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Acute Abomasitis and Sand Impaction in a Captive Sand Gazelle (*Gazella marica*): Implications for Feeding Behavior and Management

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ABSTRACT

An adult male sand gazelle (Reem, *Gazella marica*) in captivity was found dead at the Biodiversity Center (BDC) in Oman. Post-mortem examinations revealed acute abomasitis resulting from sand impaction and considerable nematode burden. Histopathological and parasitological analyses identified substantial loads of *Camelostrongylus mentulatus* (1350 eggs per gram) and *Nematodirus spathiger* (2450 eggs per gram). Molecular investigations at the internal transcribed spacer (ITS-2) confirmed both parasites. The impaction caused pressure on the thoracic cavity, resulting in lung congestion. Geophagia is hypothesized as a potential contributing factor as a behavioral adaptation to a mineral-deficient diet, wherein soil ingestion supplies essential nutrients crucial for digestion and skeletal health. Analysis of the feed provided at BDC confirmed these deficiencies and supported this assumption. These findings indicate a possible deficiency of phosphorus and cobalt, along with a secondary magnesium deficiency caused by elevated potassium levels. Further investigation into the feeding behavior of captive gazelles is strongly recommended.

Keywords: Abomasum; Sand impaction; Strongyle-type eggs; Sand Gazelle.

INTRODUCTION

The sand gazelle (*Gazella marica*), commonly referred to as reem, is a native species of West Asia, highly esteemed for its remarkable adaptations to the harsh arid climates of the Arabian Peninsula (Wacher et al. 2011, Anderson et al. 2016; Giangaspero et al. 2025). This species primarily inhabits sandy dunes and coastal plains, avoiding steep and rocky terrains (Al Jahdhami et al. 2017). Reem favors a diet consisting mainly of woody plants rather than grasses, illustrating their unique foraging behavior. They are particularly adept at reaching elevated foliage by standing on their hind legs, showcasing both agility and resourcefulness to access optimal food sources (Wronski and Schulz-Kornas 2015).

In a controlled environment, the social behavior of these gazelles undergoes a significant transformation when multiple males are confined together, often leading to heightened competition. This competitive dynamic can lead to increased social tensions and aggressive encounters as males compete for limited food resources (Horwitz et al. 1990; Soares et al., 2021). In such situations, animals may resort to geophagia, the practice of consuming soil, to cope with nutritional insufficiency. Geophagia has been recorded in various wild animals, including deer (Stepanova et al. 2019), wild goats (Slabach et al. 2015) and Bengal tigresses (Hernández-Aco et al. 2022), highlighting a shared adaptive strategy to meet their metabolic demands when resources are scarce. The condition resulted in sand impaction, which has been reported as an occasional cause of death in some animal species, including equines and white-tailed deer (Bianchi et al. 2020; Rahmani Shahraki et al. 2024). Furthermore, geophagia may result in secondary abnormal health conditions that could be linked to a decrease in the passage of ingesta through the intestine, dehydration, electrolyte imbalance, and malabsorption of trace minerals (Rahmani Shahraki et al. 2024).

Gastrointestinal parasitism is consistently reported as common in both captive and free-ranging gazelles. In mountain gazelles (*Gazella gazella*) from Türkiye, helminths were detected in 57.8% of examined animals (11/20 captive; 15/25 free-ranging), with higher helminth diversity in free-ranging individuals, underscoring

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substantial parasite exposure in natural habitats as well as in captivity (Karaer et al. 2024). Mixed-species zoo and wildlife surveys that included gazelles have generally reported gastrointestinal parasite prevalences of approximately 40–50%, involving multiple nematode and protozoan taxa and suggesting that subclinical parasitism is widespread in captive collections (Thawait et al. 2014; Lahat et al. 2021; Zerek et al. 2022; Abdullahi et al., 2023; Ahmad et al. 2024). Among these gastrointestinal parasites, strongyle nematodes, poses significant health risks to captive ungulates (Said et al. 2018). Species such as *Camelostrongylus mentulatus* and *Nematodirus spathiger* have been identified in various wild ruminants (Ortiz et al. 2001; Pato et al., 2013; Al-Habsi et al. 2017; Gibbons et al. 2018). These parasites can cause abomasitis, characterized by inflammation, ulceration, and impaired digestive function (Simpson et al. 1997; Simcock et al. 1999; Magdálek et al. 2021). In captive ruminants, regular coprological and clinical monitoring with targeted therapy only when fecal egg counts rise significantly is recommended (Lahat et al. 2021).

