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Insights into fallow deer population dynamics: Juvenile mortality in Arad County

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Abstract The fallow deer (*Dama dama*) is one of the main species of large herbivores in Romania, with a fluctuating presence over time, particularly during the last century. Population fluctuations have been driven by a combination of factors including climate, habitat quality, interspecific competition, predation, and human activities. While mortality represents a key component in the population dynamics, this study aims to quantify juvenile mortality in fallow deer during their first year of life, representing one of the first investigations of this type conducted in Romania. The study examines juvenile mortality rate in a fallow deer population from the Western Plain of Romania over the period June 2020-May 2021. Population structure was analyzed by age classes, and temporal variation in reproductive performance was evaluated by examining the number of calves per mature female over one year. The results indicate a juvenile mortality rate of approximately 50% during the first year of life. This level of mortality is considered typical for natural habitats supporting free-ranging ungulate populations in the presence of substantial mesocarnivores populations. The age-class structure of female fallow deer, together with the population dynamics of mesocarnivores, particularly the golden jackal (*Canis aureus*) and the red fox (*Vulpes vulpes*), suggests that predation plays a significant role in juvenile mortality within the study area. These findings highlight the importance of continuous monitoring of reproductive indicators and predator populations to ensure more effective wildlife management strategies.

Keywords: fallow deer, mortality rate, age structure.

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Introduction

In European temperate forest ecosystems, the most widespread ungulate species, in terms of range and population numbers, are roe deer (*Capreolus capreolus* L.), wild boar (*Sus scrofa* L.), red deer (*Cervus elaphus* L.), moose (*Alces alces* L.), and fallow deer (*Dama dama* L.) (Linnell et al. 2020, Hardalau et al. 2024). These species play a pivotal role in the development of forest ecosystems and are considered key species for wildlife management (Putman 1996). Among them, special emphasis should be placed on the fallow deer, as it represents a significant factor in food security and sustainability (Chakanya et al. 2016). A notable population of fallow deer can be found in Eastern Europe, specifically in Romania (Esattore et al. 2022), with healthy populations proven by the participation of fallow deer trophies in international game fairs (Bijl & Csányi 2022). Treated as an important game species, the fallow deer has been a notable presence since before the glaciations, as evidenced by the abundant fossil deposits from the Neolithic period found in the southwestern part of the country (Necrasov & Haimovici 1963, Bokonyi 1971, Susi 1996).

Romania is one of 37 European countries where fallow deer live in free-ranging populations that interact naturally with occupied habitats and with other coexisting wildlife species (Putman et al. 2011). The stability and dynamics of the main large herbivore species (fallow deer and roe deer) are influenced by available forage and predation (Melis et al. 2009). The fallow deer has an irregular distribution throughout Romania, with most of the population found only in certain hotspots. One of the hotspots is located in the western part of the country, in Arad County, where this species is found in 17 hunting grounds, totaling 2,852 individuals in 2023, which represents 35.5% of the total population of Romania. In five hunting grounds in a neighboring county within the Western Plain, the fallow deer population can be classified as overabundant, with four times more specimens present than the sustainable population threshold (Hardalau et al. 2025) The spread and prosperity of this species in this region are directly related to habitat quality and to wildlife management measures from the past decades (Cotta et al. 2001, Geacu 2011, Bijl & Csányi 2022). However, as part of the trophic chain, the fallow deer also experiences negative interactions, including mortality due to predation, natural causes, food limitations, and anthropogenic effects (Chapman & Chapman 1980, Linnell et al. 1995).

Natural mortality in wildlife is governed by complex relationships, particularly prevalent among juveniles under one year of age (referred to as early postnatal mortality) and older, senescent individuals. This mortality is often due to predation, disease, and parasitism (Garratt et al. 2015). In fallow deer, primary causes of mortality are attributed to predation by various carnivorous species, including the wolf (*Canis lupus* L.), golden jackal (*Canis aureus* L.), and red fox (*Vulpes vulpes* L.) (San José & Braza 1992, Kjellander et al. 2012). In the Romanian landscape, wolf habitats do not predominantly include plain regions; therefore, the main predators of fallow deer are mesocarnivore species (Rossa et al. 2021). Mesocarnivores are medium-sized carnivorous mammals, typically weighing less than 15 kilograms, that are ecologically important due to their diverse behaviors and ecological roles, collectively influencing ecosystems through predation and interactions with other species, despite their populations being more abundant than those of large carnivores (Roemer et al. 2009). However, there is insufficient research on the impact of predation on the dynamics of fallow deer populations, especially in Romanian ecosystems (Ciuti et al. 2004, Kjellander et al. 2012, Apollonio et al. 2014).

