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The varied diet of the golden jackal (*Canis aureus*): Experiences from stomach analyses

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Abstract: The golden jackal population shows a rapid expansion in Europe during the recent decades, raising several management and conservation issues. Among others, the opportunistic feeding strategies might be a reason which is responsible for the invasive spreading and survival success of the species in various parts of Hungary. Our aim was to analyze the diet composition of the jackal through stomach content analysis to provide an insight about the evolution and behavioural adaptations of this mesopredator. The stomach samples were collected between 2003 and 2014 from different parts of Hungary.The percentage frequency of occurrence (%FO) as well as the biomass (%B) of the stomach content data were analyzed. Statistical analysis tests based on the presence and absence data of the remains of wild ungulates (cervids and wild boar) from seasonal data (winter-spring and summer-autumn) and between gender groups were conducted. Also, comparisons of the presence and absence data for the three main food categories (rodents, big game and vegetative/plant parts) were statistically tested. The results of the comparisons did not show any significant differences between the classes. This can be explained due to the high spatio-temporal variation of the data. The findings of our study show the presence of a varied occurrence of food items such as rodents, insects, fruits, plant parts, ungulates (wild boar, cervids), reptiles (such as lizards and pond turtles), bird species (such as pheasants) as well as jaw remains of the red fox. It is noteworthy to mention in this context that majority of the ungulate remains from the stomach contents were associated with maggots, which indicated the presence of carrion consumption. Our study, based on varied diet composition, supports and confirms the opportunistic, scavenging and highly adaptive foraging of the golden jackal.

Keywords: Golden jackals, feeding habits, stomach analysis

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Introduction

The increasing distribution range of the golden jackals in Europe has led to arguments regarding various challenges faced by the management authorities and international legal frameworks (Heltai et al., 2000; Lanszki & Heltai, 2002; Trouwborst et al., 2015). The occurrence of any non-native species in a region can significantly influence the ecological balance along with the prey-predator relationship (Mondal et al., 2012; Kuijper et al., 2016). Despite of their indigenous status, the golden jackal after disappearing from the fauna between the 1950s and 1970s (Tóth et al., 2009), recently returned in a manner typical of invasive species (Szabó et al., 2007). Many stakeholders in Hungary, including the game managers, sport hunters and farmers assume (Szabó et al., 2009) that the golden jackal population largely affect important game species like roe deer (*Capreolus capreolus*) and fallow deer (*Dama dama*). Studies also sup-

port the fact that various species of Cervidae like red deer (*Cervus elaphus*), roe deer and fallow deer were among the notable diet components of the golden jackal in Hungary (e.g., Lanszki and Heltai (2002)), whereas, a similar study conducted in Serbia, suggests that the main components of the winter diet of the golden jackal constitutes the remains of domestic animals (Ćirović, Penezić, Milenković, & Paunović, 2014). Thus, to minimize conflicts and enhance a better understanding of the facts, it is important to understand the ecology, evolution and feeding adaptations of the species.

The hypothesis of our study based on the formerly published articles from Hungary was that the presence of small rodents and/or wild ungulates (Heltai et al., 2004; Lanszki et al., 2015; Lanszki & Heltai, 2002) will be the primary food items.The objectives of the study are: (i) to describe the general diet composition, including the season and gender related features; (ii) to obtain a detailed idea regarding the golden jackal's wild ungulate (cervids and wild boar) consumption.

Materials and Methods

Stomach content analysis was performed through standardized wet techniques (Penezic & Ćirović, 2015) of 40 samples collected by hunters from different parts of Hungary (Fig. 1). As a first step the stomachs were defrosted at room temperature. Then the wet weight of the whole stomach samples (including the abdominal wall along with the contents) were measured and registered in grams. After opening/exploring, the stomach contents were segregated and measured according to the various specified classes. The classes include: 1 – plant parts, 2 – seeds, 3 – cervids, 4 – wild boar, 5 – domestic animals, 6 – rodents, 7 – birds, 8 – insects, 9 – reptiles, 10 – plastic/garbage. The presence of the carrion consumption was identified by the presence of maggots from the associated food contents. The "unknown" class referred to the contents which cannot be identified or differentiated according to the previously prescribed classes. The wet weight of each specified class of the stomach contents was measured in grams (accuracy 0.01 grams).The microscopic analysis of the stomach contents such as hair, bones, teeth or feather samples to identify the species were analyzed using references from standardized reference books (Teerink, 1991; Ujhelyi, 1989). The frequency of occurrence (%FO) and the biomass (%B) of the contents were calculated.

