MedCrave
Step into the World of Research
International Journal of Avian & Wildlife Biology

Research Article
Open Access
CrossMark

Morphological traits, feeding preferences, and behavioral patterns of captive dorcas gazelles (gazella dorcas) in sudan: Implications for ex-situ conservation and captive management

Abstract

The Dorcas gazelle (*Gazella dorcas*), a vulnerable antelope inhabiting arid and semi-arid ecosystems, has experienced substantial population declines due to habitat loss, illegal hunting, and increasing human activities. However, information on the biology and management of captive populations in Sudan remains limited. This study evaluated the morphological traits, feeding preferences, and behavioral patterns of captive Dorcas gazelles at Kuku Zoological Garden, Sudan. A total of 14 captive individuals were evaluated for morphological traits, while feeding preference and behavioral observations were conducted on 6 individuals (three pairs). Morphological assessment revealed clear sexual dimorphism, with adult males exhibiting greater body size and weight than females, although measurements were slightly lower than those reported for some North African populations. Feeding trials demonstrated a strong preference for sorghum grain, with the highest daily intake recorded at approximately 643 g, followed by sorghum–wheat bran mixtures, whereas alfalfa hay and sorghum straw were less preferred. Behavioral observations indicated that lying down represented approximately 49% of the daily activity budget, followed by standing and pacing activities. These findings provide baseline information on the morphology, nutrition, and behavior of captive Dorcas gazelles in Sudan and highlight the importance of balanced diets, environmental enrichment, and routine behavioral monitoring to improve animal welfare and reproductive performance. Given the relatively small sample size, the findings should be interpreted as preliminary baseline information for the studied captive population. The study contributes practical knowledge for evidence-based captive management and supports conservation breeding programs aimed at strengthening ex-situ conservation of this vulnerable species.

Keywords: Gazella dorcas, captive management, ex-situ conservation, feeding preference, morphological traits, behavioral patterns, Sudan

Volume 10 Issue 3 - 2026

Badreldin A A Mohamed,[1] Ayat Y H Abdalla,[2] Fatima A Mohammed[2]

[1]Wildlife Research Center, Animal Resources Research Corporation, Ministry of Animal Resources and Fisheries, Sudan
[2]Department of Fisheries and Wildlife Sciences, College of Animal Production and Technology, Sudan University of Science and Technology, Sudan

Correspondence: Badreldin A. A. Mohamed, Wildlife Research Center, Animal Resources Research Corporation, Ministry of Animal Resources and Fisheries, Khartoum, Sudan

Received: August 07, 2026 | **Published:** November 17, 2026

Abbreviation: **AOAC**, Association of Official Analytical Chemists; **CF**, Crude Fiber; **CP**, Crude Protein; **CITES**, Convention on International Trade in Endangered Species of Wild Fauna and Flora; **DM**, Dry Matter; **EE**, Ether Extract; **IUCN**, International Union for Conservation of Nature; **ME**, Metabolizable Energy; **NFE**, Nitrogen-Free Extract; and **SPSS**, Statistical Package for the Social Science

Introduction

The Dorcas gazelle (*Gazella dorcas* Linnaeus, 1758) is a small antelope belonging to the tribe Antilopini (family Bovidae, subfamily Antilopinae) and is highly adapted to arid and semi-arid ecosystems.[1] The species occurs across North Africa and parts of the Middle East, where several subspecies have been described.[2] In Sudan, Dorcas gazelles historically inhabited extensive areas including Darfur, Kordofan, Kassala, Dongola, the Red Sea region, and western Omdurman.[3,4]

Populations of *G. dorcas* have declined considerably due to illegal hunting, habitat degradation, agricultural expansion, livestock competition, and increasing human disturbance.[5,6] The species is currently classified as Vulnerable on the IUCN Red List, and in Sudan it has disappeared from many former distribution areas, surviving mainly in fragmented populations[7] These declines highlight the importance of integrated conservation approaches that combine habitat protection with scientifically managed captive breeding programs to support population recovery.

Morphological characteristics, including body size, body weight, horn development, and sexual dimorphism, provide important indicators of growth, health condition, and adaptation in ungulates. These traits are influenced by age, sex, nutritional status, genetic variation, and environmental conditions.[8-10] In captive populations, morphological assessments can therefore contribute to evaluating management effectiveness and animal welfare. Similarly, appropriate nutritional management is essential for maintaining health, reproductive performance, and long-term sustainability of captive ungulates. Although Dorcas gazelles naturally utilize a diverse range of plant resources, including leaves, pods, grasses, and seasonal herbs,[11,12] captive diets are commonly based on available feed resources such as grains, bran, and forage. Understanding feeding preferences is therefore important for developing balanced diets that meet biological requirements.

Behavioral monitoring is another essential component of captive wildlife management because changes in activity patterns may reflect adaptation, stress, welfare status, and enclosure suitability. Wild Dorcas gazelles are mainly crepuscular, with activity concentrated during cooler periods of the day.[12] However, captive conditions

Submit Manuscript | http://medcraveonline.com

©2026 Mohamed et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and build upon your work non-commercially.

may alter natural behavioral patterns through changes in enclosure structure, feeding regimes, social organization, and environmental complexity.[10] Integrating morphological, nutritional, and behavioral assessments provides a comprehensive approach for evaluating captive management practices and improving conservation outcomes.