This study aims to provide a comprehensive assessment of fallow deer population dynamics and movement patterns throughout the year using a standardized observation plan. Furthermore, as the first study to address juvenile mortality in the country, it seeks to quantify postnatal mortality rates in fallow deer under one year old, based on the structural characteristics of the population in Arad County. By enhancing the understanding of fallow deer population dynamics in western Romania, this research aspires to inform and support the development of more effective wildlife management strategies.

Materials and Methods

Study area

The study focuses on three hunting grounds (HG) in the Western Plains of Romania: 20 Ratu Pilii, 21 Socodor, and 23 Adea (see Figure 1). This area is notable for its rich biodiversity and unique ecological features, characterized by a balanced ratio of forest and agricultural fields. Within these hunting grounds, the estimated population of fallow deer stands at 1,597 individuals, representing 56% of the total fallow deer population in Arad County and accounting for 21% of population of fallow deer found in Romania. The study area covers a total of 22,169 hectares, situated in the meadow region bordered by the Crișul Alb and Morilor Canal rivers, near the Hungarian border.

Sampling design and data collection

Between June 2020 and May 2021, a sample grid consisting of 12 permanent observation points was established (see Table 1). Four permanent observation points were set up in each hunting ground, focusing on hotspots (areas with higher movement and sightings) of fallow deer activity. For each observation point, at least four monthly observations were conducted, totaling a minimum of 48 individual observations each month. A total of 1344 of observation was done. Observations were conducted using direct observation, binoculars, and thermal imaging, with the collected data recorded on observation sheets. These sheets included information on location, observation period (morning/evening), the number of individuals observed by sex and age category, behavior of the observed animals, habitat used, and seasonal characteristics such as the date of first calving, last calving, and the start and/or end of browsing. The observations were centralized in a database for later analysis. Additionally, data on forest stands and the positions of the observation points were collected.

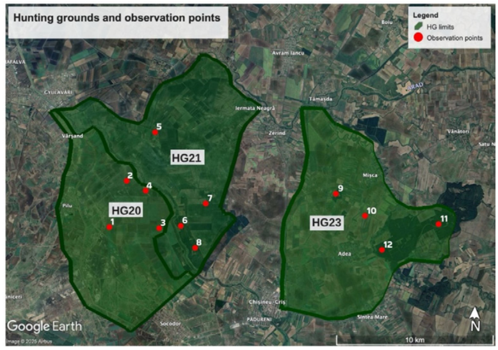

Figure 1 The location of the study and localisation of the permanent observation points in HG 20 Ratul Pilu, 21 Socodor and 23 Adea.

Table 1 Geographical location of observation points.

No.	Hunting ground	Observation point	Point number	Coordinates lat. N	Coordinates long. E
1	20 Râtul Pilu	Brihani	1	46.591587	21.390952
		Orezărie	2	46.586581	21.407132
		Bănățeni	3	46.563778	21.377177
		Fânar	4	46.56458	21.429855
2	21 Socodor	Observator	5	46.553678	21.452193
		Rica	6	46.579731	21.460261
		Crișana	7	46.621351	21.413569
		La „10”	8	46.566249	21.439061
3	23 Adea	Hămoci	9	46.576987	21.598234
		Livada	10	46.589538	21.572742
		48 v	11	46.573787	21.662135
		Capelă	12	46.557824	21.614112

The data on mesocarnivores numbers were collected from the official reports from the Ministry of Environment, Waters and Forests for the 2014-2023 interval (MMAP 2024) consisting in estimated number of individuals per hunting ground. In each hunting ground, wildlife specialists conducted comprehensive surveys using direct observations to assess the populations of various species present.

