ACTA ZOOLOGICA BULGARICA

Acta Zool. Bulg., 75 (3), September 2023: 431-437

Parasitology
Research Article

Published online 17 July 2023
DOI: https://doi.org/10.71424/azb75.3.002705

First Description of Seasonal Gastrointestinal Parasitic Infections in the Vulnerable *Gazella cuvieri* (Ogilby, 1841) (Mammalia: Bovidae) from Djebel Messaâd Forest, Northern Algeria

Naceur Benamor[1,*], Farid Bounaceur[2], Faiza Marniche[3] & Ahmed R. Benia[4]

[1] Department of Natural Sciences and Life, Tiaret University, Tiaret, Algeria
[2] Department of Natural Sciences and Life, Tissemsilt University, Tissemsilt, Algeria
[3] Superior National Veterinary School of El Alia, Algiers, Algeria
[4] Department of Biomedicine, Institute of Veterinary Sciences, Tiaret University, Tiaret, Algeria

Abstract: The Cuvier's gazelle *Gazella cuvieri* is a vulnerable species of high conservational importance, which is endemic in Northwestern Africa. The present study aimed to characterize gastrointestinal parasites in *G. cuvieri* and to understand the relationship between seasonality factor and parasitic infection rates as well as to analyse their conservational importance in seasonally-variable environments in northern Algeria. Totally, 48 faecal samples were analysed and ten gastrointestinal parasite species were identified, representing seven species of gastrointestinal helminths and three species of parasitic protozoans. It was observed that the seasonal faecal samples were mostly infected with *Nematodirus* sp. (prevalence 97.9 %). The overall prevalence of *Marshallagia* sp. and *Eimeria* sp. were significantly very higher in rainfall season compared to harsh environmental season. The highest gastrointestinal parasite counts were recorded during and soon after peak rainfall, while the lowest value was in the dry season. These findings show that seasonality can be an important driver of gastrointestinal parasitic infections. It seems that observations such as the high prevalence of gastrointestinal parasites and intensity of the infection, especially in the winter season, should be specifically considered by the wildlife conservation officers. This study could be the key to success in the long-term conservation of this vulnerable species in its native range and in providing a wealth of new information about parasite biodiversity.

Key words: Cuvier's gazelle, gastrointestinal parasites, seasonality, Algeria

Introduction

Cuvier's gazelle *Gazella cuvieri* (Ogilby, 1841) is an endemic species to the mountain ranges and hills of the Maghreb, with neighbouring ranges in Morocco, Algeria and Tunisia (Moreno et al. 2020). However, the species has declined dramatically since the 1950s (Beudels-Jamar et al. 2006) due to excessive hunting, anthropogenic barriers, feeding competition with domestic livestock and habitat degradation (Beudels-Jamar et al. 2006, Herrera-Sánchez et al. 2020, Benamor et al.

*Corresponding author: naceur_mh28@yahoo.fr

2021). The IUCN Red List of Threatened Species classified the Cuvier's gazelle as "Endangered" between 1986 and 2016. It is currently globally threatened and is classified as "Vulnerable", mainly due to its small population size (IUCN 2016). In Algeria, the primary cause of population decline is anthropogenic, and it is considered as a result of the illegal hunting and the forest fires (Bounaceur et al. 2016, IUCN 2018). The latter indicated that a wildlife monitoring healthcare network has been set up and has not reported any diseases of the species. It should be noted that some of these threats have not been quantified and are more assumed than proven; some threats e. g. diseases, are hard to be quantified.

Biodiversity decline continues largely unabated (SCBD 2020), despite efforts to set policy targets to slow the rate of decline, bend the curve of biodiversity loss and "reverse the red" (Mace et al. 2018, Rodrigues-Espeleta et al. 2021). Parasites are a crucial component of biodiversity as they are able to play a key role in causing population cycles (Hudson et al. 1998), control the host's reproductive output (Hudson et al. 1992a) and increase hosts' vulnerability to predation (Hudson et al. 1992b). Therefore, parasitic diseases represent one of these increasing threats to the natural populations (Daszak et al. 2000), and can cause endangered populations to decline either temporarily or permanently (Smith et al. 2006, Turgeon et al. 2018). In order to prevent the extinction of threatened species, attention has been focused on examining methods by which disease threats can be managed in free-ranging wildlife (Woodroffe 1999, Lafferty & Gerber 2002, Thompson et al. 2010). Studies on pathogens that cross host species boundaries are disproportionately represented (Woodhouse 2002). In addition, understanding disease processes in natural populations is an urgent priority in the face of increased rates of infectious disease emergence (Jolles & Ezenwa 2015). Thus, baseline information on patterns of infection in natural populations is critical to assess and manage wildlife disease risks (Ezenwa 2003).

