routinely treated prophylactically for the former and 21% ($n = 8$) for the latter. Over 97% (CI = ± 5) of respondent institutions ($n = 38$) detected eggs of endoparasites in faeces but only 3% (CI = ± 5) reported ectoparasites. Haemoparasites were not detected in any of the host species by blood screening.

INSTITUTION	LOCALITY	COUNTRY	HOST SPECIES
Monde Sauvage	Aywaille	Belgium	OD
Planckendael	Mechelen	Belgium	OD
Zoo Zagreb	Zagreb	Croatia	OD
Zoologická zahrada Praha	Prague	Czech Republic	OD
African Safari	Plaisance du Touch	France	OD
Parc Animalier de Branféré	Le Guerno	France	OD
Parc Zoologique de Montpellier	Montpellier	France	OD, ND
Parc Zoologique de Jurques	Jurques (Calvados)	France	OD
Planete Sauvage	Port Saint-Père	France	OD
Zoo de la Barben	La Barben (Pélissanne)	France	OD
Zoo La Boissière du Doré	La Boissière du Doré	France	OD

Zoo Frankfurt	Frankfurt am Main	Germany	ND
Zoo Krefeld	Krefeld	Germany	OD
Zoo Leipzig	Leipzig	Germany	OD
Budapest Zoo	Budapest	Hungary	ND
Dublin Zoo	Dublin	Ireland	OD
Fota Wildlife Park	Carrigtwohill	Ireland	OD
Jerusalem Biblical Zoo	Jerusalem	Israel	OD
Parco Faunistico Le Cornelle	Valbrembo	Italy	OD
Parco Zoo 'Punta Verde'	Lignano Sabbiadoro	Italy	OD
DierenPark Amersfoort	Amersfoort	Netherlands	OD
Natura Artis Magistra	Amsterdam	Netherlands	OD
Rotterdam Zoo	Rotterdam	Netherlands	ND
Miejski Ogród Zoologiczny	Lodz	Poland	OD
Miejski Ogród Zoologiczny Wybrzeża	Gdansk	Poland	OD
Estación Experimental de Zonas Áridas	Almería	Spain	GC, ND
Oasis Park	La Lajita	Spain	OD, GC
Parque de la Naturaleza Cabárceno	Villanueva de Villaescusa	Spain	OD, GC
Parque Zoológico de Barcelona	Barcelona	Spain	OD, ND
Selwo Aventura	Estepona	Spain	OD, GC
Zoo Aquarium Madrid	Madrid	Spain	OD, ND
Zoo Botánico Jerez	Jerez de la Frontera	Spain	ND
Chester Zoo	Chester	UK	OD
Cotswold Wildlife Park & Gardens	Burford	UK	OD
Marwell Wildlife	Winchester	UK	OD
Woburn Safari Park	Woburn	UK	OD, ND
Flamingo Land	Malton	UK	OD
ZSL Whipsnade Zoo	Dunstable	UK	OD

Table 1. Zoological institutions that responded to a questionnaire survey and host species at each institution: GC, Cuvier's gazelle *Gazella cuvieri*; ND, Mohor gazelle *Nanger dama mhorri*; OD, Scimitar-horned oryx *Oryx dammah*.

Responses given to questions related to endoparasites that shed eggs in the faeces, blood parasites and ectoparasites sampling and examination procedures are given in Table 2. Most institutions (92%; CI: ± 9) collected faeces from the ground for detection the eggs of gastro-intestinal parasites, with concentrating flotation technique as the preferred method (82%; CI: ± 12). Up to 25 institutions (66%; CI: ± 15) routinely took blood samples, most of them (24 out of 25) from some (unknown number) individuals rather than from all members of the herd. Detailed, individual examination for ectoparasites was carried out in 33 of the respondent institutions (87%; CI: ± 11).

The responses related to chemoprophylaxis protocols are summarized in Table 3. While 66% (CI: ± 15) of institutions had regular prophylactic treatments for endoparasites, only 21% (CI: ± 13) routinely used preventive treatments for ectoparasites. Ivermectin is the most commonly used medication to prevent parasitism. It is usually administered in medicated feed every 6 months when used for endoparasites, but

only once a year via medicated feed, topically or by parenteral injection, in similar dosages, for prevention of ectoparasites. A third of the institutions (32%; CI: ± 15) take additional measures to control parasitic diseases, including the use of an insecticide spray in the enclosures and buildings.

