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ORIGINAL PAPER

Copro-parasitological survey of striped hyena (*Hyaena hyaena*), African golden wolf (*Canis lupaster*), and red fox (*Vulpes vulpes*) in Algeria

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Abstract
This study aimed to analyze composition and prevalence of endoparasites found in feces of three wild mammal carnivores at Chrea National Park, classified as biosphere reserve since 2002 as part of the UNESCO program. Fecal samples of the red fox [*Vulpes vulpes* (Linneaus, 1758)], African golden wolf (*Canis lupaster* Hemprich and Ehrenberg, 1832), and, for the first time in Algeria, the striped hyena [*Hyaena hyaena* (Linneaus, 1758)] were collected from several sites (Oued El Marja, Tiberkent, Beni-Selmen, and Tamesguida) and then examined to identify both parasite and prey fauna. The copro-parasitological diagnosis revealed the presence of helminth species (Nematoda: *Ancylostoma caninum*, *Toxocara canis*, *Trichuris vulpis*, *Toxocara* spp., and *Strongyloides stercoralis*), and Protozoa (*Cryptosporidium* spp., *Isopora* spp., and *Eimeria* spp.). Diet composition of all three carnivore species mainly included micromammals, invertebrates, birds, and plants.

Keywords Copro-parasitology · Chrea National Park · Algeria · Mesocarnivores · Wild mammals · Diet composition · Endoparasites

Introduction

Carnivorous mammal species play an important role in the biocenosis by participating in the regulation of animal populations and maintaining the balance of ecosystems. The study of this role has been restricted by some work done in North Africa, including in Morocco by Aulagnier (1990), Aulagnier et al. (2008) and Cuzin (2003), in Algeria by Ahmim (2019), and in Tunisia by Dalhoumi et al. (2018). In addition, predators and carnivores ensure a fundamental role in ecosystem health integrity by cleaning up livestock animal carcasses and corpses. In this context, several studies highlighted the role of carnivores such as the red fox *Vulpes vulpes* (Linneaus, 1758), African golden wolf *Canis lupaster* (Hemprich and Ehrenberg, 1832) and striped hyena *Hyaena hyaena* (Linneaus, 1758) in North Africa and Mediterranean southern Europe. The most relevant studies include De Smet and Hamdine (1988) and Kowalski and Rzebik-Kowalska (1991) in Algeria, Aulagnier (1990) and Thévenot et al. (2019) in Morocco, Lahmar et al. (2009) in Tunisia, Le Berre (1990), Marguet (1991), Marguet et al. (1993) and Cuzin (2003) in France, and Padial et al. (2002) in Spain.

In Algeria, these three carnivorous species have been the subject of very few studies. However, Sellami et al. in 1989 worked on the distribution of mammals in Algeria in the wildlife reserve of mammals from Mergueb to M'sila, in which feeding habits were determined, particularly for discrete and difficult-to-observe mammal species. Therefore, knowing accurately the diet, foraging habitats and feeding habits, and shelter for each species is essential to establishing conservation measures. In this context, few studies on the trophic ecology of carnivores have been conducted, citing those of Alam and Khan (2015) on *Hyaena hyaena* in India, Bhandari et al. (2015, 2020, 2021) in Nepal and Bentabet 2016 in the Tlemcen Game

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Reserve. The aim of this work was to shed light on the diet composition of three wild carnivores (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) in Chrea National Park (CNP) on the basis of feces analysis. This study is related to food resource availability in the studied environments. As mentioned above, no research at the level of Chrea National Park had been carried out previously on the diet of the target species.

Furthermore, wild carnivores represent an important reservoir of many endoparasites. Indeed, more than 75% of human diseases are of wildlife-related zoonotic origin (Taylor et al. 2001). In this context, this study represents a copro-parasitological investigation of the three wild carnivores at Chrea National Park. These include *Vulpes vulpes*, *Canis lupaster*, and for the first time in Algeria *Hyaena hyaena*. In addition to being a vital reservoir of parasitological-wildlife diseases, wild carnivores can harbor parasitic microorganisms whose hosts are other synantropic animals (Zajac et al. 2000). Overall, studies on internal parasites of carnivores carried out in Algeria remain rare and fragmentary (e.g. Marniche et al. 2018). The objective of this investigation is to highlight the prevalence of intestinal parasites in the target wild mammals based on analysis of different forms of parasite fauna excreted in the feces of these animals.

Materials and methods

Study area and sampling sites

This study took place in Chrea National Park (CNP) in northern Algeria, located 50 km southwest of the capital Algiers (Fig. 1). It stretches over 26,587 ha along the central parts of the Atlas Tellian range (from 36°19 to 36°30′ N, and from 2°38 to 3°02′ E). It consists mainly of forests and shrublands of montane habitats. The collection of feces was carried out at CNP in five sites, namely Oued El Marja, Tibenkent, Beni-Selmen, Tamesguida, and Chrea (Fig. 2). Located far away from human activities and disturbances, these sites provide necessary food sources for the study of carnivorous mammals, especially the striped hyena (carrion, carcasses, small mammals, fruit, insects, plants, birds, and small vertebrates).