Despite the increasing importance of ex-situ conservation programs for threatened ungulates, information on the biology and management requirements of captive *Gazella dorcas* in Sudan remains limited. The lack of baseline data on morphological variation, dietary preferences, and behavioral responses restricts the development of evidence-based husbandry practices and conservation strategies. Therefore, this study aimed to assess the morphological characteristics, feeding preferences, and behavioral patterns of captive Dorcas gazelles at Kuku Zoological Garden, Sudan. The findings provide valuable baseline information to improve captive management, enhance animal welfare, and support future ex-situ conservation initiatives for this vulnerable species.

Materials and methods

Study site and animals

The study was conducted at Kuku Zoological Garden (Kuku Zoo), Khartoum, Sudan, during February and March 2018. The average ambient temperature during the study period was approximately 28°C. Fourteen captive Dorcas gazelles (*Gazella dorcas*) comprising seven males and seven females were included in the study. All animals had been maintained under captive conditions for approximately 24 months before the experiment, allowing adequate adaptation to the enclosures and management practices. Based on zoo records, the animals were classified into two age groups: adults (11–108 months; n = 10) and juveniles (4–9 months; n = 4). Four adult pairs (one male and one female per enclosure) were housed separately, whereas the remaining adult pair and the four juveniles were maintained in a larger communal enclosure. The enclosures measured approximately 6 × 2.8 × 3 m and were constructed with iron pipe fencing, concrete flooring, 0.5-m concrete side walls, and insulated metal roofs.

Morphological assessment

Morphological measurements were obtained from all fourteen Dorcas gazelles (seven males and seven females) following the standard procedures described.[13,14] Measurements were taken using a flexible metric measuring tape to the nearest millimeter, with all measurements performed by the same observer to minimize inter-observer variation. The recorded morphometric traits included horn length (measured from the base to the tip of the horn), total body length (from the point of the shoulder to the pin bone), forelimb length (from the knee joint to the fetlock), hind-limb length (from the hock joint to the fetlock), facial length (from the tip of the nostril to the base of the horn), shoulder height (from the hoof to the dorsal border of the scapula), ear length (from the ear notch to the tip), and tail length (from the tail base to the tip).

The ages of captive-born animals were obtained from zoo records, whereas the ages of the remaining individuals were estimated based on horn development and body size, following the criteria described.[15-17]

Feeding preference trial

Feeding preference was evaluated using three adult pairs of Dorcas gazelles selected on the basis of similar age and body weight. Before data collection, the animals underwent a one-week adaptation period during which they became accustomed to the experimental diets and feeding protocol. The feeding trial was conducted over 15 consecutive days, during which four diets commonly used in captive gazelle management were evaluated: alfalfa hay (*Medicago sativa*), sorghum grain (*Sorghum bicolor*), a mixture of sorghum grain and wheat bran, and sorghum straw (*Sorghum bicolor*). Each feed type was offered at a rate of 5 kg twice daily. Daily feed intake was determined by subtracting the weight of feed refusals from the amount offered. Fresh drinking water and mineral salt blocks were provided *ad libitum* throughout the experiment. The proximate chemical composition of the experimental diets was analytically determined according to the standard procedures of the Association of Official Analytical Chemists (AOAC).[18] The analyzed parameters included dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), ash, and nitrogen-free extract (NFE). The Metabolizable energy (ME) values were calculated/estimated based on the nutrient composition using the applicable standard equations. The resulting values are presented in **Table 1**.

Table 1 Proximate chemical composition of the experimental diets on a dry matter (DM) basis

Nutrient	Alfalfa hay	Sorghum straw	Sorghum grain	Sorghum grain + wheat bran mixture
DM (%)	92.84	91.11	92.66	83.20
ME (MJ kg^{-1} DM)	11.1	10.0	12.6	10.9
CP (% DM)	10.77	6.48	10.68	8.40
EE (% DM)	1.15	0.87	3.31	2.10
CF (% DM)	30.52	31.31	1.92	29.30
Ash (% DM)	8.38	8.97	2.50	12.50
NFE (% DM)	49.18	52.37	81.59	47.70
1, Dry matter; 2, Metabolizable energy; 3, Crude protein; 4, Ether extract; 5, Crude fibre; 6, Nitrogen-free extract				

Behavioral observations

Behavioral observations were conducted on the same three adult pairs throughout the feeding trial. A total of 72 observation hours were completed during the experimental period. Animals were observed during eight observation periods covering the morning, midday, afternoon, evening, and night, following the procedures described.[19] Behavioral data were collected using the instantaneous scan sampling method at 5-minute intervals.[20] During each scan, the behaviour of every individual was recorded simultaneously from outside the enclosure to minimize disturbance. Ten behavioural categories were assessed, including lying down, standing, walking or pacing, feeding, ruminating, playing, mating, drinking, urinating, and defecating. The frequency and percentage of each behavioural activity were calculated separately for males and females.