QUESTION	ANSWER	NO. OF ZOOS	% RELATIVE TO TOTAL ZOOS INCLUDED IN THE STUDY (38)	95% CONFIDENCE LIMITS
Where are faecal samples collected? (<i>n</i> = 35)	ground	35	92%	83–100
	rectum	9	24%	10–38
What types of faecal examinations are routinely performed? (<i>n</i> = 35)	flotation	31	82%	70–94
	direct smear	23	61%	45–77
	sedimentation	13	34%	19–49
	Baermann	9	24%	10–38
Were faecal samples examined individually or pooled? (<i>n</i> = 35)	individuals	28	74%	60–88
	herds	31	82%	70–94
Are blood samples taken from some of your individuals or all? (<i>n</i> = 25)	not all	24	63%	48–78
	all	1	3%	1–8
What is the method used when looking for blood parasites? (<i>n</i> = 18)	smear	18	47%	31–63
	immunology	1	3%	1–8
	other	1	3%	1–8
Where do you look for ectoparasites? (<i>n</i> = 34)	general body examination	33	87%	76–98
	ears	12	32%	17–47

Table 2. Responses to questions related to sampling and diagnostic procedures utilized for endoparasites, haemoparasites and ectoparasites examination. (n is the number of zoos that responded to the specific question). More than one option could be ticked in most questions.

QUESTION	ANSWER	NO. OF ZOOS	% RELATIVE TO TOTAL ZOOS INCLUDED IN THE STUDY (38)	95% CONFIDENCE LIMITS
Does your endoparasite control programme include routine preventive treatments for the host species? (<i>n</i> = 36)	yes	25	66%	51–81
	no	11	29%	15–43
What types of antiparasitic drugs are routinely used at your institution for endoparasites? (<i>n</i> = 27)	ivermectin	25	66%	51–81
	benzimidazoles	11	29%	15–43
	levamisoles	4	11%	1–21
	organophosphates	0		
	other	0		
What is the frequency of treatment? (<i>n</i> = 25)	once a month	1	3%	1–8
	once every 2 months	1	3%	1–8
	once every 3 months	7	18%	6–30
	once every 4 months	5	13%	2–24
	once every 5 months	0		
	once every 6 months	8	21%	8–34
	once a year	2	5%	1–12
	other	1	3%	1–8
What is the route of administration? (<i>n</i> = 26)	oral/medicated feed	24	63%	48–78
	parenteral (injection)	11	29%	15–43
Does your ectoparasite control programme include routine preventive treatments for the host species? (<i>n</i> = 34)	yes	8	21%	8–34
	no	26	68%	53–83
What types of antiparasitic drugs are routinely used at your institution for ectoparasites? (<i>n</i> = 11)	ivermectin	8	21%	8–34
	organophosphates	2	5%	1–12
	other	2	5%	1–12
What is the frequency of treatment? (<i>n</i> = 9)	once a month	3	8%	1–17

	once every 3 months	3	8%	1–17
	once every 6 months	4	11%	1–21
	once a year	6	16%	4–28
What is the route of administration? (<i>n</i> = 11)	oral/medicated feed	4	11%	1–21
	parenteral (injection)	5	13%	2–24
	topical	4	11%	1–21
	other	0		
Do you carry out any additional sanitary prophylaxis for parasite control? (<i>n</i> = 32)	yes	12	32%	17–47
	no	20	53%	37–69

Table 3. Responses to questions related to chemoprophylaxis protocol used in the surveyed zoos. (n is the number of zoos that responded to the specific question). More than one option could be ticked in most questions.

DISCUSSION

The zoological institutions surveyed in this study indicated that endoparasites, blood parasites and ectoparasites are perceived to be important threats to the health of ungulates, and preventive treatment and control were considered to be a key aspect of husbandry protocols. The three surveyed ungulates were regularly treated with ivermectin against sensitive endoparasites (generally every 6 months) and yet prevalence was still high (97% of institutions). Parasite anthelmintic resistance has been suggested as a cause of treatment failure[54,55] but the prevalence recorded could be also attributed to the timing and frequency of the prophylactic treatment[56], the route of administration, the drug dosage[47,54] or a combination of these. The uneven uptake of medication by individuals when sprinkled over food, as most institutions refer to do, is a well-recognized problem that limits treatment success as well (63%; CI: ± 15)[48,49]. Asymptomatic animals may act as a reservoir of parasites that can result in rapid infection of wild populations at the release site[57-59]. Additionally, these animals may become symptomatic as a result of the stress associated with translocation and release[23,60].