Sand impaction in the abomasum poses a critical threat to ruminant health because it occurs when excessive amounts of sand accumulate in the digestive system, most commonly in the abomasum and intestines. This accumulation can lead to severe blockage, disrupting the normal flow of digestive materials (Simsek et al. 2015; Constable et al. 2017). As a result, the gazelle may experience severe digestive obstruction, causing intense pain and discomfort. The condition can impair their ability to absorb vital nutrients, leading to further complications if left untreated. Ultimately, this affliction can lead to mortality if not addressed promptly (Navarre and Pugh 2009). Anderson et al. (2016) reported a 16% incidence of gastrointestinal issues in captive gazelles caused by substrate ingestion, including sand. Such sand impaction often arises from abnormal feeding behaviors, usually linked to nutritional deficiencies or environmental stressors that compel animals to consume sand inadvertently.

Geophagia behavior can also lead to increased parasitic infections, as observed in other species (Panichev et al. 2014). Captive ungulates face significant health risks from gastrointestinal parasitism, particularly strongyle nematodes, which can severely impact their well-being (Said et al. 2018). Several parasitic species, including *Camelostrongylus mentulatus* and *Nematodirus spathiger*, have been detected in various wild ruminants (Al-Habsi et al. 2017; Gibbons et al. 2018). The presence of these parasites can lead to abomasitis, a serious condition marked by inflammation, ulceration, and impaired digestive function, which poses risks to the health and survival of affected animals (Simpson et al. 1997; Simcock et al. 1999; Reeves et al. 2024). Parasites can damage the abomasal mucosa, raise abomasal pH, and impair digestion of protein and energy, so animals need more feed per unit of gain and often lose body condition (Li et al. 2016). Furthermore, Protein loss, anemia, and altered gut function from parasitic abomasitis compromise immunity, making affected animals more prone to secondary bacterial, parasitic, and metabolic diseases (Van Metre at al. 2008). However, the control of these parasites can be accomplished through the implementation of effective practices in intensive livestock farming, maintenance of environmental hygiene, and a comprehensive deworming program (Khan et al. 2023).

In Oman, the sand gazelle (Gazella marica) persists mainly in protected desert areas, but wild populations are small and fragmented, reflecting its vulnerable conservation status (Giangaspero et al. 2025). While free-ranging numbers are limited, large captive and semi-captive herds are maintained in enclosures and breeding centers. These populations are considered an important conservation reservoir, with planned releases in Oman using Reem gazelles (*G. marica*) to reinforce or re-establish wild groups in suitable desert habitats (Giangaspero et al. 2025). Although sand gazelles are known for their remarkable resilience in their natural habitats, limited research has examined their management practices and behavioral adaptations when held in captivity, particularly in Oman. This situation raises considerable concern, particularly in the context of the alarming report, which indicates substantial mortality rates in certain populations of these gazelles (Khurram et al. 2021). It may be considered unjust to draw parallels when analyzing the various challenges faced by the Arabian gazelle in captivity, especially when relying on assumptions regarding the health status of other ruminants in Oman (Elshafie et al. 2025).