Behavioral observations were conducted on the same three adult pairs (six individuals) used in the feeding preference trial throughout

the 15-day experimental period. A total of 72 observation hours were completed during the study and distributed across eight observation periods covering the morning, midday, afternoon, evening, and night. Behavioral data were collected using instantaneous scan sampling at 5-minute intervals, following the procedures described.[19,20] During each scan, the behavior of each individual was recorded simultaneously from outside the enclosure to minimize observer disturbance. Ten predefined behavioral categories were recorded: standing, feeding, pacing/walking, lying down, playing, drinking, ruminating, mating, urinating, and defecating. Behavioral observations were summarized by observation period and sex. The occurrence of each behavioral category was converted to the corresponding observation frequency/estimated observation time, as applicable, and expressed as mean ± standard deviation. The proportion of each behavioral category among the total behavioral observations was also calculated.

Statistical analysis

Data obtained from the morphological measurements, feeding trials, and behavioral observations were summarized using descriptive statistics. Morphological measurements and quantitative feeding and behavioral data were expressed as means ± standard deviations (SD), while categorical and frequency data were presented as frequencies and percentages, as appropriate. Statistical analyses were performed using IBM SPSS Statistics version 20.0 (IBM Corp., Armonk, NY, USA).

Results

Morphological characteristics

The morphological characteristics and approximate ages of adult male and female Dorcas gazelles are presented in **Table 2**. Adult males were generally larger than females in most measured traits. The mean body weight of adult males was 14.3 ± 2.59 kg, compared with 10.7 ± 1.15 kg for adult females, giving an overall mean of 12.5 ± 2.66 kg. Similarly, males exhibited greater mean total body length (102.2 ± 6.46 cm) than females (80.6 ± 1.67 cm). Adult males also had greater forelimb length, hind limb length, tail length, ear length, horn length, facial length, and shoulder height than females. Horn length showed the greatest degree of sexual dimorphism, averaging 36.2 ± 3.96 cm in males compared with 24.6 ± 8.96 cm in females.

Table 2 Body weight (Kg), morphological measurements (cm) and approximate ages (months) for Adult Gazella dorcas

Parameter	Male				Female				Overall		
	Range	Mean	±	SD	Range	Mean	±	SD	Mean	±	SD
Body weight	10-16.5	14.3	±	2.59	9-12	10.7	±	1.15	12.5	±	2.66
Total length	97-113	102.2	±	6.46	78-82	80.6	±	1.67	91.4	±	12.2
Forelimb length	61-68	63.8	±	2.77	51-60	55.2	±	3.70	59.5	±	5.48
Hind limb length	72-80	77.0	±	3.74	61-73	67.6	±	5.37	72.3	±	6.60
Tail	23-29	25.4	±	2.30	19-22	21.4	±	1.82	23.4	±	2.87
Ear Length	19-23	21.4	±	1.67	18-20	19.0	±	0.00	20.2	±	1.81
Horn	30-40	36.2	±	3.96	15-36	24.6	±	8.96	30.4	±	8.95
Face	18-25	21.4	±	2.51	16-21	18.6	±	2.00	20.0	±	2.58
Stand	51-59	53.8	±	3.03	42-50	46.8	±	3.31	50.3	±	4.76
Age	36-108	64.8	±	27.6	11-36	27.8	±	10.3	46.3	±	27.7

The morphological characteristics and approximate ages of juvenile Dorcas gazelles are presented in Table 3. The overall mean body weight of juveniles was 6.3 ± 1.9 kg, with female juveniles (8.0 ± 0.71 kg) being heavier than males (4.75 ± 0.35 kg). Female juveniles also exhibited greater mean total body length (82.0 ± 19.8 cm) than males (58.0 ± 11.3 cm). Similarly, forelimb length, hind limb length, ear length, facial length, and shoulder height were higher in females than in males. Mean horn length was comparable between the two sexes, averaging 11.5 ± 7.78 cm in males and 12.0 ± 5.65 cm in females. The estimated mean age of juvenile males and females was 5.5 ± 2.12 and 8.0 ± 1.41 months, respectively, with an overall mean age of 6.8 ± 2.1 months (Table 3).

Table 3 Body weight (Kg), morphological measurements (cm) and approximate ages (months) for juvenile Gazella dorcas

Parameter	Male				Female				Overall		
	Range	Mean	±	SD	Range	Mean	±	SD	Mean	±	SD
Body weight	4.5-5	4.75	±	0.35	7.5-8.5	8.00	±	0.71	6.3	±	1.9
Total length	50-66	58.0	±	11.3	68-96	82.0	±	19.8	70.0	±	19.1
Forelimb length	36-42	39.0	±	4.24	50-58	54.0	±	5.66	46.5	±	9.6
Hind limb length	45-51	48.0	±	4.24	62-62	62.0	±	0.00	55.0	±	8.6
Tail	17-20	18.5	±	2.12	18-21	19.5	±	2.12	19.0	±	1.8
Ear Length	15-16	15.5	±	0.71	18-20	19.0	±	1.41	17.3	±	2.2
Horn	6-17	11.5	±	7.78	8-16	12.0	±	5.65	11.8	±	5.6
Face	13-16	14.5	±	2.12	14-24	19.0	±	7.07	16.8	±	5.0
Stand	29-32	30.5	±	2.12	42-50	46.0	±	5.66	38.3	±	9.6
Age	4-7	5.5	±	2.12	7-9	8.00	±	1.41	6.8	±	2.1

Copyright: ©2026 Mohamed et al.