Ecological systems are responding to changes in climate and, due to their ubiquitous nature, parasites will not be exempt from such changes (Gillingham 2015). Understanding the effect that global climate change will have on parasites is of utmost importance because there will be climate-driven implications for hosts, parasites, vectors, vegetation, abiotic elements of the ecosystem and many of the associations among these that affect the parasite web and parasite flow (Cable et al. 2017). In particular, dynamics of gastrointestinal parasites (GIP) are regulated by environmental conditions such as ambient temperature, humidity and precipitation (Hudson et al. 2006, Ortiz et al. 2006, Doi & Yurlova 2011, Tinsley et al. 2011). Hence, designing and planning control strategies require the knowledge on the epidemiological factors that influence the risk for GIP infections.

The GIPs are the most important agents that affecting gazelles (Soulsby 1982). Thus, determining the identities of various parasites infecting gazelles is the first step towards an effective control program of specific parasites (Mohammed 2002). However, published information about the species and prevalence of GIP of Cuvier's gazelle in northwest Africa is very limited, while no study has been conducted in the wild range of Algeria. Since Cuvier's gazelle is a vulnerable species, the purpose of the present epidemiological study is to characterise gastrointestinal parasites as well as understand the relationship between seasonality factor and parasitic infection rates.

Materials and Methods

Study area

Our study area was in the Djebel Messaâd Forest (35°01'48" N, 4°09'00" E). Djebel Messaâd Forest is the largest forest area in the M'Sila Province, northern Algeria, with an area of about 33556.06 ha and elevation of 1675 m (Benamor et al. 2021). The Climate in Djebel Messaâd Forest is semiarid Mediterranean pattern, with moderate rainfall during spring, autumn, and winter and a hot and dry period during summer (Fig. 1). The mean annual rainfall 315.5 mm, while the mean annual temperature varies from 10.4 °C to 21.1 °C. Minimum temperature recorded 0.74 °C in January (winter), and the maximum temperature 35.1 °C occurred in July (summer).

Collection and processing of faecal samples

During this study, 48 faecal samples were collected monthly from September 2016 through August 2017. Freshly-deposited faeces were collected early in the morning during a systematic search from the different latrine sites in order to investigate different individuals. Four to six balls from each stool were collected (Ortiz et al. 2006). Parasitological Analysis of these faecal samples was done by direct smear and flotation methods as per standard techniques (MAFF 1986). Quantitative evaluation of intensity of the infection was based on the mean number of parasite eggs and oocysts per infected host, fol-

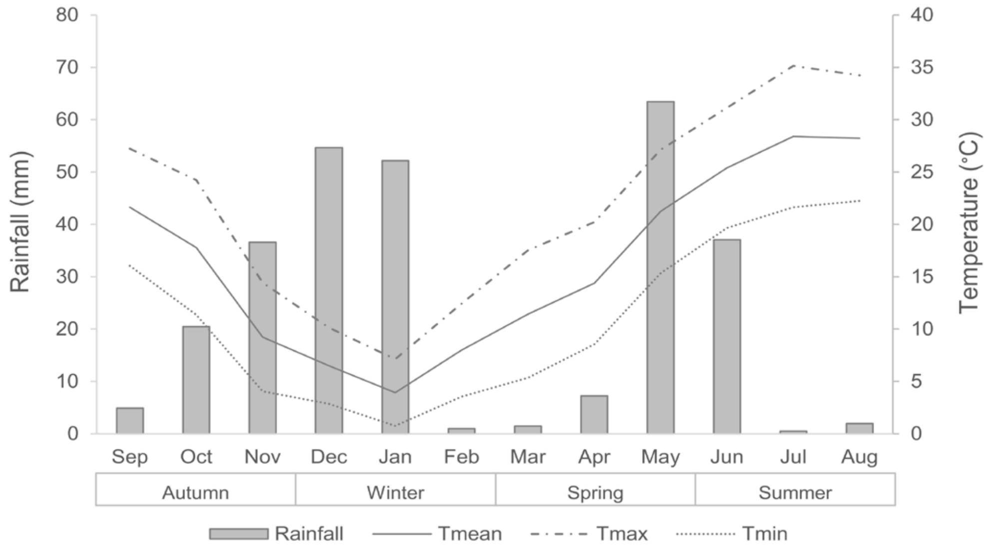

Fig. 1. Climatic conditions (rainfall, maximum, minimum and mean temperatures) during the study period in Djebel Messaâd Forest.

lowing a modified McMaster technique (Zajac & Conboy 2012). Slides were read under a light microscope at x100 magnification. The detected parasites were identified to the generic level based on their key morphological features (Zajac & Conboy 2012, Bowman 2014, Taylor et al. 2016).