Sampling and feces collection

A total of 48 droppings of wild carnivores were collected in natural habitats at CNP, of which 15 belonged to *Hyaena hyaena*, 15 to *Vulpes vulpes*, and 18 to *Canis lupaster* (Table 1). The collected feces were kept in sterile boxes tagged with the date, name of the species, and the station before being transported to the zoology laboratory at the National School of Veterinary Medicine (ENSV) in

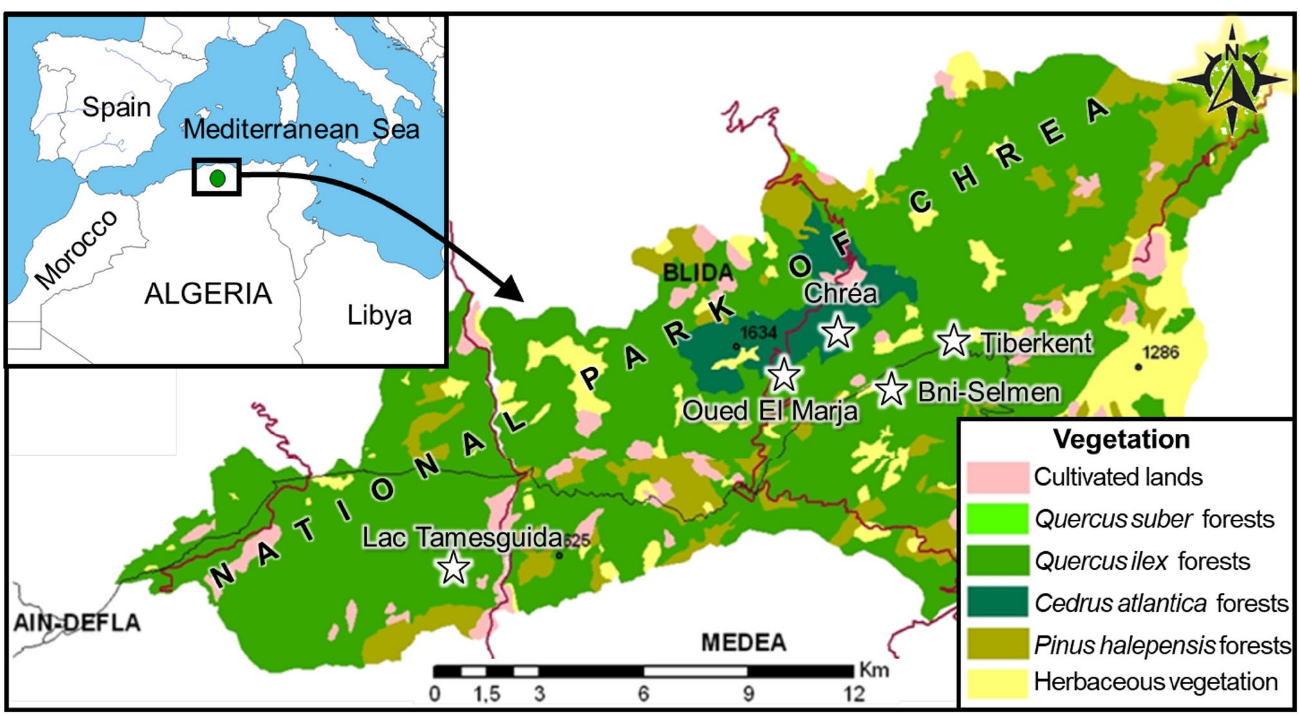

Fig. 1 Location and vegetation map of Chrea National Park in northern Algeria

Fig. 2 Landscapes of the collection sites of feces of the studied wild mammals at Chrea National Park in Algeria (**A**: Beni-Selmen, **B**: Tiberkent, **C**: Chrea, **D**: Oued El Mardja, **E**: Lake of Tamesguida)

El Alia (Algeria) for screening and analysis. All samples were stored under sterile conditions at a temperature of 4 °C until further processing. To identify the droppings of each carnivore, we used identification guides of feces of wild mammals (Cavallini 1995; Krofel and Potonik 2008; Temple and Cuttelod 2009; Gaubert et al. 2012; Chris and Mathilde 2013; Eddine et al. 2017; Gilles 2018). The identification criteria for the feces, footprints, and traces of the three wild canids around CNP are given in Table 2 and Fig. 3. All procedures were carried out in compliance with the ethical committee of the Faculty's standards and regulations. The study was performed following ARRIVE guidelines and UK Animals Act 1986 and associated guidelines, and it was conducted according to the guidelines of the Saad Dahleb University (Blida 1) Ethics Committee.

Diet composition analysis in droppings

Diet composition was examined based on prey remains found in feces of the three wild carnivores. Feces were processed and analyzed according to these in-succession steps: decortication, alcoholic wet maceration, trituration, separation of the different elements, and finally observation under a binocular microscope (magnifications: 10× and 20×). The approach used here followed the protocols conceived by Aryal et al. (2012, 2014) and Koirala et al. (2012) to ascertain what prey was eaten by each mammal, especially the

Table 1 Feces site locations, elevation, date of sampling, and number of feces collected for three wild mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) at Chrea National Park in Algeria

Target mammal species site location	Elevation (m)	Sampling date	Sample size (droppings)
Red fox (*Vulpes vulpes*)			
Lake of Tamesguida	1230	11 April 2018	8
Hamdania	850	19 February 2018	7
African golden wolf (*Canis lupaster*)			
Beni-Selmene	750	19 February 2018	7
Chrea	1400	9 March 2018	2
		6 April 2018	2
Lake ofTamesguida	1230	14 March 2018	4
		11 April 2018	3
Striped hyena (*Hyaena hyaena*)			
Oued El Mardja	380	2 April 2018	11
Tiberkent	850	10 April 2018	4

Table 2 Criteria for the identification of feces and tracks of *Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*, three wild mammals living in Chrea National Park