The Arabian gazelle has distinct behavioral and physiological traits that differ significantly from those of other ruminants, such as goats or deer. These differences can lead to oversimplifications in understanding their unique needs and difficulties in a controlled environment. Accordingly, a thorough examination of the gazelle's requirements and conditions in captivity is necessary to ensure an accurate and informed assessment of its welfare. This case report aims to examine the circumstances associated with the death of a captive sand gazelle, meticulously investigating the interrelationships among geophagia, parasitic infections, and overall management of nutritional resources. By understanding these relationships, we hope to illuminate strategies that could enhance the welfare of this vulnerable species in captivity.

Case presentation

An adult male sand gazelle housed at the Biodiversity Center (BDC), Barka (Fig. 1), was observed with progressive abdominal distension persisting for approximately two weeks prior to death. The animal exhibited lethargy and isolation from the herd. These clinical signs suggested a significant digestive disorder. The gazelle died on December 15, 2024, and the carcass was immediately refrigerated and transported to Sultan Qaboos University Laboratory for post-mortem examination on December 16, 2024 (Fig. 2).

The BDC, managed by the Omani Environment Authority, focuses on local wildlife conservation, rehabilitation, research, and public education. Covering over 34,000 square meters, it houses various wild species and supports their return to natural habitats (Fig. 1). The animal was maintained in a semi-natural enclosure with access to native vegetation and supplementary feed. Multiple male gazelles were housed together in the facility. No previous medical interventions or deworming treatments were documented for this individual.

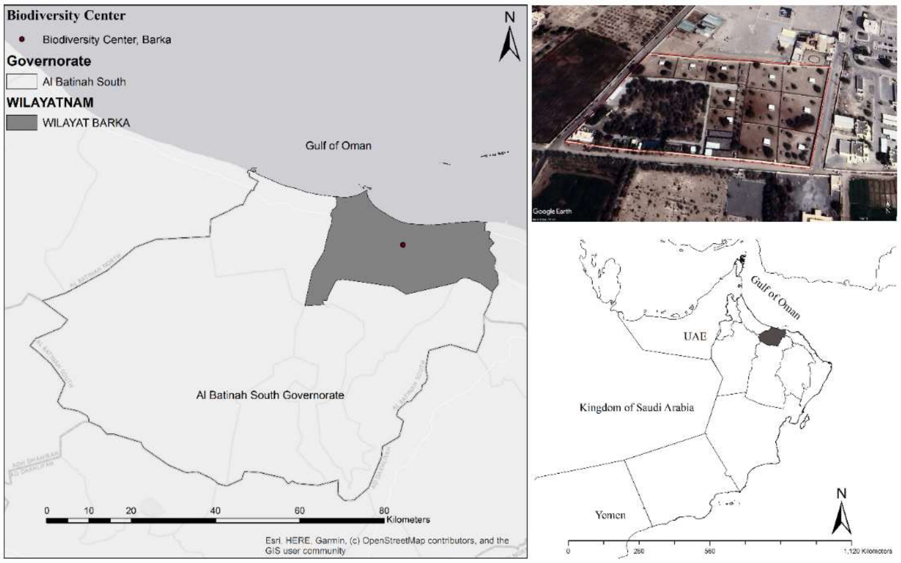

Fig. 1: Map showing the location and perimeter of the Biodiversity Center Barka in Oman.

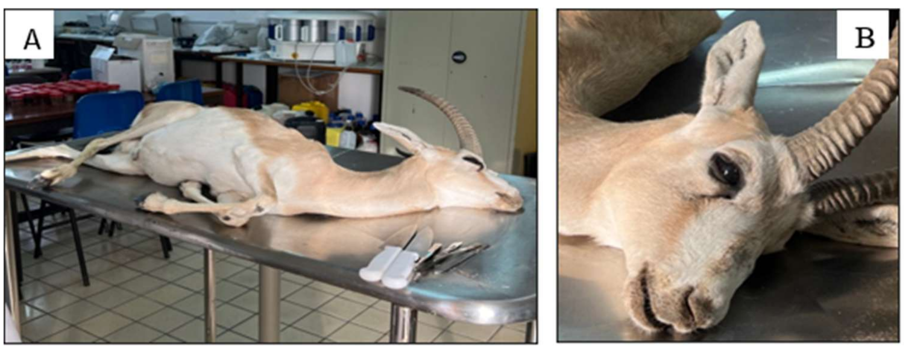

Fig. 2: Carcass of the deceased gazelle exhibiting emaciation and bloated abdomen, indicative of severe starvation and malnutrition (2A). Head of the deceased gazelle showing sand and dirt accumulation around the nasal area (2B).

