

Autumn-winter Dietary Adaptability of the Golden Jackal *Canis aureus* L., 1758 (Mammalia: Carnivora) with Respect to Type and Intensity of Human Activities in Three Areas of Central Bulgaria

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Abstract: Food preferences of golden jackal *Canis aureus* Linnaeus, 1758 from three areas with different anthropogenic impact in Central Bulgaria during the autumn and winter seasons of 2016–2018 were investigated. A total of 170 stomachs were analysed. In the mountainous area (Stara Planina Mts.), wild ungulates predominated in the jackal's diet, followed by rodents, trash and plant material (mainly fruits). Domestic mammals predominated in the jackal's diet in the hilly and semi-mountainous area (Sarnena Sredna Gora Mts.), followed by carcasses of wild carnivores and fruits. In the agricultural lowland area (Thracian Plain), rodents occurred in the jackal's diet most frequently, followed by plant materials (fruits and cereals), domestic mammals and fishes. Considering the narrower jackal's food niche in Upper Thracian Plain and in Stara Planina Mts. compared to that in Sredna Gora Mts., it can be concluded that rodents were favoured by the jackal in the lowlands, and hunter-killed ungulates in the mountainous area. In the semi-mountainous area, the species did not take advantage of a particular food category, demonstrating feeding generalization. Delivering easily accessible and high energy food in both anthropogenic environments and natural habitats makes human influence widespread.

Key words: resource selection, opportunistic dietary, rodents

Introduction

Food resource selection is fundamental for the survival and growth of species' populations and essential to their adaptability to various habitats. Many

mammalian carnivores are omnivorous, consuming a great variety of food resources. Hence, they can adapt to various habitats, including agricultural landscapes or human settlements despite intense environmental alterations by human activities (DITCH-

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KOFF et al. 2006, GEHRT et al. 2010). Moreover, in human-altered environments, wild carnivores have often access to anthropogenic food resources with higher nutrients and easy accessibility (NEWSOME et al. 2014). Due to this fact, their population growth and range expansion are accelerated (FEDRIANI et al. 2001, BINO et al. 2010, GEHRT et al. 2010, SINGH et al. 2016). Knowledge of resource uses of a carnivore species in different environments is essential to understanding their adaptability in human-altered environments.

The golden jackal *Canis aureus* Linnaeus, 1758 is an omnivorous species that uses a large number of food items (HEPTNER & NAUMOV 1967, BORKOWSKI et al. 2010, HAYWARD et al. 2017). Great variety in feeding spectrum as well as inclination to easily accessible food (i.e. livestock carrion and trash) attracts it in proximity to settlements (ROTEM et al. 2010, ALAM et al. 2015, SINGH et al. 2016). The largest European population of jackals has been registered in Bulgaria (Strandja), even before the species' expansion (SPASSOV & ACOSTA PANKOV 2019). Thus, Bulgaria, Greece and the Republic of North Macedonia have been the main sources of emigration to neighbouring countries (ARNOLD et al. 2012).

The golden jackal's expansion began in the 1970s. In Bulgaria, the species was protected from 1962 to 1984 (SPASSOV & ACOSTA PANKOV 2019, STOYANOV 2013). Three factors have been supposed to influence its expansion: (1) diversification of food base, (2) reduction in the number of the dominant competitor – wolf (*Canis lupus*), and (3) improvement of habitat conditions (GENOV & VASSILEV 1989, SPASSOV 1989). The species had expanded across the country till 1983, and single individuals had appeared in lowlands of the west regions up to 800 m a.s.l. (GENOV & VASSILEV 1991). Currently, the golden jackal spreads across the country including lowlands, hilly and lower-mountainous areas (POPOV & SEDEFICHEV 2003). Human-jackal conflicts, e.g., predation on livestock or game, have increased owing to the rapid jackal's range expansion (GENOV & VASSILEV 1991). Culling program for population control and/or eradication campaign has begun since 1980s in the country (MARKOV 2012). However, it has been unsuccessful and the jackal numbers are still growing (STOYANOV 2012). Similarly to other canids such as coyote (*C. latrans*), side-striped jackal (*C. adustus*), black-backed jackal (*C. mesomelas*) and red fox (*Vulpes vulpes*), golden jackal resists to human persecution (SILLERO-ZUBIRI et al. 2004).