Statistical analyses

For accuracy in the scientific importance, both data from the observation and official reports from the resort ministry were used. The database and the visualization were done using Microsoft Excel 16.93.1. All statistical analyses were performed using IBM SPSS 29.0.2.0. First, to assess any biases and errors in the observations, a non-parametric Wilcoxon Signed Rank Test at a confidence level of 95% was applied to determine whether differences exist between the morning and evening observations. The structure of the population was calculated based on the gender and the age of the individuals. Based on the calculated parameters, the sex ratio of male and females were calculated and a detailed age structure was obtained. A Principal Analysis Component (PCA) was conducted on a dataset containing seven variables: distance to agricultural land (DAGR), distance to road (DROAD), distance to water source (DWATER), composite index (COMP), consistency (K), age of the stand (AGE), and volume of the stand (VOL). Where the observation point was located in an agricultural field, the related parameters had the value 0. The dataset consisted of 12 observations. Secondly, based on the structure of the population, the monthly loss and the overall mortality was calculated, based on the following the equation:

$$MR = \frac{Yearlings}{Reproductive\ females},$$

where:

MR=mortality rate in %;

Yearlings= fallow deer of below 1 year of age;

Reproductive females= fallow deer females with an age above 2 years.

Thirdly, the population dynamics of the golden jackal and red fox were analyzed using the Compound Annual Growth Rate (CAGR), applying population figures from 2014 to 2023 as independent variables. This analysis was based on official data gathered from the Ministry of Environment, Waters and Forests over the same period. To evaluate the significance of the CAGR, the model was tested using ANOVA at a 95% confidence level.

Results

Fallow deer population characteristics

A total of 576 observations were made, with 285 conducted in the morning (49.48%) and 291 in the evening (50.52%). The results of the Wilcoxon Rank Test indicated no significant differences between morning and evening observations (*p=0.272*). The average count for morning observations was 71.56 individuals, while the average count for evening observations was 68.83 individuals.

In terms of the age structure of the studied fallow deer population, approximately 70% are found in the 1-3 years and 3-6 years categories (Table 2). Less than 1% of the population is over 8 years old, while yearlings account for about 22.3% of the total population. Females dominate the distribution of sexes at 68.2%, resulting in a sex ratio of *1:2.15*.

Table 2 Structure by sexes and age categories of the studied fallow deer population.

Structure by age					
Male Fallow deer proportion (%)					
< 1 year	1-3 years	3-6 years	6-8 years	>8 years	Total
35.4	40.9	17.3	5.2	1.2	100
Female Fallow deer proportion (%)					
< 1 year	1-3 years	3-6 years	6-8 years	>8 years	Total
16.4	31.3	43.8	8.6	0	100
Fallow deer proportion (%)					
< 1 year	1-3 years	3-6 years	6-8 years	>8 years	Total
22.3	34.35	35.47	7.5	0.38	100
Structure by sexes					
Male proportion (%)			Female proportion (%)		Total
31.8			68.2		100

For male fallow deer, the age structure is as follows: 35.4% in the under 1 year category, 40.9% in the 1-3 years category, 17.3% in the 3-6 years category, 5.2% in the 6-8 years category, and 1.2% in the over 8 years category. When categorized by age classes, 76.3% are classified as young, consisting of specimens under 3 years of age, 22.5% fall into the medium age category, comprising specimens between 3 and 8 years of age, and 1.2% are classified as mature, consisting of specimens over 8 years of age (Figure 2).

For female fallow deer, the age structure is as follows: 16.4% in the under 1 year category, 31.3% in the 1-2 years category, 43.8% in the 3-6 years category, and 8.6% in the 6-8 years category. When categorized by age classes, 47.7% are classified as young, consisting of specimens under 2 years of age, while 52.3% fall into the medium age category, comprising specimens between 2 and 6 years of age (Figure 3). Notably, no specimens older than 6 years were identified.