The comparison of the presence and absence data between the three prominent food categories (rodents, big game and plants) were compared and statistically tested using the Fisher's Exact test in R statistics software (Matloff, 2011). The statistical tests were conducted using 2×2 contingency tables (Mehta & Patel, 1983). For the statistical test, if p value is less than or equal to 0.05, the test can be considered as significant.

Results and Discussion

The overall diet composition indicated ungulates and small mammals consumption as the primary food sources of the species (Table 1). Besides, the jackals are also considered beneficial for the control of rodent species such as House rat (*Rattus rattus*) in Asian countries such as India and Bangladesh, where they are often considered as disease spreading pests (Jaeger et al., 2007; Majumder et al., 2011; Mukherjee et al., 2004). Small rodents found from the stomach samples were wholly swallowed, this might be considered as a suitable adaptation of a behavioural trait of the golden jackals. Chewing a rodent might consume more time which otherwise can be utilized by the species to prey on other food resources available (Mondal et al., 2012; Mukherjee et al., 2004). Also, from the results, it is evident

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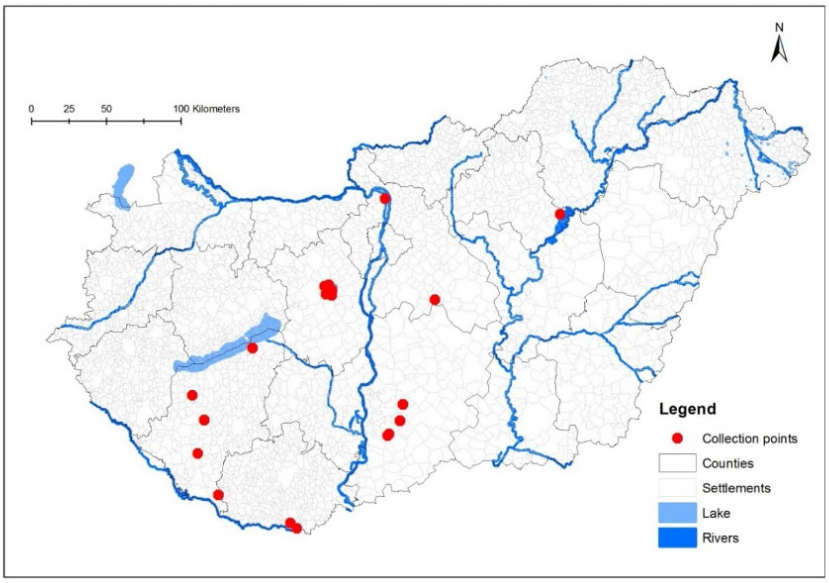

Figure 1: Collection locations of jackal stomach samples from Hungary

Table 1: Overall diet composition of the golden jackal based on biomass (%B) and occurrence (%FO) calculations ($n = 40$, mean $\pm$ SD).

Diet composition	Biomass Mean $\pm$ SD (%)	Frequency of occurrence Mean $\pm$ SD (%)
Plant parts	5.7 $\pm$ 13.7	77.5 $\pm$ 0.4
Seeds	1.4 $\pm$ 2.9	20.0 $\pm$ 0.4
Cervids	21.7 $\pm$ 37.7	47.7 $\pm$ 0.5
Wild boar	19.9 $\pm$ 72.2	15.0 $\pm$ 0.3
Domestic animals	3.1 $\pm$ 9.4	10.0 $\pm$ 0.3
Rodents	15.8 $\pm$ 24.8	52.0 $\pm$ 0.5
Birds	2.7 $\pm$ 8.8	20.0 $\pm$ 0.4
Insects	9.0 $\pm$ 24.3	27.5 $\pm$ 0.4
Reptiles	0.8 $\pm$ 3.3	7.5 $\pm$ 0.2
Plastic/Garbage	<0.1	5.0 $\pm$ 0.2

that the jackals primarily consumed ungulate remains mostly from carrions as the stomach samples found were infested with maggots in most of the cases. Thus, considering the previous literature from Europe (Ćirović et al., 2014; Lanszki et al., 2015; Lanszki & Heltai, 2002) and the findings of the study, it can be stated that the rodents and other small mammals constitute as one of the primary food sources for the golden jackals after the ungulate carrion consumption in Hungary.

