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Research Article

Private *Versus* Professional: Offspring Sex, Litter Composition and Neonate Mortality in Two Gazelle Husbandry Regimes

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Abstract

The rapid loss of biodiversity has increased reliance on captive breeding and reintroduction programs to conserve endangered species, yet these efforts face obstacles such as limited veterinary care, inbreeding, skewed sex ratios, and high juvenile mortality. This study examines breeding success and neonate survival in Arabian sand gazelles (Gazella marica) from private collections in Şanlıurfa Province, Turkey, and compares them with data from the King Khalid Wildlife Research Centre (KKWRC) in Saudi Arabia. We assessed offspring sex ratio, litter type, and survival during the first 30 days of life. Private collections showed a much higher frequency of singleton births—especially in first-time mothers—compared with KKWRC herds. Births in private facilities were concentrated between April and July, whereas KKWRC gazelles reproduced over a longer season. Although sex ratios were generally balanced, neonate survival in private collections was markedly lower. This reduced survival likely reflects management issues, including limited veterinary support and maternal inexperience. Overall, the study demonstrates how captive management conditions influence breeding outcomes and early survival in endangered species and emphasizes the need for stronger husbandry practices and reliable veterinary care in private breeding programs.

Keywords: Conservation Breeding; Private Collections; Offspring Life History Traits; Desert Ungulates; Middle East

Introduction

Due to the alarming rate of biodiversity loss, several conservation strategies were proposed to protect endangered species and populations from extinction. Sadly, captive breeding and subsequent reintroduction are often the only vital and effective strategy for conserving threatened species [1-3]. Consequently, in recent decades the recovery of endangered species has often depended on captive breeding programs [4,5], a strategy that is typically recommended when wild populations fall below critical demographic thresholds [6].

For example, the goitered gazelle (*Gazella subgutturosa*) and the Arabian sand gazelle (*Gazella marica*), two threatened Asian gazelle species, have experienced significant population declines since the 1950s, primarily due to overhunting and habitat degradation [1]. While the goitered gazelle is still relatively widespread across central Asian steppes [1,7,8], sand gazelles persist in only a few small, isolated, often reintroduced populations within their former range [1,8], prompting the IUCN to classify both species as ‘vulnerable’ [8,9]. At least for sand gazelles, *ex-situ* breeding is essential to ensure the survival of the species, and to produce healthy animals for reintroduction [10,11]. Several professional breeding centres were established across the Middle East and in central Asia, such as King Khalid Wildlife Research Centre in Saudi Arabia [12], the Bukharsky Breeding Station in Usbekistan [13,14], or the Kızılkuyu Gazelle Breeding Station in southern Turkey (KGBS; [15,16]. Beside such professional conservation breeding centres, private gazelle breeders are spread across the Middle East and North Africa, where enthusiast, collectors and hobby conservationists keep gazelles on private estates and successfully breed them [17,18].

However, numerous factors challenge the long-term viability of such captive populations, including insufficient veterinary care [19,20], elevated levels of inbreeding resulting from small or poorly managed founder groups [21,22], biased sex ratios that can disrupt breeding potential [23], and consistently high mortality rates across age all classes [24–26]. In captive ungulate populations in particular, mortality is disproportionately high among juveniles [25,27,28], making early-life survival one of the most variable and least predictable demographic parameters in both wild and captive settings [29]. Juvenile losses not only reduce the immediate growth potential of a population but also undermine genetic diversity and the long-term sustainability of breeding programs. Given these challenges, incorporating captive-bred gazelles—including those originating from private breeders as well as zoological institutions—into conservation and reintroduction programs requires a comprehensive understanding of reproductive performance and early survival. This includes accurate assessment of litter size, sex ratios at birth, and the biological, environmental, and husbandry-related factors contributing to juvenile mortality [30]. Such knowledge is essential for identifying management weaknesses, improving husbandry protocols, and ultimately increasing the likelihood that captive-bred individuals will contribute successfully to self-sustaining wild populations.