As shown in **Figure 1**, feed intake differed among the experimental diets ($P < 0.05$). Sorghum grain (*Sorghum bicolor*; locally known as Feterita) was the most preferred feed, with a mean daily intake of 643.0 ± 219.66 g (range: 355–905 g), followed by the sorghum grain–wheat bran mixture, which had a mean intake of 434.67 ± 148.39 g (range: 290–660 g). Alfalfa hay (*Medicago sativa*; locally known as Barseem) ranked third, with a mean daily intake of 199.33 ± 69.01 g (range: 150–310 g). The least preferred diet was sorghum straw (*Sorghum bicolor*; locally known as Abu 70), with a mean daily intake of 141.3 ± 52.55 g (range: 92.5–265 g) per day.

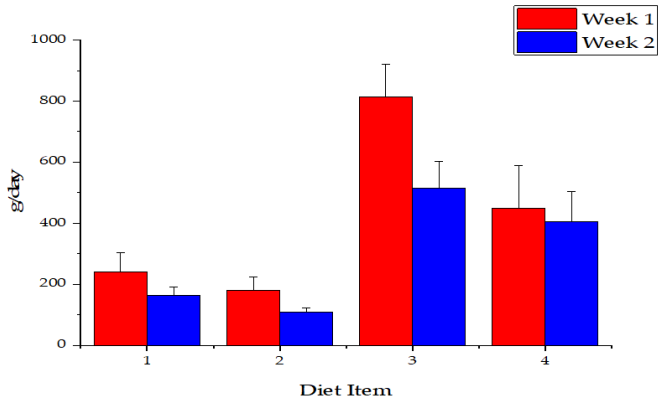


Figure 1 Average daily food consumption of D. gazelle collected 2018.

[1]Alfalfa hay, [2]Abu 70 (dry sorghum straw), [3]Sorghum grains (Feterita) and [4]Mixed diets (sorghum + wheat bran)**Figure 2** illustrates the percentage contribution of each diet to the total daily feed intake. Sorghum grain (*Sorghum bicolor*) represented the highest proportion of daily consumption (45.31%), whereas sorghum straw (*Sorghum bicolor*) accounted for the lowest proportion (9.98%).

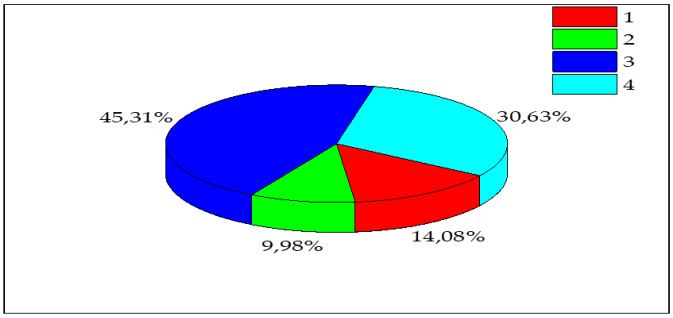


Figure 2 Percentage of average daily consumption of experimental diets.

[1]Alfalfa hay, [2]Abu 70 (dry sorghum straw), [3]Sorghum grains (Feterita) and [4]Mixed diets (sorghum + wheat bran)

Table 4 summarizes the mean time spent on each behavioural activity and its percentage contribution to the total observation time for captive Dorcas gazelles. Lying down was the predominant behaviour in both sexes, with mean durations of 87.83 ± 16.66 min in males and 85.19 ± 17.41 min in females, accounting for 48.56% of the total observation time. Standing (15.42%), pacing (11.61%), eating (10.42%), and ruminating (9.95%) were the next most frequently observed activities, collectively representing 47.40% of the daily activity budget. In contrast, playing (3.36%), drinking (0.19%), mating (0.20%), defecating (0.17%), and urinating (0.09%) were infrequently observed and together accounted for only 4.01% of the total observation time. Among these activities, urination was the least frequently recorded behaviour Supplementary Table S1 & Supplementary Table S2.