The jackals' range expansion was probably due to a great variety of easily accessible food sources (STENIN et al. 1983). In Bulgaria, carrion and food

waste are deposited near settlements, roads and in nature, as well, being available for wild animals including the jackals. Facultative scavengers exploit food from human origin, increasing their numbers and behaving as invaders (ORO et al. 2013). Therefore, understanding the jackal's feeding habits under different resource conditions is important for effective population management.

The objective of the present study was to compare food niches among various environmental conditions, with special reference to the anthropogenic food resources. In order to clarify whether human activities (e.g., animal husbandry and wildlife management) and anthropogenic environmental alterations (e.g., agricultural land uses) influence jackal's feeding preferences, its feeding habits in three different regions were investigated and compared.

Materials and Methods

Study area

Three areas with different anthropogenic alterations located in Central Bulgaria were chosen for sampling (Fig. 1). They were situated ca. 30–70 km from each other and separated by river, highway and settlements.

Stara Planina Mts (SP): The area is located in the south slopes of Central Stara Planina Mts and covers 210 km². The terrain is steep, with an elevation ranging from 400 to 1370 m a.s.l., covered with secondary forests of oak (*Quercus* sp.) up to around 1000 m a.s.l. and with primary forests of European beech (*Fagus sylvatica*) at higher altitude. There are no cultivated lands and livestock farms in the region, while there are a few rest houses and three hamlets. The railway is almost the only source of anthropogenic influence. The region holds the highest species diversity on mammalian fauna among the three studied areas, including jackals' potential preys: roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), wild boar (*Sus scrofa*) and European hare (*Lepus europaeus*), as well as some potential competitors – wolf, European badger (*Meles meles*) and red fox. Stray dogs (*C. l. familiaris*) and stray cats (*Felis catus*) are very rare and occasionally observed in forest edges only at lower elevation (authors' unpublished data).

Sarnena Sredna Gora Mts (SSG): The area borders the upper part of Thracian Plain and covers 525 km². The terrain is hilly with an altitude ranging from 260 to 750 m a.s.l. There is a number of villages at a distance of 5–6 km from each other. The area is covered with oak (*Quercus* spp.) and Oriental Hornbeam shrubs (*Carpinus orientalis*), or-



Fig. 1. Location of the studied areas in Bulgaria: 1. Stara Planina Mts. (south slopes); 2. Sarnena Sredna Gora Mts.; 3. Upper Thracian Plain.

chards, vineyards and croplands. There is extensive livestock production, represented by family farms (goat *Capra aegagrus hircus*; sheep *Ovis aries* and cattle *Bos taurus*). Plenty of illegal landfills with disposed animal wastes is typical in the area. Stray dogs and cats as well as some wild carnivores (e.g., badgers and foxes) appear to be the main competitors for the jackals (TSUNODA et al. 2018). Potential mammalian prey for the golden jackal is abundant (e.g. wild boar, roe deer, hare) but red deer is not common (TSUNODA et al. 2017, 2018). Both hunting on medium- and large-sized mammals and predator culling pressure are intensive (RAICHEV 2011).

Upper Thracian Plain (UTP): The area is situated in Southeast Bulgaria (ca. 370 km²), centred around a village Mlekarevo at an elevation ranging from 140 to 220 m a.s.l. It is an urbanised landscape with developed agriculture dominated by cereal crop and vegetable production. There are also a lot of abandoned bushy patches and pastures between arable land and dams. The major animal production is sheep, cattle and horse (*Equus caballus*) breeding. The livestock management in the area is in its traditional way: i.e., the animals graze in fields in the daytime and return to the settlements in the evening. There are illegal dumps around the settlements, where animal waste as well as livestock carcasses are often disposed of. The jackals might compete with foxes, badgers and stray dogs for food, while

wolves are absent. The potential preys for the jackal are similar to those in Sarnena Sredna Gora Mts., i.e. voles (*Microtus* spp.), hares, roe deer, young of wild boars and game birds. Captive-bred pheasants (*Phasianus colchicus*) are released in autumn for game. The most intensive hunting pressure is performed in this region among the studied areas.