Obtaining detailed life history data from private gazelle breeders in the Middle East proves often difficult since owners are rather cautious to disseminate or share information with scientists, government bodies or the general public (Wronski, pers. observ.). Since private gazelle breeders in Turkey closely cooperate with the KGBS, we were able to make use of a unique data set obtained from 15 private gazelle breeders, resident in the Salinurfa Province of southern Turkey and compared our observations to corresponding data reported from a professional breeding centre in Saudi Arabia, namely the King Khalid Wildlife Research Centre (KKWRC; [25]). In our study, we analysed offspring sex, litter composition (twins versus singletons, male versus female twins) and neonate survival to 30 days for gazelle calves born in private collections and tested for differences between private and professional husbandry regimes. Given irregular veterinary care, biased sex ratios (this study), and likely increased rates of inbreeding in the private population (Uztemur, pers. observ.), we predicted neonate mortality to be higher than in the professional breeding centre, but intrinsic factors, such as litter size and off-spring sex, to remain unaffected by the husbandry regime.

Material and Methods

Study area and husbandry

The research was carried out in 15 private gazelle collections (Table 1) located in Şanlıurfa Province of southern Turkey. The region experiences a semi-arid and subcontinental climate, characterized by hot and dry summers (maximum temperature 39°C), as well as cold and rainy (occasionally snowy) winters [31]. The current captive population of gazelles held at private collections in Şanlıurfa Province descended from wild-born individuals bred at the KGBS. Details regarding the establishment of private collections, the size of breeding pens, the numbers of adult males and females maintained, and husbandry practices—including veterinary care, confinement, feeding, and the management of surplus males—are summarized in Table 1. KKWRC is in Al Thumama, 70 km north of Riyadh in Saudi Arabia. The climate is hyper-arid with very hot summers (often exceeding 45°C) and cold, dry winters. The rainfall in the area is erratic, with a mean annual precipitation of less than 20 mm, mainly between December and April [32]. Husbandry conditions at KKWRC were described in [12,25,33]. Unfortunately, corresponding data could not be obtained from the KGBS in Şanlıurfa Province, as the husbandry conditions did not permit the collection of early life history information. Gazelles are maintained in a large enclosure under semi-captive conditions, which makes it difficult to record litter size, offspring sex, and neonate survival up to two months of age, i.e., until the end of the calves' lying-out period [34].

Table 1: Details of 15 private sand gazelle (*G. marica*) collections in Şanlıurfa Province, southern Turkey, included in this study: year of foundation, size of breeding pens, number of adult males and females held, as well as husbandry conditions such as veterinary care, constraint, feed type and the disposition of surplus males.

Breeder	Breeding since (yr)	Enclosure size (ha)	Males (No)	Females (No)	Veterinary assistance	Constraint	Feed (ad libitum)	Surplus males
Fevzettin Felhan	15	4.1	4	22	Regular, two vaccinations /year	Capture boma	Alfalfa, black barley	Separated or disposed
Ali Pınar	5	2.4	3	17	Regular, two vaccinations /year	Capture boma	Alfalfa, black barley	Separated or disposed
Hamet Felhan	2	1.5	1	2	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Hüseyin Aygutlu	2	0.8	1	1	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Eyüp Bayram	2	≈ 2.0	1	5	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Mehmet Tümtaş	4	≈ 2.0	1	8	Only if required	Immobilisation	Alfalfa, black barley	Disposed
İbrahim Halil Sancak	2	≈ 2.0	1	3	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Mehmet Ali Sökmen	2	≈ 2.0	1	5	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Mehmet Arıcı	2	≈ 2.0	1	2	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Ahmet Kaydı	3	≈ 2.0	2	9	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Müslüm Kaya	2	≈ 2.0	1	3	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Mahmut Çavlı	3	≈ 2.0	1	6	Only if required	Immobilisation	Alfalfa, black barley	Disposed
İbrahim Kaya	3	≈ 2.0	1	6	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Muhitiin Kaya	2	0.8	1	1	Only if required	Immobilisation	Alfalfa, black barley	Disposed
Mehmet Emin Yıldırım	2	1.5	1	4	Only if required	Immobilisation	Alfalfa, black barley	Disposed

Study species

Gazelles kept at KGBS as well as in the in private collections of Şanlıurfa Province are generally regarded Arabian sand gazelles (*Gazella marica*; [35,36], Figure 1), although morphologically they exhibit several traits characteristic of goitered gazelles (*G. subgutturosa*; [35]. Females of *G. marica* have well-developed horns and produce regularly twins, while those of *G. subgutturosa* hardly possess horns and rarely produce twins [34,37]. In contrast, gazelles bred at the King Khalid Wildlife Research Centre (KKWRC) are genetically and phenotypically confirmed to be pure Arabian sand gazelles [38]. For further information on the distribution, ecology, and behaviour of Arabian sand gazelles see [37,39].