Clinical examination and postmortem findings

Gross pathology

External examination revealed marked abdominal distension. Upon opening the abdominal cavity, the abomasum was severely distended and filled with approximately 2-3kg of sand mixed with ingesta resembling fecal-liquid consistency. The abomasal wall appeared thickened and edematous with areas of mucosal hyperemia (Fig. 3). The sand impaction extended throughout the entire abomasal lumen, creating a firm, consolidated mass.

Fig. 3: Dark rumen content, indicating the accumulation of ingested sand.

The thoracic cavity examination revealed bilateral lung congestion with edema (Fig. 4A), likely secondary to pressure effects from the distended abdomen on the diaphragm and thoracic organs (Fig. 4B). The liver and kidneys appeared grossly normal. The rumen contained partially digested plant material with minimal sand content. Both small and large intestines showed a mild to moderate parasitic burden with visible adult nematodes.

Histopathology

Microscopic examination of abomasal tissue sections revealed severe acute abomasitis characterized by mucosal ulceration, submucosal edema, and inflammatory cell infiltration predominantly composed of eosinophils, lymphocytes, and neutrophils. The lamina propria showed marked congestion and hemorrhage. Parasitic elements, including nematode larvae and adult worm cross-sections, were observed embedded in the mucosa.

Lung tissue sections demonstrated severe congestion, alveolar edema, and interstitial inflammation consistent with passive congestion secondary to increased intra-abdominal pressure (Fig. 4C). No evidence of primary pulmonary pathology was identified.

Sections from the small and large intestines revealed moderate parasitic enteritis with mucosal inflammation and villous atrophy in the small intestine.

Parasitological findings

Direct microscopic examination and fecal flotation analysis of samples from the abomasum and intestines revealed heavy burdens of strongyle-type eggs. Two distinct egg morphotypes were identified as larvated eggs characteristic of *Camelostrongylus* species and morulated eggs typical of *Nematodirus* species (Fig. 5A and 5B).

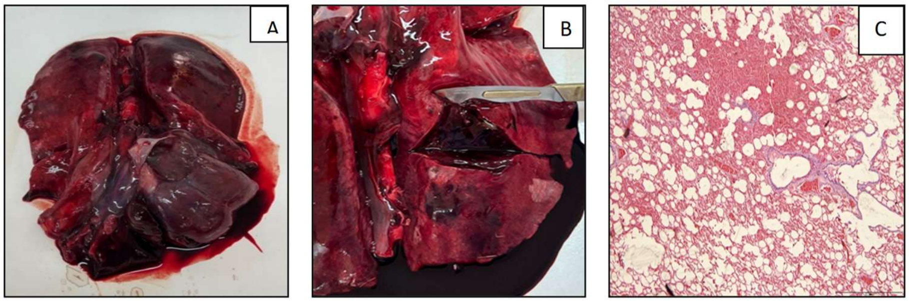

Fig. 4: Grossly congested lungs during postmortem examination (4A). An incision made to obtain a lung tissue sample reveals extensive haemorrhage (4B). Congested lung histopathological tissues (4C).