Only one institution (3%) reported that ectoparasites were detected in their gazelle or oryx herds, which may be a true reflection of the low parasite burdens in studied ungulates. Alternatively, this may be the result of the challenge of detecting ectoparasites, which requires the manual or chemical restraint of the host species. Such procedures are often limited to specific health checks (opportunistic sampling), and institutions only treat against ectoparasites when symptoms are observed. The advantage of the relatively high use of ivermectin as the preferred treatment against endoparasites might prevent ectoparasites in the hosts as well[61,62] (Table 3).

Whilst most institutions (65.8%) collected blood samples for parasite screening, none reported the presence of haemoparasites. The occurrence of blood parasites in antelope populations in zoological institutions would be a concern given their documented impact on the taxa[63,64]. The low prevalence of ectoparasites may further minimize the presence of some haemoparasites (i.e. *Babesia* or *Theileria*)[65]. However, as blood samples were not obtained from all individuals in the herd, but rather from an unknown, limited number of animals, results obtained in this study are inconclusive.

Most zoological institutions sampled faeces from the ground probably because this is a non-invasive and easy method of collecting data. Respondents reported that concentrating flotation technique is the procedure most often employed among the ones used to detect the eggs of endoparasites. However, this method fails to detect trematode and lung-nematode infections[66]. Concentrating sedimentation technique was used by only one-third of the institutions in this study (34%) and Baermann was employed by 24% of institutions (Table 2). Consequently, subclinical trematode and lung-nematode infections may not be diagnosed. Therefore, animals involved in future reintroductions should be carefully investigated for parasites using a combination of faecal concentrating techniques (sedimentating, flotating and Baermann) and even molecular or serological diagnosis tests[67-70], according to standard procedures of good veterinary practice[71].

These survey results suggest that it may be difficult to control parasites (mainly the ones that shed eggs in animal faeces) for Scimitar-horned oryx, Cuvier's gazelle and Mohor gazelle in zoological institutions, despite the preventive measures implemented and the administration of treatments when parasites are detected. Precise management practices need to be enacted to ensure that novel parasites from captive populations are not introduced to naive wild populations by translocations or reintroductions[72]. Furthermore, animals from zoological institutions need to develop a resistance to parasites to ensure that they are not completely naive when released into their historical range. This balance is difficult to achieve in zoological institutions. A recent study has shown that 'dewormed and vaccinated' and 'non-dewormed and unvaccinated' Cuvier's gazelle at an institution had similar health and fitness results (e.g. body weight, blood parameters related to immune system)[73].

Some reintroduction programmes have failed, partly or totally, as a result of parasitism[13,14,17,18]. Most of the Cuvier's gazelles released in Tunisia in 1999 and their offspring died from parasitism[46,74]. In contrast, all the reintroduced populations of Scimitar-horned oryx as well as the population of Cuvier's gazelle reintroduced in 2016 have persisted and increased in size, and parasites have not been associated with mortalities[43,75]. Faecal analyses carried out in Dghoumes National Park, Tunisia, suggest the oryx appear to be free of parasite burdens (T. Gilbert, unpubl. data).

Parasite presence in captive animals may have a contradictory importance for reintroduced animals and reintroduction programmes. It is possible that captive animals are more susceptible to parasites than wild ones (see, for instance[76]). Conversely, regular deworming of animals to avoid parasite transmission in

captivity may reduce their immunity to parasites when released[77], especially if such pathogens are present in the wild[78]. However, captive-born animals that are released could also harbour parasites that could become invasive to naïve wild populations[76]. Therefore, the treatment of captive individuals must be specific to the particular situation of each reintroduction programme.