Figure 1: Male Arabian sand gazelle (*Gazella marica*) kept at KKWRC in Saudi Arabia (left), male 'hybrid' gazelle in Kızılkuyu Gazelle Breeding Station in southern Turkey (centre), and male goitered gazelle (*Gazella subgutturosa*) held at the Hluboká Zoo in Czech Republik (right).

Data collection

Data from 123 gazelle calves were obtained from records of private gazelle breeders and included information on sex ratio at birth, litter size and composition, calf survival to 30 days, and the mother's age (reproductive experience) at parturition. We examined differences between singleton births (n = 53) and twin births (n = 35), as well as between male (singleton: n = 22; twin: n = 36) and female offspring (singleton: n = 31; twin: n = 34) recorded during a single breeding season, from February to August 2024. For comparison, corresponding data from the King Khalid Wildlife Research Centre (KKWRC)—reanalysed from Riesch., *et al*. [25] covered a period of 13 years (March 1997 – April 2010) and included 385 singleton and 391 twin births.

Data analysis

Litter size: Singleton versus twin births

In a first step, we evaluated the ratio of singleton-to-twin births for all mothers, as well as for young, inexperienced mothers (primiparous, usually ≤ 1 year of age), and those that had given birth previously (experienced females, ≥ 2 years of age). Secondly, we assessed whether birth events were non-randomly distributed across the main breeding season (February to August; [25]) using a χ^2-test, whereby the expected probability of births in each month was 0.143 (i.e., even distribution across seven months). We also tested if the ratio of singleton-to-twin births differed from random expectations in each month using separate χ^2-tests (i.e., even distribution across litter types; 1: 1 ratio).

Sex ratio at birth

Offspring sex ratios were assessed at multiple levels. First, we examined whether the overall sex ratio among all individuals included in the study (N = 123) deviated from parity. We then evaluated whether sex ratios differed according to litter size, analysing singleton and twin births separately. In each case, deviations from an expected 1: 1 male-to-female ratio were tested using a χ^2 test. Finally, we used an additional χ^2 test to assess the distribution of twin birth types, categorizing litters as male–male, female–female, or mixed-sex. Under random sex determination, the expected proportions of these categories are 0.25 for unisex twins (male–male or female–female) and 0.50 for mixed-sex twins.

Neonate survival

Neonate survival in the private population was analysed to 30 days, corresponding to the period of highest perinatal mortality in captivity [20,24,26] using data from 123 calves born between February and August 2024. Daily cumulative survival was calculated separately for males and females, and results were compared with those reported by Riesch., *et al*. [25] using a Wilcoxon–Mann–Whitney test, as Shapiro–Wilk tests indicated non-normal distributions for both sexes (males: W = 0.85, p < 0.01; females: W = 0.92, p < 0.01).

Results

Litter size: Singleton versus twin births

In private collections, the overall singleton-to-twin birth ratio was significantly biased toward singletons (1: 0.66), contrasting with the near parity reported from the professional breeding facility in Saudi Arabia (1: 1.02; KKWRC, [25], Table 2). Among inexperienced mothers, this ratio deviated strongly from 1: 1, being markedly skewed toward singleton births (1: 0.34; Table 2). In contrast, experienced mothers showed a significant bias toward twin births (1: 1.36; Table 2), indicating that the likelihood of producing twins increases with maternal age and reproductive experience. This pattern corresponds with findings from the KKWRC [25] where inexperienced mothers exhibited a slight tendency toward more singletons (1: 0.88; Table 2), while experienced mothers showed the opposite, though non-significant, trend toward more twin births (1: 1.14; Table 2).

Table 2: Chi-square test results between the observed ratio of singleton-to-twin births and random expectations for all females, for experienced and inexperienced mothers kept at 15 private gazelle collections in Şanlıurfa Province (southern Turkey), and at a professional breeding centre in Saudi Arabia (KKWRC; [25]).