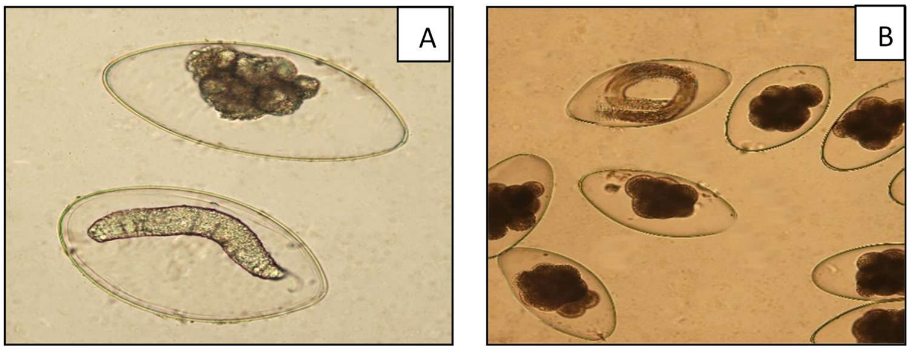

Fig. 5: Individual *Camelostrongylus mentulatus* larvated egg and *Nematodirus spathiger* morulated egg from the Reem gazelle side by side (5A). A single embryonated egg of *Camelostrongylus mentulatus* surrounded by multiple *Nematodirus spathiger* eggs (5B).

Additionally, the intensity of fecal parasites was quantified using the McMaster technique, allowing for the estimation of nematode eggs per gram of feces (EPG). The calculated EPG values by McMaster for Strongyles and *Nematodirus* spp. were recorded as high as 1350 and 2450 EPG, respectively (Zajac et al. 2021).

Molecular identification

DNA extraction from individual eggs followed by PCR amplification of the internal transcribed spacer 2 (ITS-2) region yielded amplicons of approximately 267 base pairs. Sequence analysis and BLAST searches confirmed the identity of the parasites as:

1. *Camelostrongylus mentulatus* (99.2% identity with GenBank reference sequences)
2. *Nematodirus spathiger* (98.8% identity with GenBank reference sequences)

The sequence alignment results enabled the identification of *Camelostrongylus mentulatus* and *Nematodirus spathiger* in fecal samples from the Reem gazelle. Phylogenetic analysis of 267bp ITS-2 sequences grouped *Camelostrongylus mentulatus* and *Nematodirus spathiger* from Reem gazelle in clades with *C. mentulatus* (MH047844) and *N. spathiger* (KY930420) from North African Dorcas gazelles (*G. gazella dorcas*) (Said et al. 2018; Aissa et al. 2021), with 100% and 99.24% similarity, respectively (Fig. 6A and 6B). Isolates of *Camelostrongylus mentulatus* and *Nematodirus spathiger* from the Reem gazelle of the present study were deposited in the GenBank under accession numbers PV678979 and PV658936, respectively.

Captivity and feed analysis

Following extensive postmortem and molecular analysis, the cause of increased sand consumption in Reem gazelles at the conservation area was not determined. Two possible explanations were considered: limited enclosure space combined with a higher number of males may have led to greater competition, aggression, and digging behavior resulting in sand ingestion; alternatively, dietary mineral deficiencies may have prompted the gazelles to consume sand as a compensatory response. The enclosure housed four gazelles (two males) within 1,053 m², and their diet consisted solely of Rhodes grass (*Chloris gayana*) hay and alfalfa (*Medicago sativa*), both low in mineral content. The chemical composition (g/kg DM) of Rhodes grass hay and alfalfa used is presented in Table 1. Collectively, these values suggested a risk of phosphorus and cobalt deficiency, and secondary magnesium deficiency due to high potassium. No concentrates or mineral licks were supplied as supplements. Fresh green alfalfa was provided daily without specific measures to prevent sand contamination, and clean water was provided consistently (Fig. 7).

Diagnosis and differential diagnosis

The combination of extensive sand accumulation, concurrent parasitic infestation, and underlying mineral deficiencies strongly indicated acute abomasitis secondary to sand impaction associated with pica-induced geophagia, and complicated by parasitic gastroenteritis. Differential diagnoses considered included primary parasitic abomasitis, foreign body ingestion, feed-induced impaction, abomasal displacement or torsion, and infectious abomasitis; however, these were excluded based on the nature of the impaction, absence of anatomical displacement, and lack of infectious agents.