Statistical analysis

Quantitative descriptors such as prevalence, mean intensity and ranges of infection for each parasite species were defined according to Bush et al. (1997) in order to characterise the seasonal variation of GIPs load in autumn, winter, spring and summer seasons. The prevalence values were compared between seasons using a chi-squared test. Statistical analyses were conducted in Quantitative Parasitology (Reiczigel et al. 2019). Values were considered statistically significant when the p-value was less than 0.05.

Results

Seasonal prevalence of gastrointestinal parasites

Totally, 48 faecal samples examined. Ten 10 gastrointestinal parasites were identified, representing 7 species of gastrointestinal helminths and 3 species of parasitic protozoans (Table 1). The seasonal faecal samples were mostly infected with *Nematodirus* sp. It was observed that the prevalence of *Nematodirus* sp. was 97.9 % whereas the infection rates of *Entamoeba* sp., *Balantidium* sp., *Oesophagostomum* sp. and *Trichostrongylus* sp. (8.3 %) were lower. Among the faecal samples, 58.3 % were infected by *Strongyloides* sp. The prevalence of *Eimeria* sp., *Marshallagia* sp., *Strongyloides* sp., *Oesophagostomum* sp., *Trichostrongylus* sp., *Entamoeba* sp. and *Balantidium* sp. was was significantly associated with seasons ($p<0.05$) The overall prevalence of *Marshallagia* sp. (χ^2= 26.667; p< 0.0001) and *Eimeria* sp. (χ^2= 19.556; p=0.000) were significantly very higher in peak of the rainfall season (spring) compared to harsh season - summer.

Seasonal intensities and ranges of faecal gastrointestinal parasite counts

Parasite egg and oocyst counts of the parasite species were shown in Table 2. In this study, faecal egg counts showed strong seasonal trends related to rainfall. A peak of the faecal egg counts was observed during and soon after rainfall peak. It was also revealed that gazelles were more susceptible to gastrointestinal parasitic infection in the winter season than other seasons. *Nematodirus* sp. eggs were present primarily in the faeces of Cuvier's gazelle. *Nematodirus* sp. egg shedding showed a seasonal variation, peaking in winter, declining during other seasons. We had the same observation on *Strongyloides* sp. eggs, however, in relatively low counts. No seasonal patterns were observed for *Trichuris* sp. and *Moniezia* sp. eggs excretion. The three protozoan species showed a similar pattern; however, they were totally absent during the summer (dry season). The highest gastrointestinal parasite richness of eight species was recorded in winter and autumn seasons, while the lowest richness was in summer – three species. In spring, the number of the parasite species was intermediate (six species, see Table 2).

Table 1. Seasonal prevalence of gastrointestinal parasites in Cuvier's gazelle from Djebel Messaâd forest.

Parasite group	Parasite species	Prevalence (%)				Mean (%)	χ^2	p-values
		Autumn	Winter	Springer	Summer			
Protozoans	*Entamoeba* sp.	33.3	0.0	0.0	0.0	8.3	13.091	0.004**
	Balantidium sp.	0.0	33.3	0.0	0.0	8.3	13.091	0.004**
	Eimeria sp.	33.3	0.0	66.7	0.0	25	19.556	0.000***
Cestodes	*Moniezia* sp.	33.3	33.3	33.3	0.0	25	5.333	0.149
Nematodes	*Nematodirus* sp.	100.0	100.0	100.0	91.7	97.9	3.064	0.382
	Strongyloides sp.	33.3	66.7	100.0	33.3	58.3	15.086	0.002**
	Marshallagia sp.	33.3	66.7	100.0	0.0	50	26.667	< 0.0001***
	Trichuris sp.	33.3	33.3	33.3	33.3	33.3	0.000	1.000
	Oesophagostomum sp.	33.3	0.0	0.0	0.0	8.3	13.091	0.004**
	Trichostrongylus sp.	0.0	33.3	0.0	0.0	8.3	13.091	0.004**

$p<0.05$: (*) Significant; $p<0.01$: (**) Highly significant; $p<0.001$: (***) Very highly significant.