Mammal species	Feces color and morphology	Footprint characteristics
Vulpes vulpes	Beige to black: color variation depends on the food ingested, feces rounded at one end pointed or twisted by the hair at the other end	Footprint is same size of a feral dog. It is however possible to differentiate it by the position of the pads: unlike dog, the straight line passing through the top of the outer pads passes almost below the inner pads
Canis lupaster	Feces is deposited on animal tracks at the ground level, either on low vegetation or on stones. Excrements have a characteristic odor similar to that of the sulfur	It strongly resembles that of the wolf or the feral dog; this one is imposing, the claws can be clearly seen
Hyaena hyaena	Excrements are generally large, white in color deposited on the latrine sites. The whiteness of the droppings results from the large quantities of bone fragments consumed by the hyena. Feces are generally very elongated from 4 to 53 cm, assembled with a diameter of 1–4 cm	It leaves very noticeable traces in the sand; its back pad is double and its claws clearly visible. Among the signs of presence, these leave bones scattered on the ground as well as garbage

Description of feces and footprints follows these references (Cavallini 1995; Krofel and Potočnik 2008; Tempele and Cuttelod 2009; Gaubert et al. 2012; Chris and Mathilde 2013; Eddine et al. 2017; Gilles 2018)

Striped hyena. Furthermore, prey of *Vulpes vulpes* and *Canis lupaster* were further determined according to the protocol proposed by Hamdine et al. (1993). For each target carnivore species, we referred to our own collection of mammal hair samples available at the Zoology Laboratory of National Higher Veterinary School (ENSV) in Algeria to some prey species.

Copro-parasitological analysis

Parasites in feces were examined using both the flotation technique (Sivajothi et al. 2014; Hendrin and Robinson 2016) and modified Ziehl–Neelsen coloring technique. Then, the found pathogens were determined under optical microscope (magnifications 10×, 40×, and 100×) using standard keys of identification (Zajac et al. 2021). The flotation method was implemented for the excrements of the three mammals because it is simple and fast to use. It is the most commonly used technique in veterinary medicine for the examination of droppings. This process concentrated the parasitic elements from a small amount of excrements and traced those with low density on the surface. The flotation method had a simple principle: because the eggs have a shell that protects them from external harmful conditions and/or agents, they tend to float on the surface of dense liquids. However, heavier residues or those that rapidly absorbed the liquid felt into the bottom of the container. This technique has the advantage of simplicity, execution speed, and low cost since only NaCl was needed for liquid preparation. However, this salt solution easily enters the egg, which then deforms it because the NaCl solution tends to crystallize quickly and make identification difficult after a certain time. To avoid such method limitations, the technical protocol recommend for the quantification of each parasite is that the prescribed time should be in the range of 15–20 min. Using a magnification 10× of an optical microscope, slides were

Fig. 3 Photos displaying footprints and feces of the red fox (*Vulpes vulpes*) (**A**, **B**), African golden wolf (*Canis lupaster*) (**C**, **D**) and Striped hyena (*Hyaena hyaena*) (**E**, **F**) in Chrea National Park, Algeria

scanned and read in one direction, horizontally or vertically. During the time mentioned above (15 min), and for each slide (containing the items of a feces), the number of each parasite and prey species was counted individually with a microscope magnification 40×. Species were identified following keys and related dichotomous books.

Data analysis

Mammals' diet was studied through the computation of the following parameters: the frequency of relative abundance (RA), which is the percentage of individuals of a species in relation to the total number of individuals of all species combined RA (%) = Ni/N × 100, where Ni is the number of individuals of a given prey species, and N the total number of individuals of all species combined. Finally, the parasite statistical analyses were realized by means of the software "Quantitative parasitology V 3.0." (Rozsa et al. 2000) to process parasite prevalence.

The dependency in the distribution of ectoparasite abundances among the three carnivore species was tested using Pearson's chi-squared test at $\alpha = 0.05$. Similarity of endoparasites between the studied carnivorous mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) was estimated on the basis of species richness using Jaccard similarity index (I_J) and based parasite abundance using Morisita–Horn index (I_{MH}). The partitioning and overlap of endoparasite species among the carnivorous mammals was displayed using a three-set Venn diagram.

Results and discussion

Diet composition and analysis

The number of prey species was higher in *Canis lupaster* (six species), followed *Hyaena hyaena* (five species), and *Vulpes vulpes* (one species). In the striped hyena, the analysis of fecal samples showed the presence of small vertebrates (*Gallus* spp. and *Atelerix algirus*), while *Canis lupaster* had parts of other mammals and insects such as *Oryctes* spp. and *Aphodius* spp. (Table 3). The trophic spectrum of *Hyaena hyaena* was more versatile and broader, consisting of vertebrates, insects, plants, and human wastes. Prey birds of the genus *Gallus* were a major component of its diet. Plants, soil, stones, human solid waste, and, to a lesser extent, insects and hedgehogs, were a complement to its trophic regime. While the diet of predators can be explored using several methods (Chenchouni 2014) including the analysis of fecal samples using serological and radioactive approaches, polymerase chain reaction (PCR) can be also used to identify the carnivore species itself from the collected fecal samples. This method relies on amplifying specific DNA markers that are unique to different species, allowing for accurate species identification (Kelly et al. 2012).