Treatment adopted

As this case involved a post-mortem examination, no therapeutic interventions were possible for the affected animal. Based on the post-mortem findings, the following measures were recommended to prevent recurrence among the remaining gazelles at the Biodiversity Center: mineral supplementation (calcium, sodium, magnesium, and iron) through feed or mineral blocks to correct deficiencies and

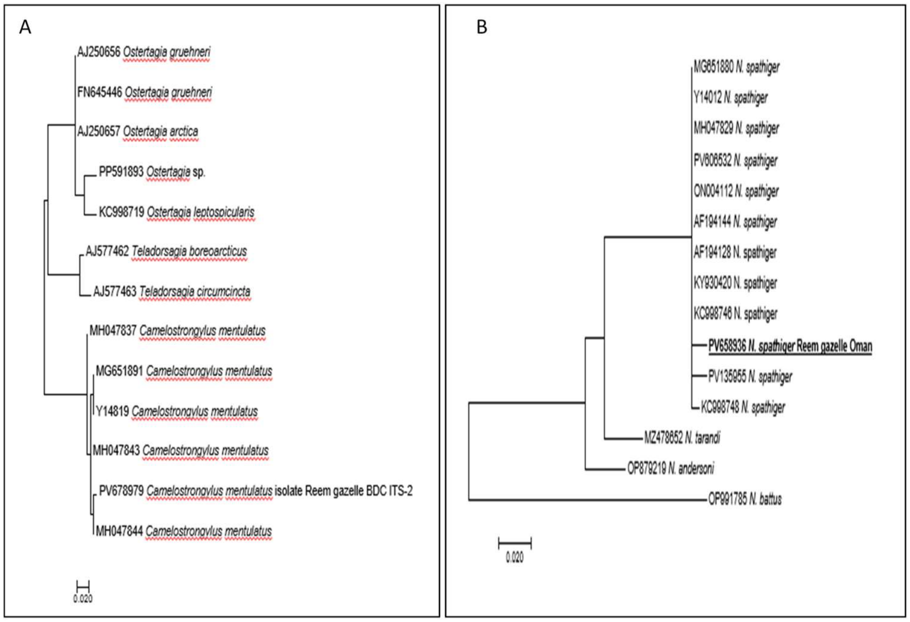

Fig. 6: Evolutionary relationships of nematodes from sand gazelle with other nematode spp. (*Camelostrongylus mentulatus* (6A) and *Nematodirus spathiger* (6B)) inferred by distance analysis of the internal transcribed spacer (ITS-2) gene. The species name follows the accession numbers of samples. The scale bar is the proportion of base substitutions per site.

Table 1: Comparative nutritional composition of the Rhodes grass hay and alfalfa used at the BDC, Barka

Nutrient	Unit	Rhodes grass (Hay)	% DM	Alfalfa	% DM
Organic matter	g/kg DM	907.4	90.74	895	89.5
Energy	kJ/g	17.0	-	18.7	-
Crude protein	g/kg DM	99.3	9.93	188.4	18.84
Ether extract	g/kg DM	12	1.20	21	2.10
Neutral detergent fiber	g/kg DM	710.1	71.0	420	42.0
Acid detergent fiber	g/kg DM	400.3	40.0	300	30.0
Hemi-cellulose	g/kg DM	300	30.0	100.5	10.05
Calcium	g/kg DM	2.0	0.20	13.5	1.35
Phosphorus	g/kg DM	1.8	0.18	2.3	0.23
Magnesium	g/kg DM	2.0	0.20	2.1	0.21
Sodium	g/kg DM	0.95	0.095	0.3	0.03
Potassium	g/kg DM	15	1.50	28	2.8
Cobalt	mg/kg DM	0.1	-	0.2	-

Fig. 7: Two gazelles feeding on green alfalfa from the ground at the BDC.

reduce geophagia; maintaining a rotational deworming program using broad-spectrum anthelmintics with regular fecal egg count monitoring; restricted access to sandy areas by providing feeding zones with compacted or concrete substrates; reformulation of the diet to ensure adequate mineral balance; and enhanced behavioral monitoring to identify and address early signs of pica or abnormal feeding behavior. These measures aimed to reduce risk factors for abomasal impaction and improve overall herd health.