Private	ratio	n	χ^2	df	p
All females	1 : 0.66	88	4.82	1	0.028
Inexperienced females	1: 0.34	30	56.84	1	<0.0001
Experienced females	1 : 1.36	59	17.62	1	<0.0001
Professional					
All females	1 :1.02	1166	0.06	1	0.15
Inexperienced females	1 : 0.88	192	0.75	1	0.39
Experienced females	1 : 1.14	551	2.49	1	0.12

The distribution of monthly birth events in private collections was significantly skewed ($n = 88$, $\chi^2 = 304.7$, $df = 6$, $p < 0.0001$), with all births occurring between April and July (Figure 2). In contrast, at the professional breeding centre (KKWRC; [25]), monthly birth events were likewise significantly skewed ($n = 778$, $\chi^2 = 3244$, $df = 11$, $p < 0.0001$), but births began earlier in the year (February), with the majority (89%) recorded in March, April, and May (Figure 2). The singleton-to-twin birth ratio in private collections was strongly biased toward twins in April (1: 3.33, $n = 13$, $\chi^2 = 76.18$, $df = 1$, $p < 0.0001$; Figure 2), in stark contrast to KKWRC data, where the ratio was significantly skewed toward twins in March (1: 1.12, $n = 434$, $\chi^2 = 15.80$, $df = 1$, $p < 0.0001$; Figure 2)—approximately two months earlier than in Turkey. During all other months, the singleton-to-twin ratio showed no significant bias, or only singletons were recorded (data not shown).

Sex ratio at birth

The overall sex ratio of singleton and twin-born calves did not deviate significantly from parity (Table 3). Likewise, sex ratios did not differ between litter sizes (Table 3). These results are consistent with findings from the KKWRC in Saudi Arabia, where sex ratios were close to parity across all categories ([25], Table 3). The frequency distribution of twin birth types differed significantly from the expected even distribution, being strongly skewed toward mixed-sex litters, while both female–female and male–male twin births were underrepresented (Table 3). This pattern contrasts sharply with the KKWRC results, where female–female twins were overrepresented and mixed-sex twins underrepresented ([25], Table 3).

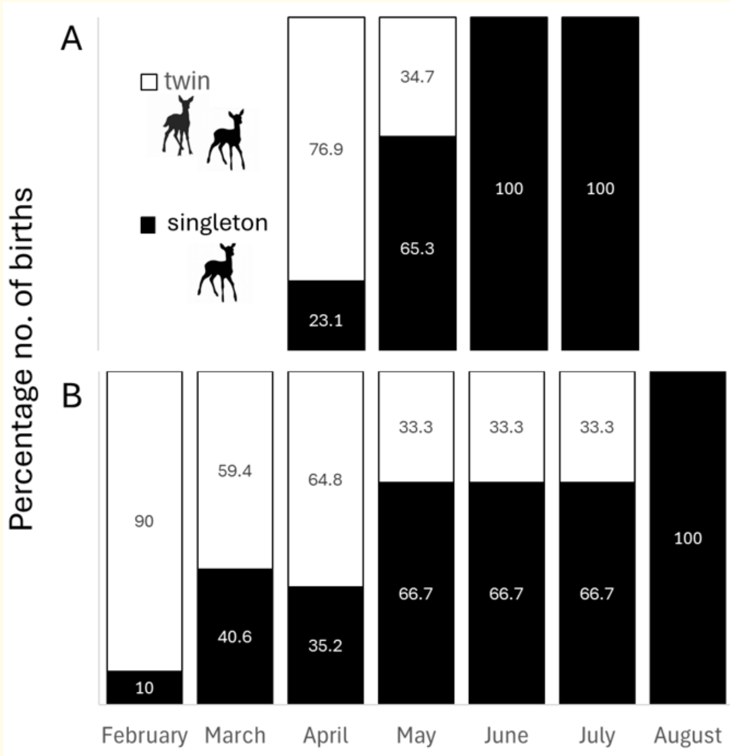

Figure 2: Distribution (%) of monthly singleton and twin births in (a) private collections of Şanlıurfa Province, Turkey, and (b) in a professional breeding centre (KKWRC, Saudi Arabia; [25]).

Table 3: Chi-square test results between random expectations and the observed sex ratios of all calves, singleton and twin-born calves born and raised in 15 private sand gazelle (*G. marica*) collections in Şanlıurfa Province (southern Turkey), and at a professional breeding centre in Saudi Arabia (KKWRC; [25]); mm: male-male, ff: female-female, fm: female male.