Our results show that parasites are widely distributed in zoological institutions although these institutions carefully apply the recommended procedures of good veterinary practices. This could be a critical point when reintroduction/translocations of animals are planned. In this sense, management practices should be improved, such as the association of coprological diagnosis with more sensitive methods (e.g. molecular techniques and serological tests) when possible, or, alternatively, the design of particular treatment strategies for each situation. Reintroduction practitioners should be aware of the parasite diversity and parasitic load affecting source populations and the impact they may have on the health of individual animals. A sub-clinical parasite burden could stimulate the immune system benefitting animals that are released into the wild where parasites are present in extant wildlife or livestock populations. In this sense, further research should be performed to facilitate the work of zoos in their role as essential components for the conservation of threatened species.

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REFERENCES

- 1 Beck BB, Rapaport LG, Price MRS, *et al.* Reintroduction of captive-born animals. In: Olney PJS, Mace GM, Feistner ATC, eds. *Creative Conservation*. Dordrecht, Germany: Springer 1994:265–286.
- 2 Carpenter JW, Gabel RR, Goodwin JG. Captive breeding and reintroduction of the endangered masked bobwhite. *Zoo Biol* 1991;**10**:439–449.doi:10.1002/zoo.1430100602

- 3 Fraser DJ. How well can captive breeding programs conserve biodiversity? A review of salmonids. *Evol Appl* 2008;**1**:535–586.doi:10.1111/j.1752-4571.2008.00036.x
- 4 Griffiths RA, Pavajeau L. Captive breeding, reintroduction, and the conservation of amphibians. *Conserv Lett* 2008;**22**:852–861.doi:10.1111/j.1523-1739.2008.00967.x
- 5 Kleiman DG. Reintroduction of captive mammals for conservation. *Bioscience* 1989; **39**:152–161.doi:10.2307/1311025
- 6 Reading RP, Miller B, Shepherdson D. The value of enrichment to reintroduction success. *Zoo Biol* 2013; **32**:332–341.doi:10.1002/zoo.21054
- 7 Gamble KC, Moyse JA, Lovstad JN, *et al.* Blood groups in the species survival plan®, European Endangered Species Program, and managed in situ populations of bonobo (*Pan paniscus*), common chimpanzee (*Pan troglodytes*), gorilla (*Gorilla* ssp.), and orangutan (*Pongo pygmaeus* ssp.). *Zoo Biol* 2011; **30**:427–444.doi:10.1002/zoo.20348
- 8 Little HA, Gilbert TC, Athorn ML, *et al.* Evaluating conservation breeding success for an extinct-in-the-wild antelope. *Plos ONE* 2016;**11**,e0166912.doi:10.1371/journal.pone.0166912
- 9 Url A, Krutak V, Kübber-heiss A, *et al.* Nephropathies in the european captive cheetah (*Acinonyx jubatus*) population. *J Zoo Wildl Med* 2016;**47**:797–805.doi:10.1638/2015-0260.1
- 10 Fischer J, Lindenmayer DB. An assessment of the published results of animal relocations. *Biological Conservation* 2000;**96**:1–11.doi:10.1016/S0006-3207(00)00048-3
- 11 Stanley Price MR, Soora PS. Reintroductions: whence and whither?. *Int Zoo Yearb* 2003;**38**:61–75.doi: 10.1111/j.1748-1090.2003.tb02065.x
- 12 Sheean VA, Manning AD, Lindenmayer DB. An assessment of scientific approaches towards species relocations in Australia. *Austral Ecol* 2012;**37**:204–215.doi:10.1111/j.1442-9993.2011.02264.x
- 13 Robinson AT, Hines PP, Sorensen JA, *et al.* Parasites and fish health in a desert stream, and management implications for two endangered fishes. *N Am J Fish Manag* 1998;**18**:599–608.doi: 10.1577/1548-8675(1998)018<0599:PAFHIA>2.0.CO;2
- 14 Larkin JL, Alexy KJ, Bolin DC, *et al.* Meningeal worm in a reintroduced elk population in Kentucky. *J Wildl Dis* 2003;**39**:588–592.doi:10.7589/0090-3558-39.3.588