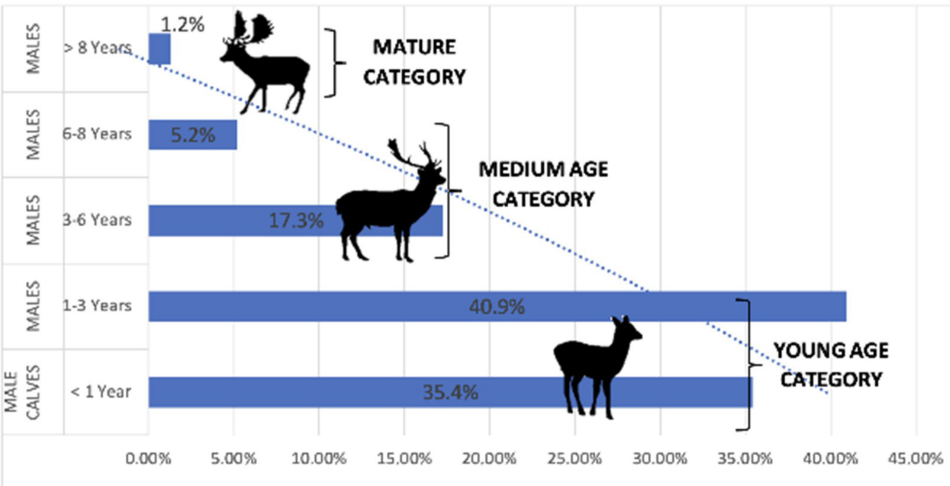

Figure 2 Age class structure of fallow deer males observed in the study area.

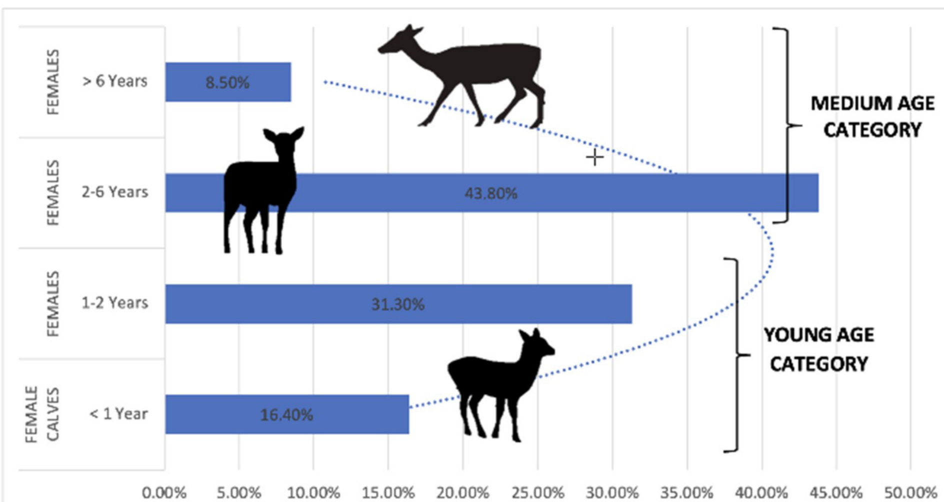

Figure 3 Age class structure of female fallow deer observed in the study area.

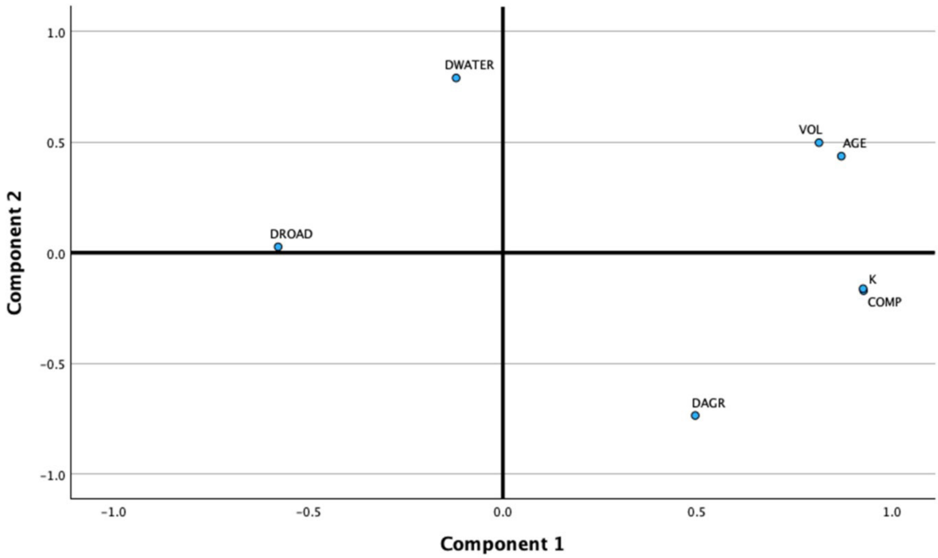

Figure 4 Component matrix based on PCA extraction method with 2 components extracted.