Table 4 Mean time (min) spent on different behavioural activities and their percentage contribution to the daily activity budget of captive Gazella dorcas

Parameter	Male			Female			Overall			Percentage of total observations (%)
	Mean	±	SD	Mean	±	SD	Mean	±	SD	
Standing	25.9	±	11.0	29.0	±	12.4	27.5	±	11.7	15.42
Eating	20.0	±	7.76	17.1	±	8.71	18.6	±	8.23	10.42
Pacing	20.4	±	7.76	21.0	±	11.2	20.7	±	17.0	11.61
Lying down	87.8	±	16.7	85.2	±	17.4	86.5	±	17.0	48.56
Playing	6.24	±	4.62	5.76	±	5.36	5.99	±	4.97	3.36
Drinking	0.23	±	0.30	0.36	±	0.32	0.34	±	0.31	0.19
Ruminating	17.6	±	7.86	17.9	±	8.19	17.7	±	8.03	9.95
Mating	0.39	±	0.53	0.43	±	0.61	0.41	±	0.57	0.20
Urinating	0.17	±	0.12	0.14	±	0.13	0.16	±	0.12	0.09
Defecating	0.29	±	0.21	0.31	±	0.24	0.30	±	0.23	0.17



Fig S1 Gazella Dorcas Feeding.



Fig S2 Gazella Dorcas Standing.

Citation: Mohamed BAA, Abdalla AYH, Mohammed FA. Morphological traits, feeding preferences, and behavioral patterns of captive dorcas gazelles (gazella dorcas) in sudan: Implications for ex-situ conservation and captive management. *Int J Avian & Wildlife Biol.* 2026;10(3):73–80. DOI: 10.15406/ijawb.2026.10.00258



Fig S3 Gazella Dorcas Lying down.



Fig S4 Gazella Dorcas Standing.

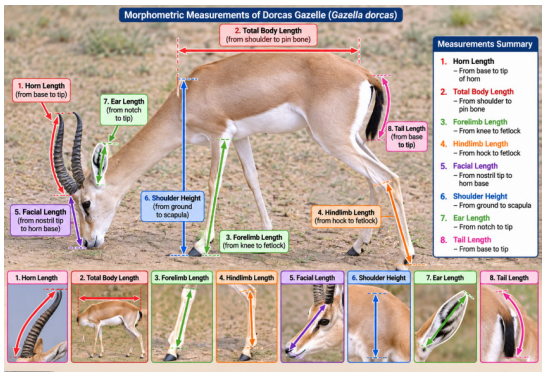


Fig S5 Illustrative diagram showing the anatomical reference points for morphometric measurements recorded in Dorcas gazelles.

Discussion

The rapid decline of wild ungulate populations has increased the importance of captive breeding and *ex-situ* conservation as complementary strategies for biodiversity conservation. Beyond preventing extinction, modern captive breeding programs aim to maintain genetically healthy populations, improve animal welfare, and support future reintroduction or reinforcement of wild populations. Consequently, evidence-based husbandry practices have become a fundamental component of successful conservation programs.[21-26]

The present study provides baseline information on the morphology, feeding preferences, and behavioral patterns of captive Dorcas gazelles (*Gazella dorcas*) in Sudan. Although *G. dorcas* is widely distributed across North Africa and the Middle East, published information describing its biology under captive conditions remains limited. The integration of morphological, nutritional, and behavioral assessments presented here therefore contributes valuable information for improving captive management and strengthening *ex-situ* conservation efforts.[22, 24,25]

Morphological characteristics

The present study confirmed clear sexual dimorphism, with adult males exhibiting greater body weight and larger body dimensions than females. Similar patterns have been reported in both wild and captive populations of *G. dorcas*.[1,11,12] Nevertheless, the body weights recorded in the present study was slightly lower than those reported from North African populations. Such differences may reflect nutritional quality, enclosure conditions, climatic variation, husbandry practices, or population-specific genetic variation.[27]

Morphological measurements are increasingly recognized as practical indicators of health, nutritional status, welfare, and adaptive responses in captive ungulates. Regular monitoring of body weight, body dimensions, and horn development can facilitate early detection of nutritional deficiencies, chronic stress, or health disorders before clinical signs become evident. Furthermore, maintaining normal body growth is essential for successful reproduction and long-term population viability in conservation breeding programs.[23, 28,29]

Feeding preferences

Captive Dorcas gazelles showed a strong preference for sorghum grain, followed by the sorghum–wheat bran mixture, whereas alfalfa hay and sorghum straw were consumed in substantially smaller amounts. These observations agree with previous studies conducted in Sudan[12] and demonstrate the high palatability of cereal grains. Although cereal-based diets provide readily available energy, excessive dependence on concentrates may increase the risk of digestive disturbances, obesity, ruminal dysfunction, and impaired reproductive performance in captive ruminants. Consequently, balanced diets combining energy-rich concentrates with adequate fiber sources are recommended to maintain digestive health and normal rumen function.[15,30,31]

In natural habitats, Dorcas gazelles consume a wide diversity of shrubs, herbs, grasses, flowers, fruits, and *Acacia* species, with seasonal changes in diet according to forage availability.[13,14,32,33] Replicating this dietary diversity under captive conditions is expected to improve nutritional balance, stimulate natural foraging behavior, reduce behavioral abnormalities, and enhance overall animal welfare. Environmental enrichment through browse provision and natural foraging opportunities also promotes species-specific feeding behavior and is increasingly regarded as a key component of evidence-based captive management.[23,34,35]