The variability in *Hyaena hyaena* diet has been reported by Kruuk (1976) and Wagner (2006), which emphasizes the generalist nature and trophic opportunities of this carnivore. On the other hand, Bentabet (2016) found in droppings of *Hyaena hyaena* at the hunting reserve of Tlemcen 16 food items including fruits, leaves and other plant fragments, wild and domestic animals, and soil and waste of human origin. The remains of animals represent 96.08% of the biomass consumed per striped hyena, while plant material represents 3.92%.

Furthermore, the red fox consumes more plants, including fruit (99.64%), than insects (0.36%). This is consistent with the findings of several researchers (Fortin 1995; Chourasia et al. 2012), who describe the fox as omnivorous, opportunistic, and generalist. Aziz and Boudjema (2016) analyzed 87 red fox feces from three locations in Algeria, distributed as follows: 18 feces from El Kala, 48 from Ait Zellal, and 21 from Ighil Bwougni, which led to the identification of 57 items for El Kala, 157 for Ait Zellal, and 65 for Ighil Bwougni. Seven food categories were consumed by foxes, including energetic plant organs (fruits and berries), non-energetic plants (grasses), birds, arthropods, and finally man-made wastes. Other food categories such as bones and eggs are also considered as separate food categories found in fox's feces. Small mammals constitute the most important part of the fox's diet with an occurrence frequency of 22.22%, followed by energetic plants (19.71%), non-energetic plants (16.85%), birds (15.77%), and arthropods (14.7%), then other categories (eggs and bones) with 6.81%, and solid wastes (3.94%). Few studies considered the diet of *Canis lupaster* in Algeria (Oubellil 2011; Eddine et al. 2017). However, in East Africa, studies indicated that more than 60% of the species' diet consisted of rodents, lizards, birds, snakes, hares, and Thomson's gazelles (Jhala and Moehlman 2004), although it also consumes invertebrates and fruits (Amroun et al. 2006). It adopts a heterogeneous and diverse diet while it feeds mainly on mammals. When conditions are difficult, *Canis lupaster* diet varies according to the food resources available in its foraging habitats (Bothma 1966, van Lawick Goodall and van Lawick, 1970). Studies of hyenas (Kruuk 1976; Hofer and Mills (1998) and red foxes (Macdonald 1977) demonstrated that the positioning

Table 3 Number of individuals (Ni) and relative abundance (RA in %) of animal-prey and plant species found in feces of three wild mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) at Chrea National Park in Algeria

Class	Order	Family	Species	Ni	RA (%)
Mammal species: striped hyena (*Hyaena hyaena* L. 1758)					
Insecta	Diptera	Calliphoridae	*Chrysomyia* sp.	10	27.78
Insecta	Diptera	Muscidae	*Musca* sp.	03	08.83
Aves	Galliformes	Phasianidae	*Gallus* sp.	12	33.33
Mammalia	Erinaceomorpha	Erinaceidae	*Atelerix algirus*	01	02.78
Pinopsida	Pinales	Pinacea	*Pinus* sp. (leaves)	10	27.78
Mammal species: red fox (*Vulpes vulpes* L.1758)					
Insecta	Coleoptera	Staphyllinidae	*Anotylus* sp.	01	00.36
Mammal species: African golden wolf (*Canis lupaster* H. and E. 1832)					
Insecta	Coleoptera	Scarabaeidae	*Oryctes* sp.	01	04.17
Insecta	Coleoptera	Aphodiidae	*Aphodius* sp.	11	04.83
Insecta	Hymenoptera	Formicidae	*Lasius* sp.	02	08.33
Plantea	Plantea ind	Plantea ind	Plantae sp. ind. (seeds)	03	12.50
Magnolipsida	Fagales	Fagaceae	*Quercus* sp. (seeds)	03	12.50
Pinopsida	Pinales	Pinaceae	*Cedrus atlantica* (leaves)	04	16.67

and distribution of feces may have an important interspecific communication function in carnivores, especially in marking specific territories. However, opportunistic foraging behavior allows the wolf to successfully compete and co-exist with ecologically similar carnivores across its wide North African range (Eddine et al. 2017).

Copro-parasitological examination

Parasite composition

The coprological analysis and parasitological diagnosis revealed the presence of different parasites with quantification of helminth eggs and larvae, and protozoan (oocysts of coccidian), in the excreta of three studied wild carnivores. The analysis showed that feces of *Hyaena hyaena* were infested by three genera of parasitic species, whereas those of *Vulpes vulpes* and *Canis lupaster* included five and six species, respectively. The results showed that the nematodes (e.g. *Ancylostoma caninum*, *Strongyloides stercoralis*, *Toxocara canis*, and *Toxocara* spp.) were the most common endoparasites found in all surveyed carnivores (Table 4, Fig. 4).

In terms of parasite abundances, *Ancylostoma caninum* were the dominant ectoparasites in *Hyaena hyaena* (86%) and *Canis lupaster* (79%), whereas *Cryptosporidium* spp. (38%) and *Toxocara canis* (32%) co-dominated in *Vulpes vulpes* (Fig. 5). *Ancylostoma caninum* and *Strongyloides stercoralis* represented 16% and 11% of the total parasites of *Vulpes vulpes*, respectively. The other ectoparasites had low relative abundances (> 7%). Pearson's chi-squared test revealed significant difference in the distribution of ectoparasite abundances among the three carnivore species ($\chi^2 = 672.4$, $df = 14$, $p < 0.0001$).