Table 2. Mean intensities, ranges and richness of gastrointestinal parasites in the Cuvier's gazelle.

Parasite group	Parasite species	Mean intensities				Ranges	
		Autumn	Winter	Springer	Summer		
Protozoans	*Entamoeba* sp.	3	-	-	-	0-10	(VL)
	Balantidium sp.	-	15	-	-	10-50	(L)
	Eimeria sp.	1	0	2	-	0-10	(VL)
Cestodes	*Moniezia* sp.	1	3	2	-	0-10	(VL)
Nematodes	*Nematodirus* sp.	1191	4168	1321	1350	>100	(H)
	Strongyloides sp.	12	87	31	1	50-100	(M)
	Marshallagia sp.	3	15	3	-	10-50	(L)
	Trichuris sp.	1	3	1	9	0-10	(VL)
	Oesophagostomum sp.	7	-	-	-	0-10	(L)
	Trichostrongylus sp.	-	3	-	-	0-10	(VL)
Richness		8	8	6	3		

Ranges: (H) high; (M) moderate; (L) low; (VL) very low.

Discussion

Seasonal prevalence of gastrointestinal parasites

In order to elucidate the patterns of emergence for pathogenic organisms and establishment of host's geographic colonization, it is necessary to understand the history and structure of parasite fauna in ruminants (Hoberg 1997). Absence of previous data of GIP in Cuvier's gazelle in their native range, either in free-ranging or in captivity, enhances the importance of this study.

We identified 10 GIP species in our surveys, which is a contribution to the parasite ecology of *G. cuvieri*. The most prevalent species were *Nematodirus* sp., *Strongyloides* sp. and *Marshallagia* sp. The present study is in agreement with previous reports recording *Nematodirus* sp. as the predominant parasite detected in gazelle species (Abáigar et al. 2009, Saud et al. 2012, Wang et al. 2016, Kahoul & Benmouaffok 2017). Specific information on *G. cuvieri* in its natural habitats is lacking; however, overall prevalence of *Nematodirus* sp. was observed in captive Cuvier's gazelle in Spain (Ortiz et al. 2006). The highest prevalence rate of *Nematodirus* sp. in different season had no statistical significance difference ($p>0.05$). On the other hand, the prevalence of *Strongyloides* sp. showed a clear seasonality, peaking in winter and being virtually absent throughout the dry season (summer). That observation corresponded to the pattern of rainfall and reinfection did not seem to be possible during the dry season (Turner & Getz 2010). Several previous studies reported that the high temperatures and the lack of rainfall produced a virtual absence of parasites (Fritsche et al. 1993).

The prevalence of *Marshallagia* sp. ranged from 10 (Kazakhstan) to 85 % (Algeria) (Meradi et al. 2011). It should be noted that it might vary a lot in the different sites of the same country, e.g., from 21 to 81 % in Algeria. In this study, *Marshallagia* sp. was recorded in autumn, winter and spring seasons. Intensity of that nematode was strongly associated with spring ($p<0.05$) and it was similar to the finding in endangered Tibetan antelope (Cao et al. 2020). With a 50 % prevalence value observed for the Trichostrongylidae, our results corroborate those already obtained by Ortiz et al. (2006) reporting a prevalence oscillating between 87.5 % for *Camelostrongylus mentulatus* and 18.8 % for *Teladorsagia circumcincta*. The latter authors reported that Cuvier's gazelles exhibited the greatest number of *Trichuris* sp. throughout the year.

Analyses of GIP in faecal sample showed an increase in the numbers of the nematode *Oesophagostomum* sp. ($p<0.05$) in September and October (Šarkūnas et al. 2007). The cestode *Moniezia* has been widely cited in the African ungulate endoparasites, notably in the scimitar-horned oryx, Roan antelope, Defassa Waterbuck, African Buffalo and the Derby eland (Graber et al. 1964, Graber & Thal 1979). Moreover, in the genus *Gazella*, tapeworms represent a significant group of endoparasites in *Gazella dama*, *Eudorcas rufifrons* and *Gazella subgutturosa marica* (Graber & Thal 1979, Saud et al. 2012). Coccidian *Eimeria* sp. oocysts were reported in 25% of faecal samples, an observation agreed with the importance of this parasites as causative agents in gazelles (Saud et al. 2012). The co-existence of GIP such as *Eimeria* sp., *Strongyloides* sp., *Oesophagostomum* sp. and *Balantidium* sp. in the faeces of *G. cuvieri* in Djebel Messaâd seems to be similar to those obtained in deer (Barmon et al. 2014, Hadi et al. 2020).