Before conducting Principal Component Analysis (PCA), Bartlett's Test of Sphericity was carried out to evaluate whether the data was suitable for dimensionality reduction. The results of the test were significant ($\chi^2 = 137.018$, $df = 21$, $p < 0.001$), suggesting that the correlation structure is appropriate for PCA. However, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was at *0.444*, which indicates that the overall adequacy for PCA is relatively weak. COMP and K were highly correlated ($r = 0.988$, $p < 0.01$), suggesting redundancy in these two variables. AGE and VOL exhibited an extremely high correlation ($r = 0.990$, $p < 0.01$), implying a strong association between these characteristics. Negative correlations were observed between DAGR and DROAD ($r = -0.437$), as well as between DAGR and DWATER ($r = -0.432$), indicating spatial dependencies. Principal Component Analysis (PCA) was performed using eigenvalues greater than 1 as the selection criterion. The analysis identified two principal components (PCs) that accounted for a total of 77.01% of the variance in the dataset. The variance explained by PC1 is 53.32%, while for PC2 is 23.69%. The other components contributed very little variance (less than 13%) and were not included in the final results.

Mortality rates in the fallow deer population

Following the last births, which occurred in mid-July across the three hunting grounds, the highest average ratio of observed yearlings to reproductive females was recorded in July, peaking at a value of 0.9. In contrast, the lowest ratio of 0.46 was identified in May. Since births began in June, the average ratio of 0.75 during that month was not considered for further analysis. The ratio of yearlings to reproductive females reaches its maximum inflection point just after the peak calving period, with the highest value of 0.94 calves per mature female observed in HG Socodor, and the lowest at 0.85 calves per mature female in HG Adea. This ratio progressively declines until May, when it drops to the lowest value of 0.43 yearlings per reproductive female in the HG Ratul Pilu game reserve and 0.53 yearlings per reproductive female in HG Socodor.

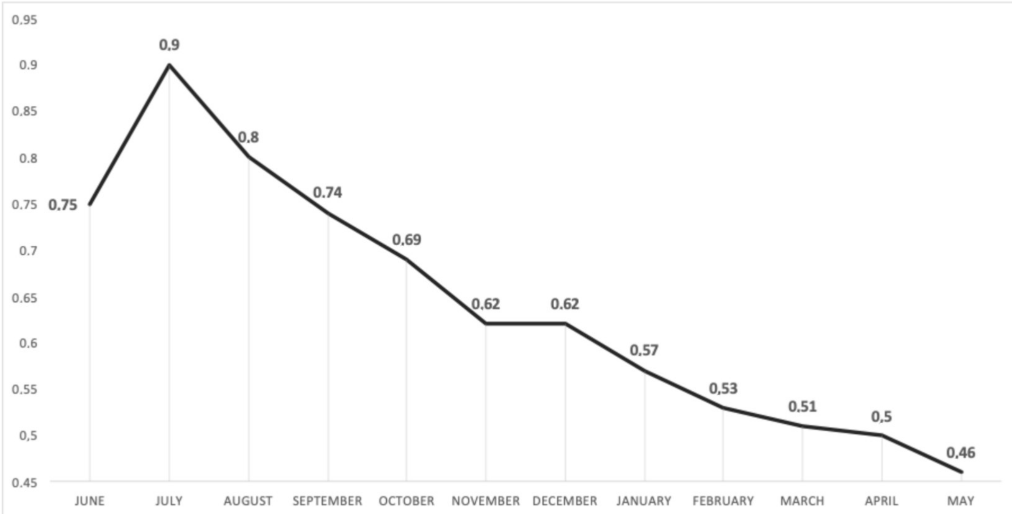

Figure 5 Average change in number of the ratio of observed yearlings and reproductive females during June 2020 and May 2021.