While the presence of *Strongyloides stercoralis*, *Cryptosporidium* spp., and *Ancylostoma caninum* was reported in all host species, *Toxocara* spp., *Toxocara canis*, and *Trichuris vulpis* parasitized exclusively *Canis lupaster*, whereas *Isospora* spp. and *Eimeria* spp. parasitized exclusively *Vulpes vulpes* (Fig. 6). The highest qualitative similarity score ($I_J = 60.0\%$) was observed between *Vulpes vulpes* and *Hyaena hyaena*, then between *Canis lupaster* and *Hyaena hyaena* ($I_J = 50.0\%$), which showed the highest abundance-based similarity ($I_{MH} = 98.4\%$).

Parasite prevalence

In striped hyena, the most dominant parasites were the embryonated eggs of *Ancylostoma caninum* (84%). In the red fox, the most common parasite was *Toxocara canis* with 32%. While in the African golden wolf, *Ancylostoma caninum* eggs (54%) were most prevalent (Fig. 7). Out of a total of 15 droppings of the striped hyena, high rates of infestation were found by *Ancylostoma caninum* (eggs), *Strongyloides stercoralis* (larvae), and *Cryptosporidium* spp. (oocyte), with a parasite prevalence of 100%, 86.7%, and 80%, respectively. However, we noted a low infestation rate of larva of *Ancylostoma caninum* (6.7%) and rare species have been recorded for *Ancylostoma caninum* (larvae) (Fig. 7a). On a total of 18 feces of *Canis lupaster*, we found a significant level of *Ankylostom* spp. (embryonated eggs and eggs), *Isospora* spp. (nonsporulated eggs), *Cryptosporidium* spp. (oocysts), and *Eimeria* spp. (nonsporulated eggs), which represented 100%, 94.4%, and 72.2%, respectively (Fig. 7b). In contrast, the species *Trichuris vulpis* (eggs) and *Strongyloides stercoralis* (larva) had a low prevalence (44.4% and 5.6%, respectively). The examination of 15 red fox's feces resulted in a high infestation rate of *Toxocara canis* (eggs) (100%), *Cryptosporidium* spp. (oocyst) (86.7%), *Strongyloides stercoralis* (eggs) (66.7%), *Ancylostoma caninum* (larva) (53.3%), *Ancylostoma caninum* (eggs) (33.3%), and *Toxocara* spp.

Table 4 Abundances of endoparasites found in feces of the three wild mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) at Chrea National Park in Algeria

Taxa	Parasite life stage	*Hyaena hyaena*	*Vulpes vulpes*	*Canis lupaster*
Phylum: Nematoda				
Ancylostoma caninum	Embryonated eggs	365	5	210
Ancylostoma caninum	Non-embryonated eggs	37	2	210
Ancylostoma caninum	Larvae	1	8	52
Strongyloides stercoralis	Larvae (L1)	33	10	2
Toxocara canis	Eggs	0	30	0
Toxocara spp.	Eggs	0	4	0
Trichuris vulpis	Eggs	0	0	11
Phylum: Protozoa				
Eimeria spp.	Non-sporulated oocytes	0	0	21
Isospora spp.	Oocytes	0	0	61
Cryptosporidium spp.	Oocytes	30	36	30
Total (4 helminth species and 3 protozoan genera)	Total	466	95	597