The secondary food items of the species include insects and plant material (fruits and seeds). In other studies, it was found that jackals consumed domestic animals more frequently, especially from offal/by-products and carrion (Mondal et al., 2012; Ćirović et al., 2014; Lanszki et al., 2015; Lanszki &

Figure 2: European Pond Turtle (*Emys orbicularis*) embryo found from one of the jackal stomachs

Figure 3: Nasal part of juvenile red fox (*Vulpes vulpes*) found in a golden jackal stomach sample

Heltai, 2002; Majumder et al., 2011). It is noteworthy to mention in this context that for food components of plant origin, the biomass percentage (%B) value is much lesser than the frequency of occurrence (%F) (see Table 1). This might be due to the fact that the jackals consistently consumed plant parts as being opportunistic predators, but this does not constitute as the primary food items for the species. The presence of bird and reptile remains found in the stomach contents can be found occasionally. The consumption frequency and biomass of domestic animals were found to be negligible. Also, in most of the occassions (see Table 1) the ungulate (deer species and wild boar) remains found from the stomach contents were associated with the presence of maggots which indicated the direct evidence of carrion consumption or scavenging behaviour of the jackals (Lanszki et al., 2015).

The Presence/Absence analyses of the big game category shows similar distributions in every comparisons (Seasonal, Gender based,

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Table 2: Presence / Absence analyses of the big game category based on different variables. (Legend: * = Big game as the only consumed food source).

Analysis	Categories	Big Game Category		P value
		Presence (n)	Absence (n)	
Seasonal data	Winter-Spring	8	4	0.486
	Summer-Autumn	11	10	
Gender based	Male	11	10	0.500
	Female	11	5	
Big game*	Other food source Presence	23	14	0.553
	Other food source Absence	1	2	

Big game). Only one stomach was found which contained big game solely (Table 2).This result does not prove the extreme ungulate consumption theory of certain game managers. From the economic point of view, jackals feeding on ungulates might cause a huge impact on the trophy hunting industry and hence will directly interfere with the game management policies. On the contrary, as the jackals are considered as opportunistic predators they are often known to feed on any available food sources, such as reptile and bird species, for instance the hatchlings of *Emys orbicularis*.

According to the statistical analysis of the presence and absence data of the three main categories of food items (Table 3), this case study did not show difference between the seasons and genders in the feeding habit of the jackals in Hungary. The high spatio-temporal difference of the data might be one of the reasons. It might be interesting to note that during the winter-spring season, the stomachs containing big game remains were twice as compared to the stomachs where the big game remains were absent, as this may indicate the consumption of young or sub adult individuals.

There were some unusual findings from the stomach content analysis. One stomach sample collected in autumn in a wetland area (Lake Velence) contained six European pond turtle eggshells along with embryos (Fig. 2). The jackal might have consumed a clutch of nearly formed un-hatched turtle eggs (Brown & Macdonald, 1995). The embryos were found to be attached with the eggshells in the sample. Another important finding from one of the stomach samples was the upper jaw and nasal part of a red fox (*Vulpes vulpes*) (Fig. 3). It is unknown whether the individual was preyed or scavenged, but competition based on high trophic niche overlap between the two canids might be expectable (Lanszki, Körmendi, Hancz, & Zalewski, 1999; Lanszki, Molnár, & Molnár, 2006).

Conclusions

The results of the study yielded a variety of diverse and interesting knowledge about the feeding ecology, dietary preferences and evolution of the golden jackals in Hungary. It is evident from this case study that the golden jackal in Hungary has successfully evolved as a mesocarnivore with several feeding adaptations and preferences (Aiyadurai & Jhala, 2006; Giannatos et al., 2010; Yumnam et al., 2015). Hence due to the high adaptability of the species, its population is increasing in several parts of Europe, including Hungary (Lanszki et al., 2018; Szabó et al., 2009). The findings of the study exhibit both the opportunistic feeding patterns as well as the scavenging behavioural traits of

Table 3: Comparison of only Absence data for the main food categories based on the stomach size.

Comparison	Food Category	Average stomach size (73.3 g)		P value
		Smaller	Bigger	
Rodents and	Rodents	13	6	1.000
Big Game	Big game	11	5	
Big Game and	Big game	11	5	0.126
Vegetative/Plant part	Vegetative /Plant parts	9	0	
Rodents and	Rodents	13	6	0.136
Vegetative/Plant part	Vegetative /Plant parts	9	0	

the species. Hence, to obtain a better understanding of the effects caused by the golden jackal on the nature conservation management in Hungary, more such studies about the feeding ecology of the species should be conducted. Besides, to address conflicts between stakeholders such as livestock /poultry farmers and game managers, results of scientific studies, such as this one, should be widely communicated and shared.

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