Seasonal intensities and ranges of faecal gastrointestinal parasite counts

Understanding the different GIPs epidemiology and lifecycle is necessary to interpret the results, especially for the faecal egg counts for parasite species that have high seasonal fluctuations (Carlsson et al. 2018). Faecal egg counts showed that seasonality can be an important driver of gastrointestinal parasitic infections during and soon after peak rainfall (Fritsche et al. 1993). The seasonal relationship between parasite egg counts and rainfall is similar to findings in captive wild gazelle *Gazella cuvieri* in a semiarid region of Spain (Ortiz et al. 2006) and Algerian captive gazelles (Abágar et al. 2009, Kahoul & Benmouaffok 2017). Our data perfectly corroborate those already obtained for captive *Gazella cuvieri*, which reveal the higher *Nematodirus* sp. egg excretion throughout the year (Ortiz et al. 2006, Saud et al. 2012), especially in winter season via the delayed effects of rainfall (Shearer & Ezenwa 2020). During harsh environmental conditions, reinfection becomes more difficult and the level of egg excretion decreases (Turner & Getz 2010). The finding of low *Strongyloides* sp. eggs shedding and predominantly in dry season by this study is similar to findings by Ortiz et al. (2006) in Cuvier's gazelle in Spain, Apio et al. (2006) in bushbucks in Uganda and Nalumbabma et al. (2012) in captive wild impala in Zambia. These low number of *Strongyloides* eggs detected in the samples indicate low *Strongyloides* sp. infection. Prior to the study, it was anticipated that unfavourable weather conditions in summer would delay *Marshallagia* sp., *Trichostrongylus* sp., and *Oesophagostomum* sp. eggs availability, thus resembling the general pattern of Cuvier's gazelle gastrointestinal nematodes in Spain (Ortiz et al. 2006).

Our study showed a low shedding in the numbers of *Moniezia* sp. eggs; due to the low intensity of infection, it seems that these parasites have only a limited pathogenic role (Graber & Thal 1979). On the other hand, previous study in ungulate populations revealed a relatively lower intensity rate for protozoan infections than helminth infections. *Balantidium coli* is a cosmopolitan protozoan, which lives in the intestine of herbivore hosts (Rahman et al. 2014); in our study, the intensity of infection with *Balantidium* sp. in *G. cuvieri* was low. The intensity of other parasitic protozoans (*Eimeria* sp. and *Entamoeba* sp.) was very low (Ben Belgacem 2015), and being totally absent during the summer. Nevertheless, it seems that the genus *Gazella* is very vulnerable to this group of intestinal protozoans, represented in this host genus by *Eimeria idmii*, *E. rheemi* and *E. dorcadis* (Mohammed & Hussein 1992).

Generally, the findings of the current study showed that GIP infections are a heath status challenge for the Cuvier's gazelle in the Djebel Messaâd forest, northern Algeria. It seems that observations such as the high prevalence of GIPs and intensity of the infection, especially in the winter, should be specifically considered by the wildlife conservation officers. This study could be the key to success in the long-term conservation of this vulnerable species in its native range and in providing a wealth of new information about parasite biodiversity.

Acknowledgements. We thank Nouari Amara for his invaluable help in collecting faecal samples and in providing informa-

tion about the gazelle populations.

References

Abáigar T., Belbachir-Bazi A. & Cano M. 2009. Proposal for the development and management of a gazelle breeding centre in captivity. Spanish-Algerian international cooperation project (AECI-MESRS) Ref: A/01101/2017. Almería (Spain) and Bejaïa (Algeria): Scientific-technical report 36 p. (In French).

Apio A., Plath M. & Wronski T. 2006. Patterns of gastrointestinal parasitic infections in the bushbuck *Tragelaphus scriptus* from the Queen Elizabeth National Park, Uganda. Journal of Helminthology 80(3): 213–218.

Barmon B. C., Begum N., Labrony S. S., Kundu U. K., Deyand A. R. & Dey T. R. 2014. Study of gastro-intestinal parasites of deer at Char Kukri Mukri in Bhola District. Bangladesh Journal of Veterinary Medicine 2(1): 27–33.