Behavioral activity patterns

Behavioural observations showed that lying down represented almost half of the daily activity budget, followed by standing, pacing, eating, and rumination. This pattern generally agrees with previous observations of captive Dorcas gazelles[12] but differs from wild populations, where activity is concentrated during dawn and dusk to minimize heat stress and predation risk.[14,36-39]

Citation: Mohamed BAA, Abdalla AYH, Mohammed FA. Morphological traits, feeding preferences, and behavioral patterns of captive dorcas gazelles (gazella dorcas) in sudan: Implications for ex-situ conservation and captive management. *Int J Avian & Wildlife Biol.* 2026;10(3):73–80. DOI: 10.15406/ijawb.2026.10.00258

Reduced activity under captive conditions has been reported for several captive ungulates and is frequently associated with restricted space, predictable food availability, absence of predators, and limited environmental complexity.[40-42] Salas demonstrated that behavioral indicators, including activity budgets, enclosure use, social interactions, and stereotypic behaviors, provide reliable measures of welfare in captive Dorcas gazelles.[23] Recent welfare frameworks also emphasize that environmental enrichment, behavioral diversity, and opportunities for animals to express natural behaviors are fundamental indicators of positive welfare.[28,34,35,43,44]

Accordingly, increasing enclosure complexity through vegetation, browsing material, shade structures, variable substrates, and larger exercise areas may encourage natural locomotion, improve physical fitness, reduce stress-related behaviors, and ultimately enhance reproductive performance and long-term population sustainability.[23,35,40,41]

Conservation and management implications

The findings of this study extend beyond descriptive biology by providing practical recommendations for conservation management of captive Dorcas gazelles in Sudan. Morphological measurements provide valuable indicators for monitoring health, growth, and welfare; whereas feeding preferences can guide the development of nutritionally balanced diets that better reflect the natural ecology of the species. Likewise, behavioural observations provide objective indicators for evaluating enclosure quality and management effectiveness.[23, 28,29]

Modern conservation increasingly recognizes that successful captive breeding depends not only on maintaining animal numbers but also on preserving behavioral competence, physical condition, genetic diversity, and reproductive capacity. Integrating routine morphological assessment, nutritional management, behavioral monitoring, veterinary care, and environmental enrichment into husbandry protocols will therefore improve animal welfare while increasing the conservation value of captive populations. These practices are consistent with current international recommendations for conservation breeding and *ex-situ* wildlife management.[21-26]

Conclusion and recommendations

This study provides a comprehensive baseline assessment of the morphological traits, feeding preferences, and behavioral patterns of captive Dorcas gazelles (*Gazella dorcas*) in Sudan. The findings confirmed clear sexual dimorphism, distinct dietary preferences, and behavioral activity patterns characteristic of captive conditions, highlighting the important influence of husbandry practices on animal health, welfare, and conservation outcomes. Differences in body measurements compared with previously reported wild populations suggest that nutrition, enclosure design, environmental conditions, and management practices may influence the morphology and behavior of captive animals.

The strong preference for sorghum grain and sorghum–wheat bran mixtures, together with the predominance of resting behavior, emphasizes the importance of providing nutritionally balanced diets and appropriate environmental enrichment to maintain animal health while promoting natural behavioral expression. Routine monitoring of morphological traits, feeding behavior, and activity budgets can provide practical indicators for assessing animal welfare, evaluating husbandry effectiveness, and supporting evidence-based management decisions in captive breeding programs.

From a conservation perspective, the results contribute valuable baseline information for improving captive management and strengthening ex-situ conservation programs for *G. dorcas* in Sudan. Well-managed captive populations may serve as important conservation reservoirs by supporting demographic stability, maintaining healthy breeding populations, reducing harvesting pressure on wild populations, and providing opportunities for future conservation breeding and population reinforcement where appropriate.

Future studies should evaluate the long-term effects of nutrition, environmental enrichment, enclosure design, reproductive management, and health monitoring on the welfare and reproductive performance of captive Dorcas gazelles. Integrating behavioral, morphological, nutritional, and veterinary assessments with genetic management will further enhance the sustainability and conservation value of captive populations and contribute to evidence-based conservation strategies for this vulnerable species.

Limitations

This study has several limitations that should be considered when interpreting the findings. **First**, the relatively small sample size reflects the limited number of captive Dorcas gazelles available at the study site, which may limit the generalizability of the results. The feeding preference trials and behavioral observations were conducted on only six individuals (three pairs), further limiting the representativeness of these findings. **Second**, the study was conducted at a single zoological facility over a relatively short period and therefore did not account for seasonal, environmental, or management-related variation in morphology, feeding preferences, or behavioral patterns. **Third**, behavioral observations were restricted to captive conditions and may not fully represent the ecological and behavioral complexity of free-ranging populations. In addition, the study focused primarily on descriptive assessments and did not evaluate physiological, genetic, or reproductive parameters that are increasingly recognized as important components of conservation breeding programs. Despite these limitations, this study establishes an important baseline for future research and provides practical information to improve captive husbandry, animal welfare, and ex-situ conservation of *Gazella dorcas* in Sudan.