- 15 Stockwell MP, Clulow S, Clulo WJ, *et al.* The impact of the amphibian chytrid fungus *Batrachochytrium dendrobatidis* on a green and golden bell frog *Litoria aurea* reintroduction program at the Hunter Wetlands Centre Australia in the Hunter Region of NSW. *Aust. Zool.* 2008;**34**:379–386.doi:10.7882/AZ.2008.015
- 16 Obanda V, Kagira JM, Chege S, *et al.* Trypanosomosis and other co-infections in translocated black (*Diceros bicornis michaeli*) and white (*Ceratotherium simum simum*) rhinoceroses in Kenya. *Scientia Parasitologica* 2011;**12**:103–107.
- 17 Almberg ES, Cross PC, Dobson AP, *et al.* Parasite invasion following host reintroduction: a case study of Yellowstone's wolves. *Philos Trans R Soc Lond B Biol Sci* 2012;**367**:2840–2851.doi:10.1098/rstb.2011.0369
- 18 Kock RA, Woodford MH, Rossiter PB. Disease risks associated with the translocation of wildlife. *Rev Sci Tech* 2010;**29**:329–350.
- 19 Kock RA, Soorae PS, Mohammed OB. Role of veterinarians in re-introductions. *Int Zoo Yearb* 2007;**41**:24–37.doi:10.1111/j.1748-1090.2007.00013.x
- 20 CBSG. Mountain bongo conservation planning workshop report. Apple Valley, MN: *IUCN/SSC Conservation Breeding Specialist Group*, 2010
[Http://www.cpsg.org/sites/cbsg.org/files/documents/KWS_Bongo_CPW__Report_Final_Oct_2010.pdf](http://www.cpsg.org/sites/cbsg.org/files/documents/KWS_Bongo_CPW__Report_Final_Oct_2010.pdf).
 Accessed February 12, 2018.
- 21 Mccallum H, Dobson A. Detecting disease and parasite threats to endangered species and ecosystems. *Trends Ecol Evol* 1995;**10**:190–194.doi:10.1016/S0169-5347(00)89050-3
- 22 Mathews F, Moro D, Strachan R, *et al.* Health surveillance in wildlife reintroductions. *Biological Conservation* 2006;**131**:338–347.doi:10.1016/j.biocon.2006.04.011
- 23 Wisser J, Tscherner W, Jantschke B. Infestation with *Camelostrongylus mentulatus* in dorcas gazelles (*Gazella dorcas neglecta*) caused lethal abomasitis. *Erkrankungen der Zootiere: Verhandlungsbericht* 2001;**40**:81–86.doi:10.1638/03-065.1
- 24 Goossens E, Dorny P, Boomker J, *et al.* A 12-month survey of the gastro-intestinal helminths of antelopes, gazelles and giraffids kept at two zoos in Belgium. *Vet Parasitol* 2005;**127**:303–312.doi:10.1016/j.vetpar.2004.10.013
- 25 Mir AQ, Dua K, Singla LD, *et al.* Prevalence of parasitic infection in captive wild animals in Bir Moti Bagh mini zoo (Deer Park), Patiala, Punjab. *Vet World* 2016;**9**:540–543.doi:10.14202/vetworld.2016.540-543