Ben Belgacem H. 2015: Contribution to the study of the parasites of Gazelles *Gazella cuvieri* (Ogilby, 1841), *Gazella dorcas* (Linnée, 1788) and *Gazella leptoceros* (Cuvier, 1842) living in captivity in the Jardin d'Essai of El Hamma (Algiers) and a Camelin *Camelus dromedarius* (Linné, 1758) from H'Taiba (Laghouat). Master Thesis, University of Science and Technology Houari Boumediene of Algiers, Algeria. (In French).

Benamor N., Bounaceur F. & Aulagrier S. 2021. Dietary overlap of wild ungulate Cuvier's gazelle with livestock (sheep and goats) in Djebel Messaâd Forest, Algeria. Russian Journal of Theriology 20(1): 31–43.

Beudels-Jamar R. C., Lafontaine R. M. & Devillers P. 2006. *Gazella cuvieri.* In: Beudels-Jamar R. C. et al. (Eds.): Sahelo-Saharan Antelopes. Status and Perspectives. Report on the Conservation Status of the Six Sahelo-Saharan Antelopes. Second Edition. UNEP/CMS Secretariat: CMS Technical Series Publication, pp. 83–92.

Bounaceur F., Boualem A., Benamor N., Fellous A., Benkheira A., Bissaad F. Z. & Aulagnier S. 2016. Updated distribution and local abundance of the endangered Cuvier's gazelle (Mammalia, Bovidae) in Algeria. Folia Zoologica 65(3): 233–238.

Bouwman D. D. 2014. Georgis' parasitology for veterinarians. Tenth Edition. MO: Elsevier, St. Louis. 477 p.

Bush A. O., Lafferty K. D., Lotz J. M. & Shostak A. W. 1997. Parasitology meets ecology on its own terms: Margolis et al. revisited. Journal of Parasitology 83(4): 575–583.

Cable J., Barber I., Boag B., Ellison A. R., Morgan E. R., Murray K., Pascoe E. L., Sait S. M., Wilson A. J. & Booth M. 2017. Global change, parasite transmission and disease control: lessons from ecology. Philosophical Transactions of the Royal Society B: Biological Sciences 372(1719): 20160088.

Cao Y., Yang Y., Duszynski D. W., Zhu Y., Shang G., Hou C., Zhang T. & Bian J. 2020. Prevalence and parasite composition of gastrointestinal parasites in the endangered Tibetan antelope (*Pantholops hodgsonii*) from the calving ground of Hoh Xil nature world heritage site, Qinghai, China. Journal of Wildlife Diseases 56(2): 372–377.

Carlsson A. M., Albon S. D., Coulson S. J., Robstad E., Stein A., Wilson K., Loe L. E., Veiberg V. & Irvine R. J. 2018. Little impact of over-winter parasitism on a free-ranging ungulate in the high Arctic. Functional Ecology 32(4): 1046–1056.

Daszak P., Cunningham A. A. & Hyatt A. D. 2000. Emerging infectious diseases of wildlife-threats to biodiversity and human health. Science 287: 443–449.

Doi H. & Yurlova N. I. 2011. Host-parasite interactions and global climate oscillations. Parasitology 138(08): 1022–1028.

Ezenwa V. O. 2003. Habitat overlap and gastrointestinal parasitism in sympatric African bovids. Parasitology 126(4): 379–388.

Fritsche T., Kaufmann J. & Pfister K. 1993. Parasite spectrum and seasonal epidemiology of gastrointestinal nematodes of small ruminants in The Gambia. Veterinary Parasitology 49(2–4): 271–283.

Gillingham E. L. 2015. The Effect of Climate on Host-Parasite Interactions. PhD Thesis, Cardiff University. 135 p.

Graber M., Doutre M. P., Fingelle P., Kéravec J., Ducroz G. & Mokotaingar P. 1964. The helminths of some wild artiodactyls belonging to the families Bovidae and Suidae. These mammals in the Republic of Chad and in R.C.A. are they reservoirs of parasites for domestic animals living in contact with them? Revue d'élevage et de médecine vétérinaire des pays tropicaux 17(3): 377–420. (In French).

Graber M. & Thal J. 1979. Anoplocephalid parasites of the intestine and bile ducts of wild herbivores from Central Africa. Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux 32(4): 371–378. (In French).

Hadi H. D., Al Makawi Z. & Taher T. A. 2020. Prevalence of intestinal protozoa in deer in middle of Iraq. Plant Archives 20(1): 2013–2016.