Acknowledgments

The authors sincerely thank Kuku Zoo, Department of Fisheries and Wildlife Sciences, College of Animal Production and Technology, Sudan University of Science and Technology, for providing the facilities and logistical support necessary to conduct this study. We are deeply grateful to the late Prof. Ali Saad Mohamed for his supervision and guidance and to Prof. Aisha El Faki and Dr. Lubna M. A. Hassan for their valuable scientific comments and constructive suggestions. We also thank everyone who contributed, directly or indirectly, to the completion of this research.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval

All procedures involving animals were conducted in accordance with the ethical standards and animal welfare guidelines of Kuku Zoo. The study involved non-invasive observations and routine morphometric measurements, and no animals were harmed during the study.

Conflict of interest statement

The authors declare that they have no competing interests

Funding statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sector.

References

1. Ahmed FA, Mohammed Salih RR, Yousif RA. Some haematological values for captive *Gazella dorcas*. J Anim Feed Res. 2012;2(4):348–350.
2. Groves CP. Notes on the gazelles. III. The dorcas gazelles of North Africa. Ann Mus Civ Stor Nat Giacomo Doria. 1981;83:455–471.
3. Ghobrial LI. *Physiological adaptation of desert mammals* [PhD thesis]. Khartoum (Sudan): University of Khartoum; 1967.
4. Nimir MB. *Wildlife values and management in northern Sudan* [PhD thesis]. Fort Collins (CO): Colorado State University; 1983.
5. Lerp H, Wronski T, Butynski TM, et al. Speciation of Arabian gazelles. In: Michalak P, editor. Speciation: Natural Processes, Genetics and Biodiversity. Hauppauge (NY): Nova Science Publishers; 2013. p. 59–82.
6. Sokolov VE, Dash YA, Lushchekina AA, et al. Contemporary distribution and population of the dzeren in the Mongolian People's Republic. In: Zoological Researches in the Mongolian People's Republic. Moscow: Nauka; 1982. p. 7–21.
7. Mallon DP, Kingswood SC. *Antelopes. Part 4: North Africa, the Middle East, and Asia. Global Survey and Regional Action Plans*. Gland, Switzerland: IUCN/SSC Antelope Specialist Group, International Union for Conservation of Nature; 2001.
8. IUCN SSC Antelope Specialist Group. *Gazella dorcas*. The IUCN Red List of Threatened Species. 2017
9. Sayied ARS, Mohammed Ahmed BA, Makkawi SEA. Foetometric reading and foetal disposition during pregnancy and at birth in Dorcas gazelles (*Gazella dorcas* Linnaeus 1758) employing ultrasound techniques. *Sudan Acad Sci J.* 2013;4(2):89–109.
10. Ghobrial LI. Water relation and requirement of the dorcas gazelle in the Sudan. *Mammalia.* 1974;38(1):88–107.
11. Yom-Tov Y, Mendelssohn H, Groves CP. *Gazella dorcas*. *Mamm Species.* 1995;(491):1–6.
12. Mohamed AA. *Food preference and daily activity of Dorcas gazelle in captivity* [master's thesis]. Khartoum (Sudan): Institute of Environmental Studies, University of Khartoum; 2014.
13. Habibi K. *Arabian gazelles*. Riyadh (Saudi Arabia): National Commission for Wildlife Conservation and Development; 1991.
14. Ward D, Saltz D. Foraging at different spatial scales: Dorcas gazelles foraging for lilies in the Negev Desert. *Ecology.* 1994;75(1):48–58.
15. Clauss M, Kienzle E, Hatt JM. Feeding practice in captive wild ruminants: peculiarities in the nutrition of browsers, concentrate selectors and intermediate feeders. *Zoo Animal Nutrition*.2003. p. 27–52.
16. Cunningham PL, Mohamed AS, Wronski T. Morphological characteristics and ageing criteria of sand gazelle (*Gazella subgutturosa marica* Thomas, 1897) and their use for wildlife management. *Eur J Wildl Res***.** 2011;57(5):945–954.
17. Mohamed AFA, Takona NY, Yousif RA, et al. Some behavioral traits of striped hyaena under captive conditions. *J Life Sci Biomed.* 2012;2(5):196–199.
18. Hvidberg-Hansen H, De Vos A. Reproduction, population and herd structure of two Thomson's gazelle (*Gazella thomsonii* Günther) populations. *Mammalia.* 1971;35(1):1–16.
19. Robinette WL, Archer AL. Notes on ageing criteria and reproduction of Thomson's gazelle. *Afr J Ecol.* 1971;9(1):83–98.
20. Loggers C. Population characteristics of dorcas gazelle in Morocco. *Afr J Ecol*. 1992;30(4):301–308.
21. Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Conservation of and trade in African and Asian gazelles. Geneva (Switzerland): CITES Secretariat; 2006.
22. International Union for Conservation of Nature (IUCN). *Guidelines for conserving connectivity through ecological networks and corridors*. Gland (Switzerland): IUCN; 2020.
23. Salas M, Manteca X, Abáigar T, et al. Using farm animal welfare protocols as a base to assess the welfare of wild animals in captivity: case study: Dorcas gazelles (Gazella dorcas). *Animals (Basel).* 2018;8(7):111.
24. World Association of Zoos and Aquariums. Building a Future for Wildlife: The World Zoo and Aquarium Conservation Strategy. Barcelona: *WAZA*; 2023.
25. IUCN Species Survival Commission. Guidelines on the Use of Ex Situ Management for Species Conservation. Version 2.0. Gland, Switzerland: International Union for Conservation of Nature; 2014.
26. Beer HN, Shrader TC, Schmidt TB, et al. The evolution of zoos as conservation institutions: A summary of the transition from menageries to zoological gardens and parallel improvement of mammalian welfare management. *J Zool Bot Gard.* 2023;4(4):648–664.
27. Thouless CR, Habibi K, Dougherty ER. Conservation status of gazelles in Saudi Arabia. *Biol Conserv.* 1991;58(1):85–98.
28. Tallo-Parra O, Salas M, Manteca X. Zoo animal welfare assessment: Where do we stand? *Animals (Basel).* 2023;13(12):1966.
29. Martin TE, Lemasson AJ, Wayman JP, et al. Husbandry and management interventions for the conservation and welfare of captive animals: a systematic evidence map. *J Zoo Aquar Res.* 2025;13(3):152–163.
30. Clauss M, Hatt JM, Dierenfeld ES, et al. Feeding and nutrition of captive wild ungulates: Lessons from ruminant biology. *Zoo Biol***.** 2018;37(5):361–374.
31. Espinosa S, Celaya R, Ferreira LMM, et al. How dietary diversity enhances hedonic and eudaimonic well-being in grazing ruminants. *Front Vet Sci*. 2020;7:191.
32. Codron D, Clauss M, Hummel J, et al. Browse silage as potential feed for captive wild ungulates in southern Africa: A review. *Anim Nutr***.** 2018;4(1):1–10.
33. Veldhuis MP, Kihwele ES, Cromsigt JPGM, et al. Large herbivore assemblages in a changing climate: incorporating water dependence and thermoregulation. *Ecol Lett.* 2019;22(10):1536–1546.
34. Troxell-Smith SM, Whelan CJ, Magle SB, et al. Zoo foraging ecology: Development and assessment of a welfare tool for captive animals. *Anim Welf.* 2017;26(3):265–275.
35. Robinson MH. Enriching the lives of zoo animals, and their welfare: Where research can be fundamental**.** *Anim Welf.* 1998;7(2):151–175.
36. Henley SR, Ward D, Schmidt I. Habitat selection by two desert-adapted ungulates. *J Arid Environ***.** 2007;70(1):39–48.
37. Chammem M, Selmi S, Nouira S, et al. Factors affecting the distribution of dorcas gazelle. *J Zool.* 2008;275(2):146–152.
38. Baharav D. Habitat utilization of the dorcas gazelle in a desert saline area. *J Arid Environ.* 1980;3(2):161–167.
39. Lawes MJ, Nanni RF. The density, habitat use and social organization of dorcas gazelle (Gazella dorcas) in Makhtesh Ramon, Negev Desert, Israel. *J Arid Environ.* 1993;24(2):177–196.
40. Schaffer A, Caicoya AL, Colell M, et al. Neophobia in 10 ungulate species—a comparative approach. *Behav Ecol Sociobiol.* 2021;75:102.
41. Rose PE. Zoo animal welfare in the 21st century—Contemporary thinking, assessment, and best practice. In: Miller RE, Lamberski N, Calle PP, editors. *Fowler's Zoo and Wild Animal Medicine Current Therapy.* 2023. p. 245–250.