DISCUSSION

This case report provides a detailed examination of a fatal outcome in a captive sand gazelle resulting from the complex interaction of geophagia, sand impaction, parasitism, and nutritional deficiencies. The findings shed light on critical management challenges in captive wildlife conservation programs.

Geophagia, the deliberate consumption of soil or sand, has been documented in various wildlife species as a compensatory behavior for mineral deficiencies (Panichev et al. 2014; Hasan 2021; Griffiths et al. 2024). In this case of the deceased sand gazelle, comprehensive feed analysis revealed a concerning lack of crucial minerals needed to maintain skeletal integrity, support nerve function, and sustain other vital metabolic processes (Griffiths et al.

2024). The sand gazelle likely engaged in geophagia to supplement these deficiencies, inadvertently leading to fatal abomasal impaction. Similar behaviors have been reported in deer (Stepanova et al. 2019), wild goats (Slabach et al. 2015) and captive felids (Hernández-Aco et al. 2022), supporting the hypothesis that geophagia represents an adaptive response to nutritional inadequacies. In natural habitats, sand gazelles may access mineral-rich soils or plants that provide adequate trace minerals such as Cu, Zn and Fe (Slabach et al. 2015), but captive environments may lack these resources. Conversely, geophagia alone may lead to mild illness with less severe symptoms. However, if it persists over an extended period, it could result in mortality among animals, when combined with other risk factors (Rahmani Shahraki et al. 2024).

The identification of parasitic species, specifically *Camelostrongylus mentulatus* and *Nematodirus spathiger*, through molecular marks a significant advancement in our understanding of parasites affecting sand gazelles. In the study conducted in Spain, these were the most prevalent and abundant parasites of captive gazelles (Ortiz et al. 2001). *Camelostrongylus* species are known pathogens of wild and domestic ruminants inhibiting arid ecosystems. They are known to cause abomasitis, which is characterized by mucosal damage and impaired gastric function in gazelle (Said et al. 2018; Rossi and Ferroglio 2001; Rahmani Shahraki et al. 2024) and other ruminant species (Strydom et al. 2023). Parasitic abomasitis can lead to reduced feed efficiency, weight loss, and increased susceptibility to other diseases (Simpson et al. 1997; Li et al. 2016). Infestation also causes chronic inflammation and negatively affects abomasal mucin formation in wild ruminants (Magdálek et al. 2021). These negative effects may be mitigated through the supply of protein and mineral supplements, including copper, zinc, and iron, which have the potential to significantly boost the animals' immunity against nematodes (Atiba et al. 2020). The heavy parasitic burden (combined EPG of 3,800) observed in this case likely contributed to mucosal damage, predisposing the abomasum to complications from sand impaction. The inflammatory response to parasites may have compromised the abomasal motility and secretory functions necessary for normal digestion (Van Metre et al. 2008; Li et al. 2016).

The massive sand accumulation (2-3 kg) in the abomasum created mechanical obstruction and pressure effects (Constable et al. 2017). The distended abomasum compressed the diaphragm and thoracic organs, leading to pulmonary congestion and respiratory compromise, a likely contributing factor to death. Additionally, the sand impaction prevented regular abomasal emptying, leading to fermentation, gas accumulation, and further distension (Simsek at al. 2015; Anderson et al. 2016). The combination of sand impaction and parasitic inflammation created a vicious cycle: parasites damaged the mucosa, reducing motility and secretion, while sand accumulation exacerbated inflammation and mechanical dysfunction. This chain of harmful physical events may eventually lead to death (Navarre and Pugh 2009; Fowler and Bravo 2010). Our findings are consistent with those of Rahmani Shahraki et al. (2024), who reported that a significant abomasal sand impact could exert vulnerable pressure on the diaphragm, thereby affecting the lungs in white-tailed deer.