- 26 Bernardi B, Fichi G, Finotello R, *et al.* Internal and external parasitic infections in captive psittacine birds. *Vet Rec* 2014;**174**:69–69.doi:10.1136/vr.101748
- 27 Yeruham I, Rosen S, Hadani A, *et al.* Arthropod parasites of Nubian ibexes (*Capra ibex nubiana*) and gazelles (*Gazella gazella*) in Israel. *Vet Parasitol* 1999;**83**:167–173.doi:10.1016/S0304-4017(99)00073-4
- 28 André MR, Adania CH, Teixeira, RHF, *et al.* Molecular and serological detection of *Babesia* spp. in neotropical and exotic carnivores in Brazilian zoos. *J Zoo Wildl Med* 2011;**42**:139–143.doi:10.1638/2010-0074.1
- 29 Chagas CRF, Valkiūnas G, De Oliveira Guimarães L, *et al.* Diversity and distribution of avian malaria and related haemosporidian parasites in captive birds from a Brazilian megalopolis. *Malar J* 2017;**16**:83.doi:10.1186/s12936-017-1729-8
- 30 Elsheikha HM, Clayton SJ, Morsy TA, *et al.* Parasitic zoonoses at the rodent-captive primate-human health interface. *J Egypt Soc Parasitol* 2009;**39**:447–460.
- 31 Geurden T, Goossens E, Levecke B, *et al.* Occurrence and molecular characterization of *Cryptosporidium* and *Giardia* in captive wild ruminants in Belgium. *J Zoo Wildl Med* 2009;**40**:126–130.doi:10.1638/2008-0152.1
- 32 Broadhurst MJ, Ardeshir A, Kanwar B, *et al.* Therapeutic helminth infection of macaques with idiopathic chronic diarrhea alters the inflammatory signature and mucosal microbiota of the colon. *PLoS Pathog* 2012;**8**(11),e1003000.doi:10.1371/journal.ppat.1003000
- 33 Ibrahim UI, Mbaya AW, Geidam YA, *et al.* Helminth parasites and reservoir status of captive wild ruminants in the semi-arid region of north-eastern Nigeria. *Vet World* 2012;**5**:530–534.doi:10.5455/vetworld.2012.530-534
- 34 Rossiter PB. Rinderpest. Infectious diseases of livestock (2nd Edn). In: Coetzer AW, Tustin RC, eds. Cape Town, South Africa: Oxford University Press 2004:629–659.
- 35 Kolodziej-Sobocinska M, Demiaszkiewicz AW, Lachowicz J, *et al.* Influence of management and biological factors on parasitic invasions in the wild – Spread of the blood-sucking nematode *Ashworthius sidemi* in European bison (*Bison bonasus*). *Int J Parasitol Parasites Wildl* 2016;**5**:286–294.doi:10.1016/j.ijppaw.2016.09.005
- 36 IUCN/SSC. Guidelines for Reintroductions and Other Conservation. 2013.

- 37 IUCN. The IUCN Red List of Threatened Species. 2017: Version 2017-3. [Http://www.iucnredlist.org](http://www.iucnredlist.org). Accessed February 12, 2018
- 38 Abáigar T, Cano M, Espeso G, *et al.* Introduction of Mhorr gazelle *Gazella dama mhorri* in Bou-Hedma National Park, Tunisia. *Int Zoo Yearb* 1997;**35**:311–316.
- 39 Wiesner H, Müller P. On the reintroduction of the Mhorr gazelle in Tunisia and Morocco. *Naturwissenschaften* 1998;**85**:553–555.
- 40 Gilbert T, Woodfine T. The biology, husbandry and conservation of scimitar-horned oryx (*Oryx dammah*). Marwell Preservation Trust. Winchester: United Kingdom 2004.
- 41 Woodfine T, Zahzah K, Chetoui A, *et al.* Reintroduction of scimitar-horned oryx to Dghoumes National Park, Tunisia. Report for the Direction Générale des Forêts, Tunis. Marwell Wildlife, Winchester: United Kingdom 2009.
- 42 Newby J, Wachter T, Durant SM, *et al.* Desert Antelopes on the Brink. In: Bro-Jørgensen J, Llon DP, eds. Antelope Conservation. New Jersey, U.S.A. 2016:253–279.
- 43 Moreno E, Jebali A, Espeso G. La gacela de Cuvier vuelve a Túnez. El papel del CSIC en la recuperación de ungulados amenazados. Editorial Digital CSIC. Madrid: Spain. 2018.doi:10.20350/digitalCSIC/858
- 44 Valente A, Valente J, Fonseca C, *et al.* The success of species reintroductions: a case study of red deer in Portugal two decades after reintroduction. *International Journal of Biodiversity Science Ecosystem Services & Management* 2017;**13**:134-138.doi:10.1080/21513732.2016.1277265
- 45 Cano M, Abaigar T, Vericad JR. Establishment of a group of Dama gazelles for reintroduction in Senegal. *Int Zoo Yearb* 1993;**32**:98–107.doi:10.1111/j.1748-1090.1993.tb03521.x
- 46 Moreno E, Espeso G. Cuvier's gazelle *Gazella cuvieri*. International studbook. Managing and husbandry guidelines. Roquetas de Mar, Almería: Spain: Consejo Superior de Investigaciones Científicas 2008.
- 47 Ortiz J, Ruiz De Ybáñez MR, Garijo MM, *et al.* Abomasal and small intestinal nematodes from captive gazelles in Spain. *Journal of Helminthology* 2001a;**75**:363–365.doi:10.1017/S0022149X01000567
- 48 Ortiz J, Ruiz De Ybáñez MR, Abaigar T, *et al.* Oral administration of mebendazole failed to reduce nematode egg shedding in captive African gazelles. The Onderstepoort. *J Vet Res* 2001b;**68**:79–82.
- 49 Ortiz J, Ruiz De Ybáñez MR, Abaigar T, *et al.* Effect of different methods of administration of ivermectin on its efficacy against the shedding of gastrointestinal nematode eggs by gazelles. *Vet Rec* 2001c;**149**:12–15.doi:10.1136/vr.149.1.12