Private	ratio	n	χ^2	df	p
All (single, twins)	1: 1.13	98	0.40	1	0.53
Singletons	1: 1.35	54	0.77	1	0.38
Twins	1: 0.91	44	0.06	1	0.80
ff/mm/fm twins	1: 1.25: 6.5	89	6.28	2	**0.04**
Professional					
All (single, twins)	1: 1.02	1166	0.12	1	0.73
Singletons	1: 1.02	384	0.04	1	0.84
Twins	1: 1.02	782	0.08	1	0.78
ff/mm/fm twins	1: 0.83: 0.76	390	5.74	2	0.056

Neonate survival

The Wilcoxon–Mann–Whitney test revealed a significant difference in cumulative survival between males born in private collections and those from the professional breeding centre (KKWRC; [25]) (W = 76.5, p < 0.01; Figure 3). Similarly, female survival differed significantly between the two breeding contexts (W = 143.5, p < 0.01; Figure 3).

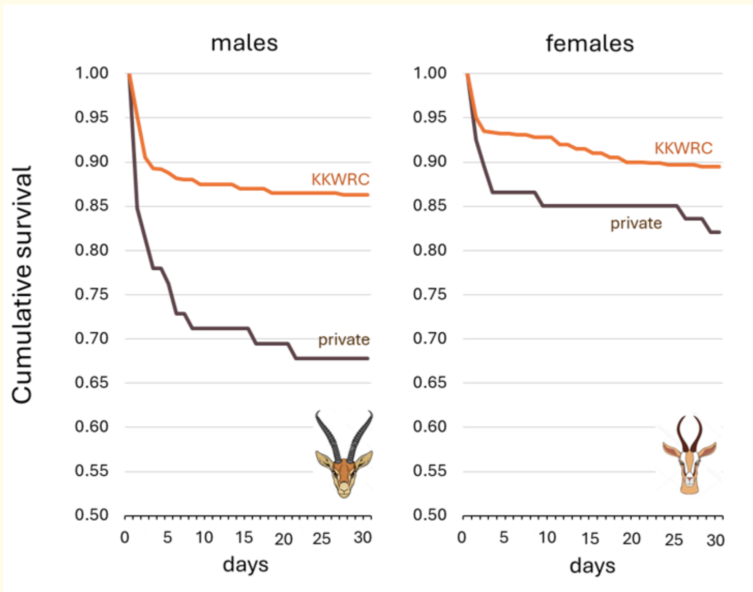

Figure 3: Cumulative survival (%) over 30 days for male and female gazelle offspring born and raised in private collections of Şanlıurfa Province in Turkey, and in a professional breeding centre (KKWRC, Saudi Arabia; [25]).

Discussion

In private collections, female gazelles were generally more likely to give birth to singletons than twins, a trend particularly pronounced in primiparous mothers, whereas experienced females showed a higher likelihood of producing twins (Table 2), indicating that twin births increase with maternal age. These patterns are consistent with observations from professional breeding centres such as KKWRC in Saudi Arabia (*G. marica*; [25]) or the Estación Experimental de Zonas Áridas (EEZA) in Almeria, Spain (*G. cuvieri*; [40]).

Most births in private collections occurred between April and July, with twin births restricted to April and May. At KKWRC, the main breeding season was similarly skewed but started earlier in the year (February), with twin births occurring almost throughout the entire breeding season from February to July ([25], Figure 2). Moreover, the ratio of singleton-to-twin births in Turkey peaked in April, while that reported from KKWRC was highest from February to April, i.e., two months earlier than in Turkey. This pattern may reflect climatic differences between the hyper-arid environment in Saudi Arabia (main vegetation period starts in early spring after sporadic winter rains) and the more Mediterranean climate of southern Turkey where the vegetation period is delayed due to shorter days and lower temperatures in spring [31,32].

Overall sex ratios, as well as sex ratios between singletons and twins did not differ from parity (Table 3). This was not unexpected since the same pattern was unrevealed for ratios reported from

KKWRC (Table 3), from reintroduced *G. marica* in Saudi Arabia [41], and from Cuvier's and Mhorr gazelles (*Nanger dama mhorr*) at the EEZA [30,42]. Here, only the inbreeding of *G. cuvieri* females influenced offspring sex, with inbred mothers having a higher probability of producing daughters than sons, a phenomenon commonly reported from newborn ungulates [23,43,44].