Captive deer are typically dependent on formulated feed and confined pastures, which often lack the mineral diversity found in natural habitats. This reliance may elevate the risk of deficiencies, particularly in calcium, phosphorus, sodium, and essential trace elements (Pierce II et al. 2022). Moreover, providing sufficient calcium-phosphorus (Ca–P) and other minerals enhances bone and antler mineralization, leading to improved body weight and overall health, especially in developing fawns (Olguin et al. 2013). The absence of mineral supplementation and less protein in the diet of gazelles observed in this study following the field visit indicates a deficiency in nourishment that may impair the gazelle's immunity and overall health. This finding aligns with the work of Atiba et al. (2020), who proposed that protein and mineral supplementation may improve the overall health status of small ruminants and manage nematode infections by enhancing the immunity of these animals, thereby reducing the reliance on anthelmintic drugs.

This case underscores the importance of evidence-based nutritional management within captive wildlife facilities. Based on investigations performed in this study, several key recommendations emerge. For captive animals, it is essential to conduct regular and thorough nutritional assessments, including routine feed analysis and comparisons with species-specific dietary requirements. Based on the findings of this study, it is recommended that mineral supplementation be promptly administered in situations where deficiencies are identified to promote optimal health and minimize the risk of associated complications. Implementation of targeted parasite control strategies, which should be informed by routine fecal monitoring and an awareness of seasonal fluctuations in parasite prevalence. Additionally, the use of molecular identification methods is advocated to facilitate precise, species-specific treatment of parasitic infections in captive sand gazelles. It is essential that captive wildlife facilities establish clear behavioral monitoring protocols to help detect geophagia and abnormal feeding behaviors early. Staff should receive focused training in wildlife observation so they can quickly identify unusual behaviors like geophagia. Environmental design should minimize access to non-nutritive substrates while promoting natural foraging behaviors. Finally, preventive health programs, including periodic body condition scoring and fecal examinations, are recommended to identify and manage at-risk individuals before clinical disease develops.

This report is limited by its post-mortem nature, which precluded therapeutic intervention and longitudinal observation. Future research should focus on defining the mineral requirements of captive sand gazelles, assessing the prevalence and consequences of geophagia in captive ungulates, investigating the molecular epidemiology of parasitic infections in endangered gazelle species, and developing species-specific nutritional and management guidelines to support sustainable captive care.

Conclusion

The death of this sand gazelle resulted from a multifactorial disease process involving geophagia-induced sand impaction, heavy parasitic burden, and underlying nutritional deficiencies. This case highlights the complex challenges of maintaining endangered species in captivity and emphasizes the need for comprehensive nutritional management, parasite control, and behavioral monitoring programs. Implementation of evidence-based management strategies is essential for the health and conservation of captive sand gazelle populations.

DECLARATIONS

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Conflict of Interest: The authors declare no conflict of interest.

Data Availability: De-identified data may be made available from the corresponding author upon reasonable request and with permission of the relevant authorities.

Ethics Statement: Ethical approval was not necessary for this study, as it involved examining an animal post-mortem that had died. The carcass was evaluated according to standard veterinary diagnostic protocols. All procedures followed applicable institutional ethical guidelines for using animal materials in research.

Author's Contribution: Khalid Al-Habsi: Resources; data curation; formal analysis; investigation; writing original draft; Asil Al-Kiyumi: Data curation; investigation; conventional parasitology and PCR, phylogenetic analysis; Abeer Al-Hamrashdi: investigation; postmortem; histopathology; Haytham Ali: Postmortem, writing review and editing. Kaadhia Al-Kharousi: Feed analysis; investigation. Hani Al-Saadi: Conceptualization; visualization. Elshafie I. Elshafie: Data curation; formal analysis; investigation; writing review and editing; Muhammad H. Hussain: Data curation; software, writing review and editing.

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