- 50 Ortiz J, Ruiz De Ybáñez MR, Abaigar T, *et al.* Output of gastrointestinal nematode ova in the feces of captive gazelles (*Gazella dama mhorh*, *Gazella cuvieri* and *Gazella dorcas neglecta*) in a semiarid region of southeastern Spain. *J Zoo Wildl Med* 2006;**37**:249–254.doi:10.1638/03-065.1
- 51 Asmode JF, Khoja AR. Arabian Oryx captive breeding and reintroduction in Saudi Arabia. Proceedings of Captive Breeding Specialist Group Aridland Antelope Workshop. San Antonio, Texas. In: Seal US, Sausman K, Mikolai J, eds. Captive Breeding Specialist Group/Species Survival Commission. Apple Valley, Minnesota, 1990:109–125.
- 52 Mikota SK, Aguilar RF. Management protocols for animals in captive propagation and reintroduction programmes. *Rev. Off. Int. Epizoot.* 1996;**15**:191–208.
- 53 Northover AS, Godfrey SS, Lymbery AJ, *et al.* Evaluating the effects of ivermectin treatment on communities of gastrointestinal parasites in translocated woylies (*Bettongia penicillata*). *Ecohealth* 2017;**14**:S117–S127.doi:10.1007/s10393-015-1088-2
- 54 Isaza R, Courtney CH, Kollias GV. Survey of parasite control programs used in captive wild ruminants. *Zoo Biol* 1990;**9**:385–392.doi:10.1002/zoo.1430090506
- 55 Nalubamba KS, Mudenda NB. Anthelmintic efficacy in captive wild impala antelope (*Aepyceros melampus*) in Lusaka, Zambia. *Vet Parasitol* 2012;**186**:532–537.doi:10.1016/j.vetpar.2011.11.020
- 56 Fernández-Salas A, Rodríguez-Vivas RI, Alonso-Díaz MA, *et al.* Ivermectin resistance status and factors associated in *Rhipicephalus microplus* (Acari: Ixodidae) populations from Veracruz, Mexico. *Vet Parasitol* 2012;**190**:210–215.doi:10.1016/j.vetpar.2012.06.003
- 57 Langrova I, Jankovska I. Arrested development of *Trichostrongylus colubriformis* in experimentally infected rabbits. Effect of decreasing photoperiod, low temperature and desiccation. *Helminthologia* 2004;**41**:85–90.
- 58 Turne, WC, Getz WM. Seasonal and demographic factors influencing gastrointestinal parasitism in ungulates of Etosha National. *J Zoo Wildl Med* 2010;**46**:1108–1119.doi:10.7589/0090-3558-46.4.1108
- 59 Meradi S, Cabaret J, Bentounsi B. Arrested development of abomasal trichostrongylid nematodes in lambs in a steppe environment (North-Eastern Algeria). *Parasite* 2016;**23**:39.doi:10.1051/parasite/2016048
- 60 Jenni L, Keller N, Almasi B, *et al.* Transport and release procedures in reintroduction programs: stress and survival in grey partridges. *Anim Conserv* 2015;**18**:62–72.doi:10.1111/acv.12136