Sample collection

The jackal carcasses were delivered by hunters and forestry staff into the laboratory of Trakia University during the autumn and winter seasons of 2016–2018, through the population control program. A total of 170 stomachs from golden jackals (42 from SP, 58 from SSG and 70 from UTP) were sampled through the studied period. To sort the food items, the stomach content was washed in a plastic tray. Due to the fact that stomach samples provide well distinguishable food items, the content was identified macroscopically to the species or genus level. A hair and feather collection from the Taxidermy Laboratory and specimens from the Museum in the Faculty of Agriculture at the Trakia University were used for reference. Then, the food items were combined in the following eleven categories: rodents (*Arvicolidae* spp., *Muridae* spp., *Myocastor coypus*), hare, wild ungulates (wild boar and cervids), wild carnivores (fox and jackal), domestic animals (including stray dogs and cats), wild birds, poultry,

reptiles, fishes, plants (wild fruits and seeds), trash (mainly envelops of human meals such as salami and sausage). The jackal's diet was expressed as the relative frequency of occurrence (RFO), the ratio of the occurrence of a singular food item in all samples (stomachs from the given area) and the total number of detected food items in the same samples $\times 100$.

To assess overall differences in jackal diets among the three studied areas as well as among the sampled months (i.e., November, December, January and February), across the study years, permutational multivariate analysis of variance (PERMANOVA) was performed, using RFO values as response variable and both areas and months as explanatory variables, respectively. After confirming any statistical significance in the PERMANOVA, a generalised linear model (GLM) and post hoc Tukey's multi comparison test to assess regional differences for each food category were performed. Taking into account small sample sizes, this procedure was avoided to perform for minor food items (i.e., commonly observed $<10\%$ for the RFO among the studied areas). For the analyses, binomial distribution and logit link function were applied. All statistical analyses were performed using R ver. 3.3.2 (R CORE TEAM 2016), with the 'adonis' function of 'vegan' package (OKSANEN et al. 2015) for the PERMANOVA and the 'glht' function in 'multcomp' package (HOTHORN et al. 2008) for Tukey's multi comparison test for R, respectively.

For estimating similarity of food items in the jackal's diet regionally, Czekanowski-Sørensen Index (SØRENSEN 1948) was used.

$$s = 2 n_t / (n_x + n_y),$$

where n_t is the number of food items observed in both areas x and y , and n_x and n_y is the total number of food items observed in area x and area y , respectively.

The Levins Index (KREBS 1989) was used for standardisation of the jackal's food niche breadth in the three areas:

$$B = \frac{(1/\sum p_i^2) - 1}{n - 1},$$

where n was the number of found food items and p_i was the RFO of each food item i in the jackals' diets. B ranges from 0 to 1 and the larger value represents a broader niche (KREBS 1989).

Results

The percentages of the empty stomachs were 19.0% ($n = 8$) in the SP, 22.4% ($n = 13$) in the SSG and 14.3% ($n = 10$) in the UTP.

In the SP (mountainous area), wild ungulates predominated in the jackal's diet (RFO = 47.6%; Fig. 2), comprising wild boar and cervids. Rodents (RFO = 14.3%), trash (RFO = 11.9%) and plant materials (RFO = 9.5%; mainly fruits) were also found in high proportions in the jackal's food, as well (Fig. 2). Contrary to the SP, domestic mammals (RFO = 30.8%) predominated in the jackal's diet in the SSG (hilly and semi-mountainous habitats), comprised primarily by dogs and sheep. Both, wild carnivores and fruits were secondary food items and their occurrences in the diet were relatively low (12.3%). In the UTP (arable land), rodents (RFO = 47.4%) were the main prey for the jackals (Fig. 2), consisting of Arvicolidae spp. and Muridae spp. The other food types of importance in the region were plant materials (fruits and cereals), domestic mammals and fishes (Fig. 2).

The PERMANOVA tests indicated that the overall diets of golden jackal significantly differed among the studied areas (Table 1). It could be mentioned that the factors depending on area ($p < 0.001$) were stronger than these on the month ($p > 0.05$). Within a month, the diet of a jackal varied depending on the habitat.

The results of GLM analyses indicated significant differences for the RFOs of rodents, wild ungulates and domestic mammals among the three studied areas (Table 2): thus the post hoc Tukey's multi comparison tests for these three food items were

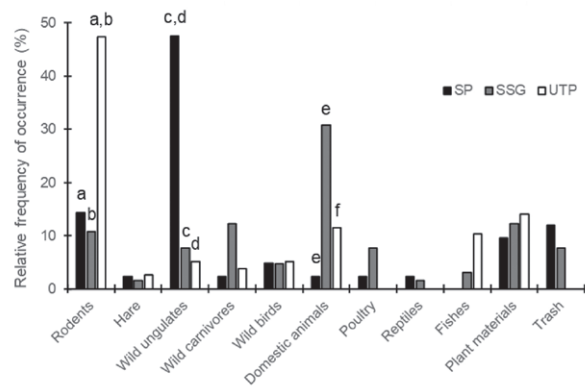


Fig. 2. Relative frequency of occurrences (%) for food items in the golden jackal's autumn–winter diet in Stara Planina Mts (SP), Sarnena Sredna Gora Mts (SSG) and Upper Thracian Plain (UTP) in Central Bulgaria. If there were any statistical significances counted by generalised linear model analyses, lowercase letters above bars (i.e., a–f) were used for representing regional comparisons. The same lowercase letters in each food category represent significant differences revealed by the Tukey's multi comparison test for the three regional pairwise, whereas the different letters represent non-significances.