Herrera-Sánchez F. J., Gil-Sánchez J. M., Álvarez B., Cancio I., de Lucas J., Arredondo Á., Diaz-Portero M. Á., Rodriguez-Siles J., Sáez J. M., Pérez J., McCain E., Oninba A. & Abáigar T. 2020. Identifying priority conservation areas in a Saharan environment by highlighting the endangered Cuvier's Gazelle as a flagship species. Scientific Reports 10: 8241.

Hoberg E. P. 1997. Phylogeny and historical reconstruction: host-parasite systems as keystones in biogeography and ecology. In: Reaka-Kudla M. L., Wilson D. E. & Wilson E. O. (Eds.): Biodiversity II: Understanding and Protecting Our Biological Resources. Washington, D. C: Joseph Henry Press, National Academy of Sciences, pp. 243–261.

Hudson P. J., Cattadori I. M., Boag B. & Dobson A. P. 2006. Climate disruption and parasite–host dynamics: patterns and processes associated with warming and the frequency of extreme climatic events. Journal of Helminthology 80(2): 175–182.

Hudson P. J Dobson A. P. & Newborn D. 1992b. Do parasites make prey vulnerable to predation? Red grouse and parasites. Journal of Animal Ecology 61(3): 681–692.

Hudson P. J., Dobson A. P. & Newborn D. 1998. Prevention of population cycles by parasite removal. Science 282(5397): 2256–2258.

Hudson P. J., Newborn D. & Dobson A. P. 1992a. Regulation and stability of a free-living host-parasite system: *Trichostrongylus tenuis* in red grouse. I. Monitoring and parasite reduction experiments. Journal of Animal Ecology 61(2): 477–486.

IUCN. 2016. The IUCN Red List of Threatened Species 2016: e.T8967A50186003. https://dx.doi.org/10.2305/IUCN.

UK.2016-2.RLTS.T8967A50186003.en.

IUCN. 2018. Conservation strategy and action plan for Cuvier's gazelle (*Gazella cuvieri*) in North Africa 2017-2026. Gland, Switzerland and Malaga, Spain: IUCN. x + 42 pp.

Jolles A. E. & Ezenwa V. O. 2015. Ungulates as model systems for the study of disease processes in natural populations. Journal of Mammalogy 96(1): 4–15.

Kahoul K. & Benmouaffok M. 2017. Contribution to the study of endoparasites in Dorcas gazelles (*Gazella dorcas*) living in semi-captivity in Brezina region of El Bayadh. Master Thesis, Higher National Veterinary School of Algiers, Algeria. (In French).

Lafferty K. D. & Gerber L. R. 2002. Good medicine for conservation biology: the intersection of epidemiology and conservation theory. Conservation Biology 16(3): 593–604.

Mace G. M., Barrett M., Burgess N. D., Cornell S. E., Freeman R., Grooten M. & Purvis A. 2018. Aiming higher to bend the curve of biodiversity loss. Nature Sustainability 1(9): 448–451.

MAFF (Ministry of Agriculture, Fisheries and Food) 1986. Manual of Veterinary Parasitological Laboratory Techniques. London: Her Majesty's Stationery Office. 160 p.

Meradi S., Bentounsi B., Zouyed I. & Cabaret J. 2011. The steppe species of gastrointestinal nematodes of small ruminants, with a focus on *Marshallagia*: climate as a key determinant. Parasite 18: 261–269.

Mohammed O. B. 2002. Control of gazelle parasites at King Khalid Wildlife Research Centre (KKWRC), Saudi Arabia. In: Scullion F. T. & Bailey T. A. (Eds.): Proceedings of the World Association of Wildlife Veterinarians. Wildlife sessions at the 27th World Veterinary Congress, Tunis, 26th September 2002. World Association of Wildlife Veterinarians, pp. 15–18.

Mohammed O. B. & Hussein H. S. 1992. *Eimeria idmii* sp. n. (Apicomplexa: Eimeriidae) from the Arabian Mountain Gazelle, *Gazella gazella*, in Saudi Arabia. Journal of the Helminthological Society of Washington 59: 120–124.

Moreno E., Jebali A., Espeso G. & Benzal J. 2020. Reintroducing Cuvier's gazelle. Better than expected from captive-bred founders. Global Ecology and Conservation 23(12): e01094.

Nalubamba K. S., Mudenda N. B. & Malamo M. R. 2012. A seasonal survey of gastrointestinal parasites in captive wild impala antelope on a game facility south of Lusaka, Zambia. Journal of Helminthology 86(4):418–425.