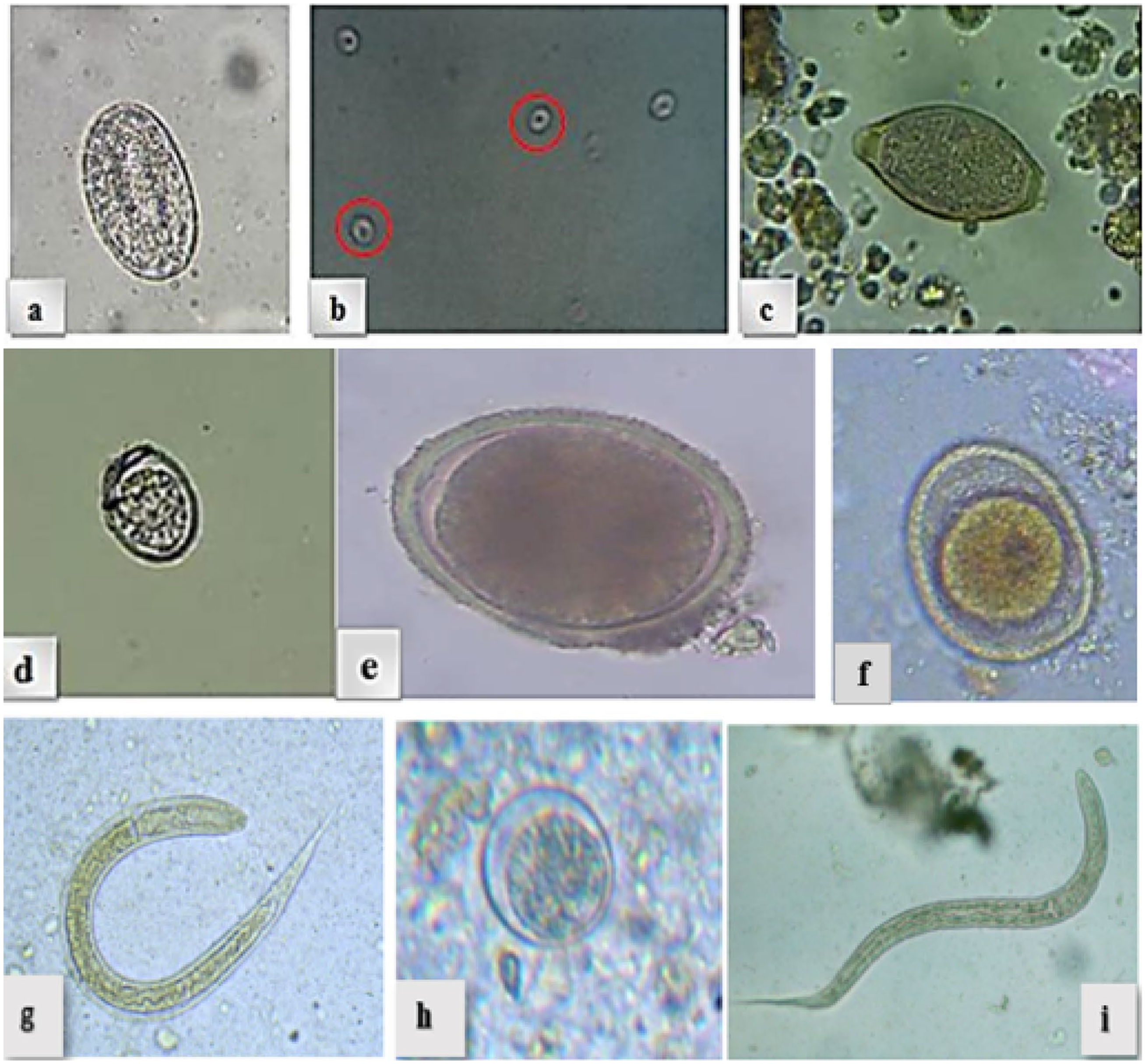

Fig. 4 Low-magnification optical microscope images of endoparasites found in feces of three wild mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) at Chrea National Park in Algeria **a** egg of *Ancylostoma caninum* (magnification 40×); **b** oocyst of *Cryptosporidium* sp. (magnification 40×); **c** egg of *Trichuris vulpis* (magnification 40×); **d** oocyste of *Eimeria* spp. (magnification 10×); **e** egg of *Toxocara canis* (magnification 40×); **f** egg of *Toxocara* sp. (magnification 40×); **g** larvae of *Strongyloides stercoralis* (magnification 40×); **h** oocyst of *Isopspora* sp. (magnification 40×); **i** larvae of *Ancylostoma caninum* (magnification 10×)

(eggs) (20%). However, *Ancylostoma caninum* (egg) had a low infestation rate of 6.3%. Satellite species are recorded for *Ancylostoma caninum* (eggs) and *Toxocara* spp. (eggs). Finally, *Ancylostoma caninum* (eggs) was classified as a rare species (Fig. 7c).

As a result, analysis of the 48 fecal samples allowed the identification of 11 parasite species. The reason for the dominant presence of nematodes and protozoa in all of this wildlife may be related to the climatic conditions in the study area because most samples were taken near water points. Our results indicated no trematode infestation, which are quite in line with those of Laborde (2008), in the Mercantour National Park (France) and Leslie (2015) in urban suburban habitats of France, which marked a very low rate of trematode infestation.

In Tunisia, Lahmar et al. (2014) identified 12 helminth species in 9 red foxes, which indicated higher parasite diversity and prevalence. Their findings included Cestoda: *Dipylidium caninum* (55.6%), *Diplopylidium noelleri* (55.6%), *Mesocestoides lineatus* (55.6%), *Mesocestoides*