Our study further revealed a significant difference between the cumulative survival of males and females born in a professional breeding centre (KKWRC; [25],) and that of gazelles born in private collections. To address newborn mortality in zoos and captive breeding programs, it is essential to identify factors affecting their early death. Newborn gazelles that die within the first days of life were reported to have suffered from hypothermia, infectious diseases, injuries, or starvation prior to death [45-47]. It was also shown that the length of the nursing period is important for the survival of newborn gazelles [48]. and that calves raised in KGBS are more prone to maternal neglect than those born under natural conditions [49,50]. Maternal neglect occurs usually in primiparous mothers [20,26,51] and the high proportion of young, inexperienced females in private facilities may have contributed to the low survival rates observed in our study. Climatic factors like low temperatures, dampness or drought were also reported to have a direct impact on the survival of newborn desert ungulates [52,53]. Since the private collections in southern Turkey are about 1,500 km north of KKWRC, it could be argued that the differences unravelled by our study are due to latitudinal differences, i.e., a milder and more humid climate. This is, however, unlikely since neonate mortality would be expected to be higher in the harsher climate of Saudi Arabia, than in the Mediterranean climate of Şanlıurfa Province [31,32].

Furthermore, management related factors are known to influence newborn mortality in breeding facilities, such as inbreeding, crowding, or the breeding regime [21,54,55]. Husbandry conditions at KKWRC are more professional with shielded, spacious breeding pens (100 x 50 m) comprising standardised breeding groups of one male and 10 females [12,33]. Pens are equipped with capture bomas to remove yearling males and to perform regular veterinary screening and annual vaccinations [33]. Feed at KKWRC was provided *ad libitum*, mainly dried, baled alfalfa (*Medicago sativa*) together with pellet concentrate and mineral lick, while feed given by private breeders was solely based on black barley, supplemented with baled alfalfa. This rather one-sided nutrition and the lack of natural grazing and mineral supply may cause malnutrition due to a deficiency of minerals, vitamins and trace elements (Uztemur pers. observ.). Among the private breeders, only Fevzettin Felhan and Ali Pınar have capture facilities, and provide regular veterinary care and vaccinations to their captive stock, while others request veterinary assistance only in case of disease or trauma (Table 1). Since postmortem and necropsy are not performed on dead gazelles, the causes of death are not investigated and precautions to avoid future casualties are difficult to implement. Most private breeders, are inexperienced in breeding gazelles since facilities were only recently established and are usually poorly equipped with enrichment structures, hides or shelters (Table 1). Most importantly, yearling males are often not separated from their mothers in time, leaving them vulnerable to aggression from adult males. Such persistent antagonistic interactions frequently result in injuries and psychological stress (Uztemur, pers. observ.). Furthermore, private breeders typically fail to conduct regular (daily) monitoring of their gazelles and neglect to maintain systematic records—practices that are essential for improving animal health, welfare, breeding success, and neonate survival.

Conclusion

The findings highlight clear differences in reproductive patterns and offspring survival between private gazelle collections and professional breeding centres. Twin births increased with maternal age, breeding seasons varied geographically with climatic influences, and sex ratios remained balanced across sites. However, newborn survival was markedly lower in private facilities, likely due to inexperienced primiparous mothers, insufficient husbandry standards, limited veterinary care, inadequate nutrition, and the lack of structured breeding regimes and monitoring. These results underscore the need for improved management practices to enhance neonate survival and support sustainable gazelle conservation. In addition, further research into reproductive parameters—such as mating behaviour, pregnancy, abortion, and birth rates—in both private facilities and professional stations (especially Kızılkuyu

Gazelle Breeding Station), combined with more regular veterinary care, will be essential for improving reproductive success and producing healthy individuals for future reintroductions in Şanlıurfa Province or other suitable areas in the region.

Acknowledgment

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Ethics and Integrity

The data supporting the findings of this study are available within the article. Raw data can be accessed upon reasonable request from the corresponding author. Data sharing will be subject to any applicable ethical and legal restrictions, as well as the consent of participants involved in the study. Our study was financially supported by the Ministry of Agriculture and Forestry of the Republik of Turkey, General Directorate of Nature Conservation and National Parks. All authors disclose no conflict of interests. Ethical approval was obtained from the Ministry of Agriculture and Forestry, General Directorate of Nature Conservation and National Parks (approval number: E-21264211-288.04-13396710), as well as from the Local Ethics Committee of Harran University (approval number: 310123).

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