Table 1. The results of PERMANOVA analysis for regional and monthly differences of golden jackal's autumn-winter diet in Central Bulgaria

Variable	d.f.	R ²	Sum of squares	Mean of squares	F	P
Area	2	0.680	1.086	0.543	10.212	0.0001
Month	1	0.054	0.086	0.086	1.623	0.202
Residuals	8	0.266	0.425	0.053		
Total	11	1.000	1,59			

Table 2. The results of GLM for regional and monthly comparisons of the RFO of the major food items in the jackal diets in autumn-winter period (SP, Stara Planina Mts; SSG, Sarnena Sredna Gora Mts; UTP, Upper Thracian Plain)

Food category	Estimated coefficient			
	Intercept - SP	SSG	UTP	Month
Rodents	0.524	-0.161	1.898***	-0.186
Wild ungulates	0.291	-2.260***	-2.703***	-0.031
Domestic mammals	-4.837***	2.818**	1.783	0.089
Wild carnivores	-6.106	1.847	0.568	0.189
Fishes	-17.950	16.256	17.542	-0.129
Plant materials	0.061	0.454	0.607	-0.185
Trash	-2.721	-0.371	-18.576	0.057

p < 0.01; *p < 0.001

performed. Rodents were more predominant foods in the UTP than in the other two areas ($p < 0.001$ for both), while there were no significant differences between the SP and the SSG ($p = 0.960$; Fig. 2). Wild ungulates were more predominant in the SP than in the other two areas ($p < 0.001$ for both), while there were no significant differences between the SSG and the UTP ($p = 0.799$; Fig. 2). Finally, the RFO values of domestic mammals significantly differed between the SSG and the SP ($p = 0.018$), and insignificantly differed between the SSG and the UTP ($p = 0.057$), while there was no statistically significant difference between the SP and the UTP ($p = 0.207$; Fig. 2).

The highest similarity in the jackal diets was observed between the SP and the SSG (74 %), moderate between the SSG and the UTP (60 %) and the lowest between the SP and the UTP (52 %).

The widest jackal's food niche (0.68) was estimated for the SSG. The value of this parameter was 0.52 for the SP and 0.51 for the UTP.

Discussion

The golden jackal is an opportunistic predator that uses abundant and available food sources in each area (JHALA & MOEHLMAN 2004, VLASSEVA ET AL. 2017). The food of the jackal in the present study was mainly based on mammals (livestock, rodents

and wild ungulates) in the three studied areas. The same food preferences were reported for the jackal in the neighbouring Balkan countries, too: Croatia (RADOVIC & KOVACIC 2010) and Greece (GIANNATOS et al. 2010) as well as in regions out of Europe (e.g., Pakistan, see MAHMOOD et al. 2013). The present study indicated the major significance of rodents in the agricultural landscape (i.e., the UTP) in autumn and winter. In the previous study, rodents were found to be important for raising youngsters in summer (MARKOV & LANSZKI 2012). A similar importance was observed in Hungary in autumn (LANSZKI et al. 2010). Abundance and species richness of rodents are higher in agricultural lands (i.e., meadows and croplands) alternated with patches of forest, than these in typical forest habitats (DELATRE et al. 1996, ALAIN et al. 2006, PANZACCHI et al. 2010). Human activities contribute to the increasing number of rodents by growing cereal crops (ALAIN et al. 2006). Thus, the jackal's food base is enriched indirectly.