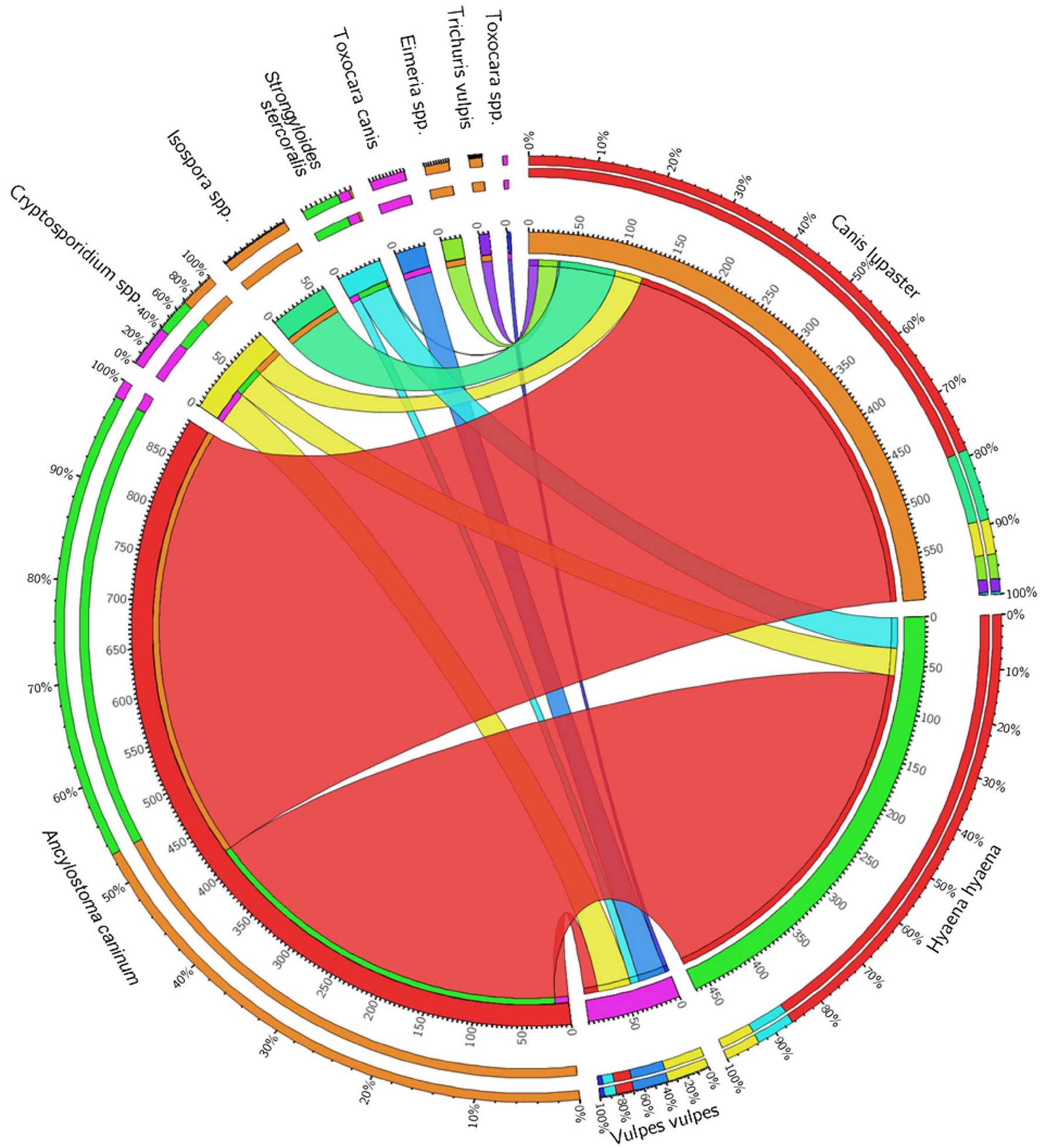

Fig. 5 Cord diagram displaying the abundance-based distribution of ectoparasite taxa for the carnivorous mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) in Chrea National Park in Algeria

litteratus (33%), *Mesocestoides corti* (22%); Nematoda: *Ancylostoma caninum* (11%), *Uncinaria stenocephala* (44%), *Spirura rytipleurites* (11%), *Trichuris vulpis* (33%), *Pterygodermatites affinis* (67%), *Oxynema linstowi* (33%), and Acanthocephala: *Macracanthorhynchus hirudinaceus* (22%).

In addition, the study of Marniche et al. (2018) of red fox endoparasites in the Réghaia marsh revealed the presence of *Strongyloides stercoralis* with a rate of 31.82%, followed by *Uncinaria*, *Ancylostoma*, and *Eimeria*, each with 22.73%. Deppiere (1999) also determined a prevalence of 40% and 24% for *Uncinaria* and *Toxocara* in red fox at Ain (France). The dominance of nematodes is related to the corporal aspect of the parasite (Worley 1987). Putignani and Menichella (2010) have explained that parasite protozoa, such as *Eimeria* spp., *Isospora* spp., and *Cryptosporidium* spp., prefer living in water or at least in wet or humid earth. Wild mammals are an important reservoir of parasitological fauna. With urban sprawl, the risk of disease transmission to human is increasing. There are several parasite species found in wild carnivores that

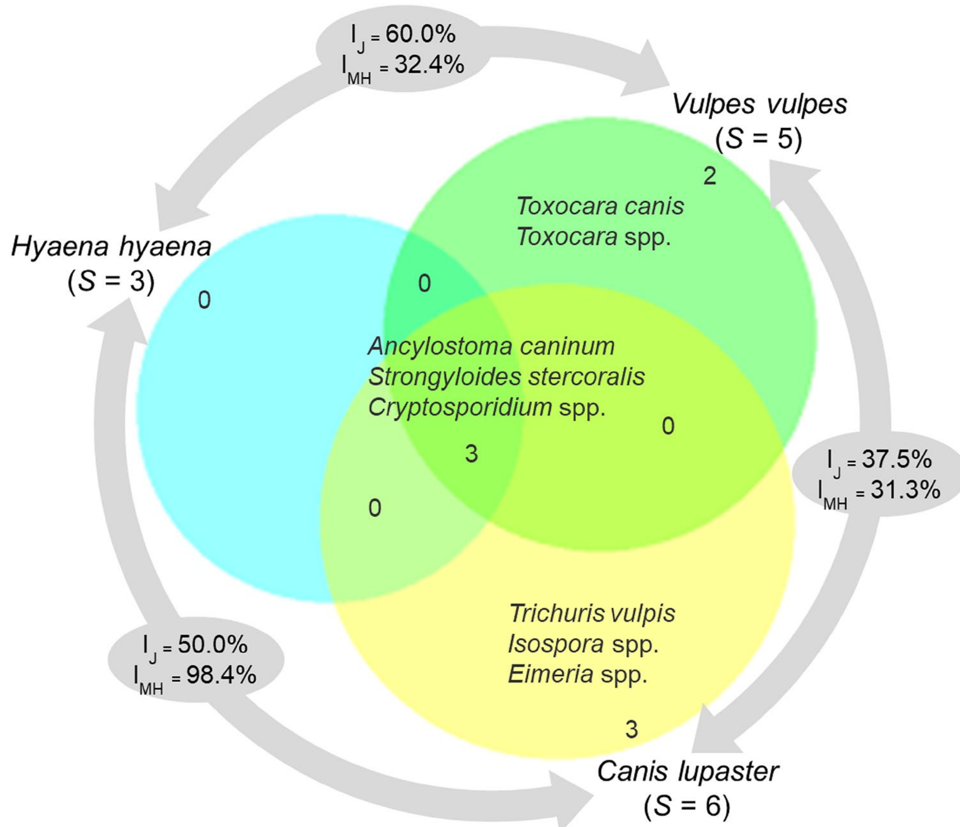

Fig. 6 Three-set Venn diagram showing overlap of species richness (*S*) of endoparasites between carnivorous mammals (*Hyaena hyaena*, *Vulpes vulpes*, and *Canis lupaster*) in Chrea National Park in Algeria. Values (in %) reported within gray arrows refer to similarity scores between the carnivores using the classic Jaccard index (I_J) and Morisita–Horn index (I_{MH})