42. Miranda R, Escribano N, Casas M, et al. The role of zoos and aquariums in a changing world. *Annu Rev Anim Biosci.* 2023;11:287–306.

43. Azevedo CS, Cipreste CF, Pizzutto CS, et al. Review of the effects of enclosure complexity and design on the behaviour and physiology of zoo animals. *Animals (Basel).* 2023;13(8):1277.

44. Sherwen SL, Hemsworth PH. The visitor effect on zoo animals: Implications and opportunities for zoo animal welfare. *Animals (Basel).* 2022;12(3):276.

45. AOAC. Official Methods of Analysis of AOAC International. 18th ed. Gaithersburg (MD): Association of Official Analytical Chemists; 2005.

46. Oduro W, Ellis WO, Oduro I, et al. Behavior and food preference of Maxwell's duiker (*Cephalophus maxwelli*) in captivity. *Nature Faune.* 2002;18(2):1–11.

47. Altmann J. Observational study of behavior: Sampling methods. *Behaviour.* 1974;49(3–4):227–267.

Citation: Mohamed BAA, Abdalla AYH, Mohammed FA. Morphological traits, feeding preferences, and behavioral patterns of captive dorcas gazelles (gazella dorcas) in sudan: Implications for ex-situ conservation and captive management. *Int J Avian & Wildlife Biol.* 2026;10(3):73–80. DOI: 10.15406/ijawb.2026.10.00258