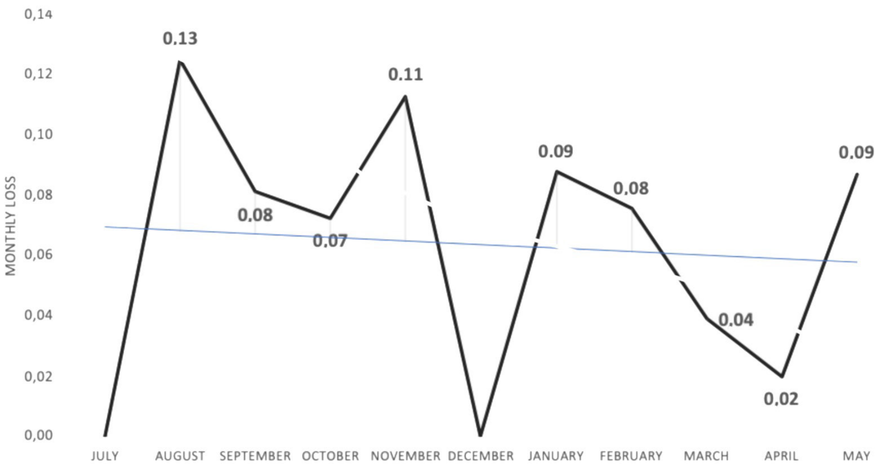

Figure 6 Monthly losses based on the ratio of observed yearlings and reproductive females during June 2020 and May 2021.

The reference month for calculating the monthly losses in the yearling and reproductive females was taken into account as July, when the births have been completed. Since the reference month, a decreasing trend of monthly losses was identified. The highest losses were in August and November, with 0.13 and 0.11 (Figure 5). Between November and December, the ratio of observed yearlings and reproductive females remained the same.

The mortality rate was considered to achieve its peak in the month of May, the last month prior to the beginning of the birth period. The mortality rate ranged from a minimum value of 42.4% recorded in HG Adea to a maximum value of 53.3% in HG Ratul Pilu. The average value of the mortality rate was found to be 46.4%.

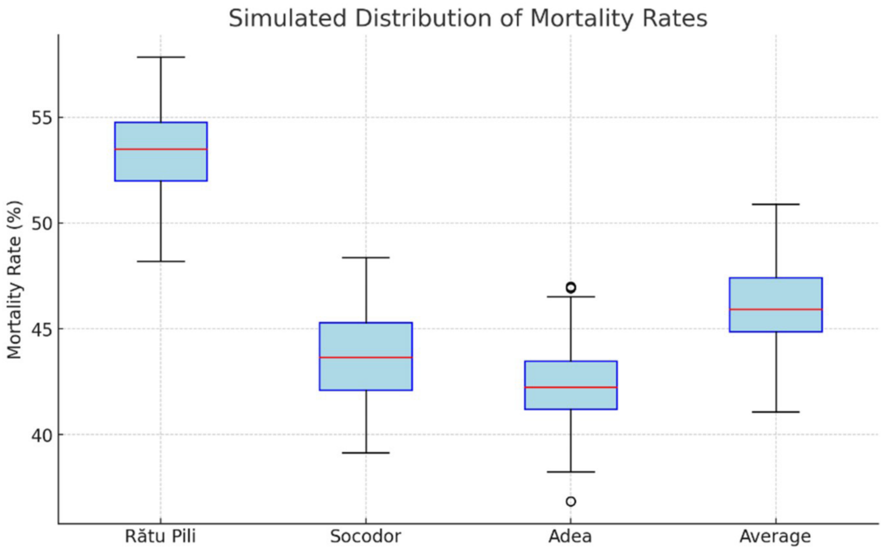

Figure 7 Juvenile mortality values in young red deer in the first year of life in the studied population in Arad County.

Meso-carnivores dynamics

Based on CAGR, in the red fox population, a decreasing trend is identified, while in the case of the golden jackal the trend is of increase, with an increase of 828.8% in 2023 compared to 2013, both trends being significant with a *p<0.001*. Based on these numbers, a ratio of 0.92 individual of red fox corresponds to an individual of fallow deer and 0.57 individual of golden jackal correspond to an individual of fallow deer in the study area. The Compound Annual Growth Rate.