- 61 Gakuya F, Ombui J, Maingi N, *et al.* Sarcoptic mange and cheetah conservation in Masai Mara (Kenya): epidemiological study in a wildlife/livestock system. *Parasitology* 2012;**139**:1587–1595.doi:10.1017/S0031182012000935
- 62 Cornall K, Wall R. Ectoparasites of goats in the UK. *Vet Parasitol* 2015;**207**:176–179.doi:10.1016/j.vetpar.2014.11.005
- 63 Burridge MJ. The role of wild mammals in the epidemiology of bovine theilerioses in East Africa. *J Wildl Dis* 1975;**11**:68–75.
- 64 Nijhof AM, Pillay V, Steyl J, *et al.* Molecular characterization of *Theileria* species associated with mortality in four species of African antelopes. *J Clin Microbiol* 2005;**43**:5907–5911.doi:10.1128/JCM.43.12.5907-5911.2005
- 65 Weny G, Okwee-Acai J, Okech SG, *et al.* Prevalence and risk factors associated with hemoparasites in cattle and goats at the edge of Kibale National Park, Western Uganda. *J Parasitol* 2017;**103**:69–74.doi:10.1645/16-33
- 66 Mehlhorn H, Raether W, Düwel D, *et al.* Atlas de parasitología veterinaria. Barcelona: Spain: Grass ediciones 1992.
- 67 Piergili FD. Problems and limitations of conventional and innovative methods for the diagnosis of Toxoplasmosis in humans and animals. *Parassitologia* 2004;**46**:177–181.
- 68 Tavares RG, Staggemeier R, Borges ALP, *et al.* Molecular techniques for the study and diagnosis of parasite infection. *J Venom Anim Toxins Incl Trop Dis* 2011;**17**:239–248.doi:10.1590/S1678-91992011000300003
- 69 Széll Z, Sréter-Lancz Z, Sréter T. Evaluation of faecal flotation methods followed by species-specific PCR for detection of *Echinococcus multilocularis* in the definitive hosts. *Acta Parasitol* 2014;**59**:331–336.doi:10.2478/s11686-014-0248-9
- 70 Van Lieshout L, Roostenber GM. Clinical consequences of new diagnostic tools for intestinal parasites. *Clin Microbiol Infect* 2015;**21**:520–528.doi:10.1016/j.cmi.2015.03.015
- 71 Carpenter N, Chinnadurai S, Helmick K, *et al.* Guidelines for zoo and aquarium veterinary medical programs and veterinary hospitals. *J Zoo Wildl Med.* 2016.
<https://c.ymcdn.com/sites/www.aazv.org/resource/resmgr/files/aazvveterinaryguidelines2016.pdf>.
Accessed February 12, 2018.

- 72 Rendón-Franco E, Romero-Callejas E, Villanueva-García C, *et al.* Cross transmission of gastrointestinal nematodes between captive neotropical felids and feral cats. *J Zoo Wildl Med* 2013;**44**:936–940.doi:10.1638/2013-0015R2.1
- 73 Ibáñez B, De Andrés Cara DF, Moreno E. Haematology and serum biochemistry parameters in vaccinated versus unvaccinated captive Cuvier's gazelles: implications for zoo management practices. *J Zoo Aquar Res* 2016;**4**:1–6.doi:10.19227/jzar.v4i1.157
- 74 Cano M, Abáigar T. An update on the reintroduction of Cuvier's gazelle in Bourkornine National Park, Tunisia. Proceedings of third annual Sahelo-Saharan Interest Group meeting, Bratislava, Slovakia, 2002;30.
- 75 Abáigar T, Youm B, Niaga M, *et al.* The role of Senegal in the recovery of the Sahelo-Saharan antelope species: The case of the reintroduction of Dorcas Gazelle. *Gnusletter* 2009;**28**:6–8.
- 76 Vadlejš J, Kyriánová IA, Rylková K, *et al.* Health risks associated with wild animal translocation: a case of the European bison and an alien parasite. *Biol Invasions* 2017;**19**:1121–1125.doi:10.1007/s10530-016-1306-z
- 77 Faria PJ, Van Oosterhout C, Cable J. Optimal release strategies for captive-bred animals in reintroduction programs: Experimental infections using the guppy as a model organism. *Biol Conserv* 2010;**143**:35–41.doi:10.1016/j.biocon.2009.06.002
- 78 Kołodziej-Sobocińska M, Demiaszkiewicz AW, Pyziel AM, *et al.* Increased Parasitic Load in Captive-Released European Bison (*Bison bonasus*) has Important Implications for Reintroduction Programs. *Ecohealth* 2018;**15**:467-71.doi:10.1007/s10393-018-1327-4