can pose a risk of disease transmission to humans. The notable parasites found in canids include (1) *Echinococcus* spp., which causes hydatid disease with eggs of the tapeworms that are shed in the feces of infected animals and can be ingested by humans through contaminated food or water (Ohiolei et al. 2020); (2) *Toxoplasma gondii*, which causes toxoplasmosis, transmitted to humans through contact with canid feces or consumption of undercooked meat; (3) *Trichinella* spp., which causes trichinellosis, where these roundworms can infect humans by consuming raw or undercooked meat from infected animals (Veronesi et al. 2023); (4) *Sarcoptes scabiei*, which causes sarcoptic mange, a highly contagious skin disease in a variety of mammalian species [while the mites themselves do not directly infect humans, they can cause temporary skin irritation if they come into contact with human skin (Gherman and Mihalca 2017)]; and (5) rabies virus, though not a parasite, transmitted from wild carnivores, a deadly viral disease that can be transmitted to humans through the bite or scratch of an infected animal (Cypher et al. 2017). It is important to note that the risk of disease transmission from wild carnivores to humans is relatively low, but it is still important to take precautions when interacting with wildlife and handling or consuming their carcasses. Proper hygiene, cooking meat thoroughly, and avoiding contact with wild animal feces are key preventive measures.

Conclusion

This study provided, for the first time, a coprological data and diet composition of the newly described African golden wolf (*Canis lupaster*), *Vulpes vulpes*, and *Hyaena hyaena* from CNP. Copro-parasitological exploration revealed the presence of helminth nematode species (*Ancylostoma caninum*, *Toxocara canis*, *Strongyloides stercoralis*, and *Trichuris vulpis*), and Protozoa (*Cryptosporidium* spp., *Isopora* spp., and *Eimeria* spp.). The results of diet composition showed the generalist feeding character of *Hyaena hyaena* as well as the opportunistic use strategy of feeding resources by *Canis lupaster* and *Vulpes vulpes*. This study suggests that *Hyaena hyaena* is characterized by versatility in its trophic spectrum, which consists of a wide variety of items (vertebrates, insects, plants, anthropogenic waste). The African golden wolf and red fox seem to have a preference for insects and plants during spring rather than vertebrate prey. Though this study surveyed three wild carnivores at CNP and determined some aspects of feeding and ecology, it would be interesting to examine

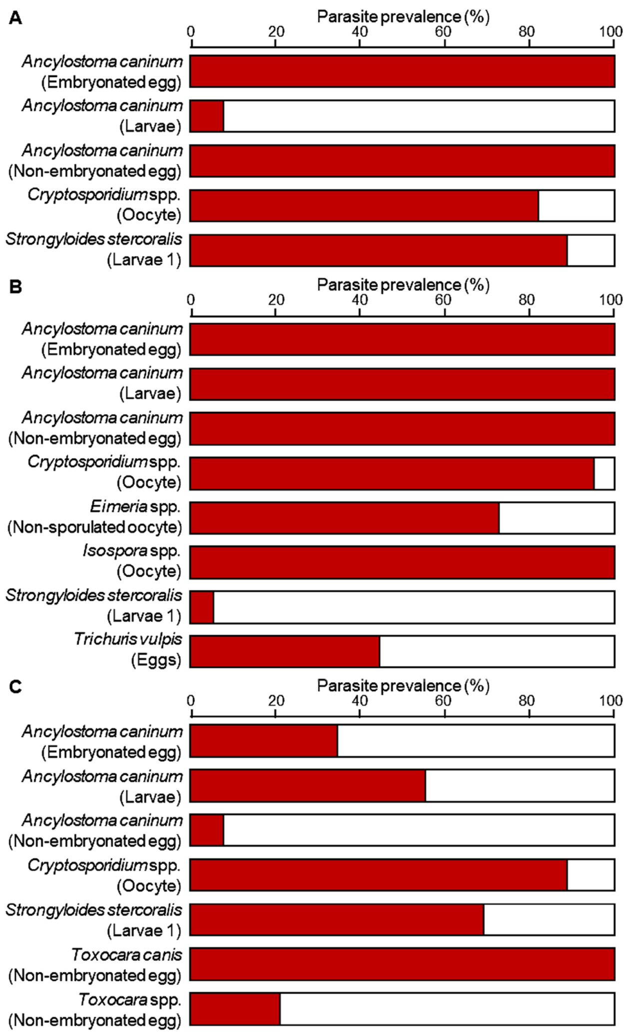

Fig. 7 Prevalence of endoparasites found in feces of the three mammals (**a**: Striped hyena, **b**: African golden wolf, **c**: Red fox) at Chrea National Park in Algeria. Prevalence values (in %) were computed with the software "Quantitative Parasitology V 3.0"

these aspects seasonally at larger geographic scale in North Africa.

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Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of animal rights No animal suffered during the course of the experiment. All the animal studies were conducted with the utmost regard for animal welfare, and all animal rights issues were appropriately observed.

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