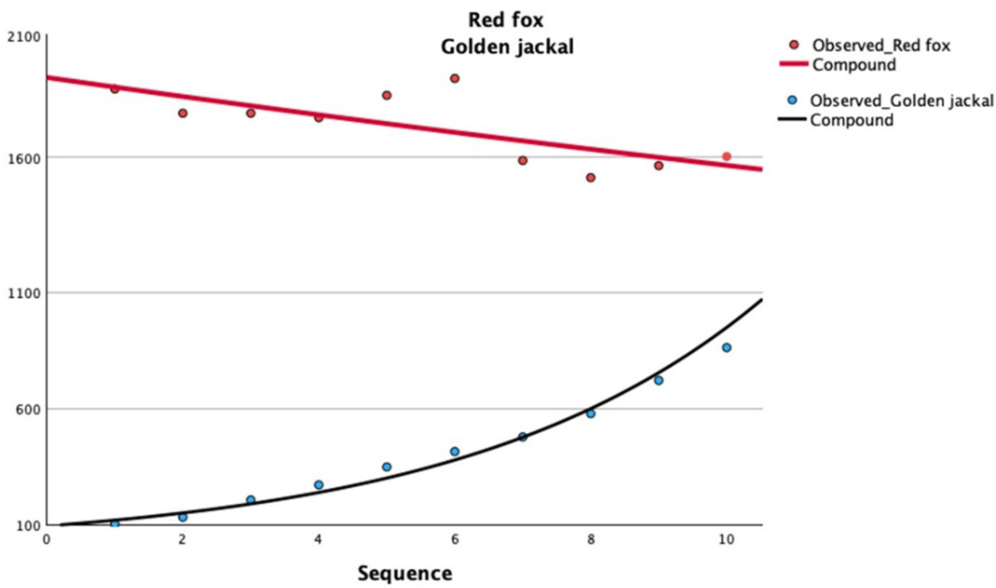

Figure 8 Mesocarnivores CAGR in the 2014-2023 decade in the study area.

Discussion

The observed sex ratio of *1:2.15* indicates a clear numerical deficit of males compared to females, deviating from the natural ratio of *1:1*, which is the ratio recommended for consideration in hunting harvesting (Ueckermann & Hansen 1968, Chapman & Chapman 1975). Furthermore, the age distribution among male fallow deer is irregular, the polynomial trend line reveals a slightly flattened age pyramid, reflecting a low number of individuals in the middle (3-8 years) and old (over 8 years) age classes. This age structure likely results from management measures that predominantly targeted male individuals over the age of 6, significantly altering the composition of upper age classes and affecting the sex ratio. In contrast, the age structure for females shows a different pattern, characterized by an irregular distribution wherein the middle age classes (one to six years) are numerically dominant, while the under-one and over-six-year age classes are comparatively scarce. Here, the polynomial trend line widens in the area of one to six years, indicating a greater density of individuals, and narrows in the categories of under-one and over-six years. Principal Component Analysis effectively condensed the dataset into two primary dimensions: (1) structural/demographic variation and (2) spatial characteristics. The strong correlation observed among certain variables implies that there may be redundancy, thus, future research might focus on simplifying or refining these variables. Although the KMO value was low (0.444), the components retained account for a significant amount of variance (77.01%), which supports their inclusion in subsequent analyses. This pattern may suggest active intervention in these specific age categories through targeted hunting practices and/or the impact of predation, which is known to be more prevalent among females and their calves than among males (Ciuti et al. 2004).

From this perspective, it is crucial to monitor the number of calves per mature female (with a mature female defined as a reproductively viable female at least two years old) and how this value varies with the intensity of predation and other factors such as hunting throughout the year. With more than 99% of births resulting in a single calf, any loss due to predation, climatic influences, disease, or anthropogenic factors is particularly detrimental for the mother deer. This leads to increased vigilance following parturition (Bergvall et al. 2016). The mortality rate for juvenile fallow deer is notably highest during the first two months post-birth, decreasing rapidly as they mature (Langbein 1990, Clutton-Brock et al. 1985b). An increase in juvenile mortality often serves as an early indicator of a declining population and is a critical element in the natural regulation of ungulate populations. Juvenile ungulates, including fallow deer, are among the most vulnerable to predation, with older individuals also facing significant risks (Barber-Meyer & Mech 2008). Various studies have documented a range of juvenile mortality rates in fallow deer: 4.4% in England (Langbein 1990), 10% in Doñana National Park, Spain (Braza et al. 1990), 16.2% in New Zealand (Asher 1987), 21.6% in Denmark (Vigh-Larsen 1988), 23.6% in Sweden (Kjellander 2012, referencing work by Ida Svarthalm in 2010), and even up to 30% (Lanszki et al. 2018). The finding of a 46.4% juvenile mortality rate in this study represents an alarming threshold, necessitating immediate intervention.