Ortiz J., Ruiz de Ybañez R., Abaigar T., Goyena M., Garijo M., Espeso G. & Cano M. 2006. Output of gastrointestinal nematode eggs in the feces of captive gazelles (*Gazella dama mhorr, Gazella cuvieri* and *Gazella dorcas neglecta*) in a semiarid region of southeastern Spain. Journal of Zoo and Wildlife Medicine 37(3): 249–254.

Rahman S. M., Dey A. R., Kundu U. K. & Begum N. 2014. Investigation of gastrointestinal parasites of herbivores at Dhaka National Zoological Garden of Bangladesh. Journal of the Bangladesh Agricultural University 12(1): 79–85.

Reiczigel J., Marozzi M., Fábián I. & Rózsa L. 2019. Biostatistics for Parasitologists – A Primer to Quantitative Parasitology. Trends in Parasitology 35(4): 277-281.

Rodrigues-Espeleta N., Zinger L., Kinziger A., Bik H. M., Bonin A., Coissac E., Emerson B. C., Lopes C. M., Pelletier T. A., Taberlet P. & Narum S. 2021. Biodiversity monitoring using environmental DNA. Molecular Ecology Resources 21(5): 1405–1409.

Šarkūnas M., Veličkaité S., Bružinskaité R., Malakauskas A. & Petkevičius S. 2007. Faecal egg output and herbage contamination with infective larvae of species of *Ostertagia* and *Oesophagostomum* from naturally infected farmed sika deer *Cervus nippon* in Lithuania. Journal of Helminthology 81(1): 79–84.

Saud M. A., Oleiwi K. I. & Omar A. A. 2012. Prevalence of gastro-intestinal parasites in Gazelles (*Gazella subgutturosa marica*) in Al-Theabeyafarm in Iraq. Al-Anbar Journal of Veterinary Sciences 5(2): 75–79.

SCBD (Secretariat of the Convention on Biological Diversity) 2020. Global Biodiversity Outlook 5. Montreal: SCBD. 208 p.

Shearer C. L. & Ezenwa V. O. 2020. Rainfall as a driver of seasonality in parasitism. Intertantional Journal for Parasitology: Parasites and Wildlife 12: 8–12.

Smith K. F., Sax D. F. & Lafferty K. D. 2006. Evidence for the role of infectious disease in species extinction and endangerment. Conservation Biology 20(5): 1349–1357.

Soulsby E. J. L. 1982. Helminths, Arthropods and Protozoa of Domesticated Animals. Seventh Edition. London: Billieri Tindall. 809 p.

Taylor M. A., Coop R. L. & Wall R. L. 2016. Veterinary parasitology. Fourth Edition. UK: Wiley Blackwell. 1006 p.

Thompson R. C. A., Lymbery A. J. & Smith A. 2010. Parasites, emerging disease and wildlife conservation. International Journal for Parasitology 40(10): 1163–1170.

Tinsley R. C., York J. E., Everard A. L. E., Stott L. C., Chapple S. J. & Tinsley M. C. 2011. Environmental constraints influencing survival of an African parasite in a north temperate habitat: effects of temperature on egg development. Parasitology 138(8): 1029–1038.

Turgeon G., Kutz S. J., Leujeune M., St-Laurent M.-H. & Pelletier F. 2018. Parasite prevalence, infection intensity and richness in an endangered population, the Atlantic-Gaspésie caribou. International Journal for Parasitology: Parasites and Wildlife 7(1): 90–94.

Turner W. C. & Getz W. M. 2010. Seasonal and demographic factors influencing gastrointestinal parasitism in ungulates of Etosha National Park. Journal of Wildlife Diseases 46(4): 1108–1119.

Wang Y., Du S., Yang Y., Zhang X., Duszynski D. W., Bian J. & Cao Y. 2016. Intestinal parasites in the critically endangered Przewalski's Gazelle (*Procapra przewalskii*) in China, with the Description of a New Species of Eimeria (Apicomplexa: Eimeriidae). Journal of Wildlife Diseases 52(4): 945–948.

Woodroffe R. 1999. Managing disease threats to wild mammals. Animal Conservation 2(3): 185–193.

Woodhouse M. E. 2002. Population biology of emerging and re-emerging pathogens. Trends in Microbiology 10(10): S3–S7.

Zajac A. M. & Conboy G. A. 2012. Veterinary Clinical Parasitology. Eighth Edition. UK: Wiley Blackwell. 368 p.

Received: 26.01.2023
Accepted: 05.07.2023