In the absence of large carnivore species in the study area, mesocarnivores such as the red fox and golden jackal have assumed the role of primary predators within the ecosystem. Positioned at the top of the trophic pyramid, these species have proliferated due to a lack of interspecific competition and an abundance of food sources, becoming significant factors in the population dynamics of fallow deer.

Both the golden jackal and red fox are known to prey on fallow deer, particularly juveniles and senescent individuals, which are frequently part of their diet (Lanszki & Heltai 2002, Cirovic et al. 2014). In fact, estimates from Lange (2020) indicate that ungulates constitute the third most commonly consumed category by golden jackals. Additionally, McDiarmid (1974) reported that red foxes contribute significantly to the mortality of red deer calves. Under ideal conditions, such as those in enclosed game parks, growth rates of more than 0.9 offspring per mature female have been recorded. However, no growth rates exceeding 1.0 calf per mature female have been documented, with twin pregnancies in this species being extremely rare (less than 1%) (Ueckermann & Hansen 1968, Chapman & Chapman 1975).

Predation is a pressing phenomenon affecting fallow deer, particularly impacting females and their young in their first year of life (Ciuti et al. 2004). In response to predation threats, fallow deer exhibit several anti-predation strategies soon after birthing. These strategies include synchronizing births among the herd, distancing the female from her newborn calf to mislead predators, and adopting cryptic coloration by young calves as a camouflage measure (José & Braza 1992). Population-level changes can influence the timing of births, which may reduce the effectiveness of these anti-predation strategies. This scenario can lead to shifts in the sex ratio of offspring, a decrease in the age of breeding males, destabilization of social structures, and disruption of dominance hierarchies, ultimately resulting in an unstructured population composition (José & Braza 1992, Milner et al. 2006). Furthermore, there is a weak correlation between the growth rate of fallow deer populations and annual harvest quotas (Bijl & Csanyi 2022). These harvest quotas tend to have a more significant impact on the age classes of both males and females rather than on juvenile mortality, as prior studies have demonstrated. From a wildlife management perspective, to reduce the mortality rate not only in the study area but also in similar scenarios, the hunting quota for mesocarnivores should not only be completely harvested, but also special derogations should be applied to increase the harvest rate of these predators. Additionally, when there is an overabundance of mesocarnivores, the hunting quota for these species should be eliminated, allowing wildlife managers the possibility to extract as many specimens as needed without affecting ecosystem balance.

Current findings indicate a neonatal mortality rate of 46.4% for fallow deer in the studied area, closely mirroring the 30% rate observed by Kjellander (2012) in Sweden. This discrepancy can largely be attributed to heightened predation intensity in the Romanian hunting grounds under study. Notably, higher mortality rates are found in open habitats lacking forest cover, as demonstrated in the Ratu Pil hunting ground, compared to forested and shrubby areas like those in Socodor and Adea hunting grounds. This variation can be explained by the greater effectiveness of anti-predation strategies in covered habitats compared to those in open environments (Pierce et al. 2004, Panzacchi et al. 2009).

Conclusion

In this study, a significant juvenile mortality rate of 50% was observed in fallow deer during their first year of life, highlighting the vulnerability of young individuals, particularly due to predation by mesocarnivores such as golden jackals and red foxes. These findings underscore the critical role of predator-prey dynamics in shaping fallow deer population structures and suggest that both habitat quality and interspecific competition are important factors influencing mortality rates. To ensure the sustainability of fallow deer populations, it is essential to implement effective wildlife management strategies that consider the delicate balance between preserving habitat and managing predator populations. Furthermore, the study emphasizes the need for ongoing research to monitor these dynamics over time and develop informed conservation practices to support the resilience of fallow deer in the face of environmental and anthropogenic pressures.

Conflict of interest

The authors declare no financial or personal interests that could influence the work presented in this paper.

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