In the higher altitude region (SSG) the human activities are similar to these in the UTP, but woodlands predominate. In the SSG, the residents often discard domestic animals' offals or carcasses in villages' surroundings (see 'Study area'). These "dump sites" become easily accessible for the wild animals (RAICHEV et al. 2013), ensuring possibili-

ties for scavenging. Thus, the human influence on the jackal's diet in this area could also be defined as unintentional. STENIN et al. (1983) and GENOV & VASSILEV (1991) reported that the significant number of domestic mammals and ungulates in the jackal's food in the semi-mountainous regions in Bulgaria resulted from predation, as well as in India (BHAGWAT 2018), contrary to the statement in the present study. BAUER & KARI (2001) and BHAGWAT (2018) pointed out that predation depends on the system of breeding, especially on the presence/absence of shepherds. The same as for the SSG area, other studies based on consumed biomass also consider domestic animals as a main food source for the jackals (NADEEM et al. 2012 for Pakistan, GIANNATOS et al. 2010 for Greece, CIROVIC et al. 2014 for Serbia and STENIN et al. 1983 for Bulgaria). As an opportunistic species, the jackal adapts to food availability (LOVERIDGE & MACDONALD 2003). In the present study, it is more likely to assume that the remains of domestic animals in the samples are resulting from scavenging rather than predation (RAICHEV et al. 2013) since they are abundant around the settlements and no evidence on domestic animal attacks is available.

The SP is characterised by the typical for the mountainous habitats mammalian fauna (e.g., wild ungulates and forest rodents). The only human presence here is owing to logging and hunting. Consumption of remains (e.g., skins, viscera, etc.) of hunter-killed ungulates from the jackals might be associated with regional and/or temporal availabilities of these resources (CIROVIC et al. 2014, LANSZKI et al. 2015). It could be assumed that the pieces of skin and bones, viscera and/or meat from wild ungulates found in the sampled stomachs originated from hunting and poaching activities. Adults of wild ungulates are difficult for the jackal to prey on, probably owing to their large body sizes and/or the risk of counterattacks. The wild ungulates' yearlings were already grown up during the studied season (i.e., autumn and winter), becoming a hard prey for the jackals. Moreover, hunters remain ungulates' offal in nature as a common practice in Bulgaria (RAICHEV et al. 2013). Scavenging carcasses gives an advantage to wild carnivores because these sources supply richer nutrients without expecting a counter-attack by the prey (WILSON & WOLKOVICH 2011). In the SP area, the jackals coexist with wolves, which also take advantage of this waste but also actively hunt game. It is possible for jackals to benefit from the wolf's prey (WILMERS et al. 2003). Human activity had a dual effect on the studied jackal's population by carrying out hunting events: i.e., jackals are a target of eradication campaigns, while they are

supplied food resources unintentionally.

Despite the differences in climatic and habitat conditions, the jackals from Ngorongoro Crater in Africa (TEMU et al. 2008) as well as these from Bulgaria (MARKOV 2012), benefit from the abundance of wild herbivores the same way.

The secondary found food items in the jackals' diets differed among the studied areas and were also affected by local human activities. Although plant material was observed in the jackals' diets in the three studied areas, seeds of cereal crops were only found in the samples from the UTP. The jackals from the UTP ate the stems of the sprouted wheat and silage in the end of the winter season, when the other food resources became scarce. According to HEPTNER & NAUMOV (1967), jackals sometimes consume large amounts of plant material and could be characterised as omnivorous. Thus, they could damage crops (ALLSEN 2006).

The carcasses of wild carnivores (mainly canids) were among the additional food sources for the jackals in the SSG. In the process of the Carnivore Control Program, hunters often leave the shot predators in the hunting area (RAICHEV et al. 2013). Another reason enabling the consumption of this type of food was road mortality.

Despite that the numerous illegal dumps in Bulgaria provide an easily accessible food source for the jackal, trash was rarely found in the samples. Thus, it could not be classified as a vital food item.

The detected fish and poultry leftovers in the jackals' stomachs were in minimum quantities, possibly eaten from dumps, contrary to the ALLSEN's (2006) findings that jackals prey on poultry.

Considering the narrower range of the jackal's food niches in the UTP and in the SP, it can be concluded that the species relied on a certain group of foods (mostly rodents) in the agricultural land, and on hunter-killed ungulates in the mountainous area. Thus, the jackal is manifested as a scavenger in the SP. In the semi-mountainous area (SSG), however, it did not rely on a particular food category, being manifested as a generalist. In accordance with the suggestion of LANSZKI et al. (2010), the food habits of the golden jackal are strongly associated with human activities. This species tends to forage near human settlements due to its opportunistic feeding behaviour (ROTEM et al. 2010).

It can be concluded that the human influence on the jackal's diet could be traced in different habitats.

The strategy for controlling the jackal's increasing population needs to be fundamentally reviewed. It has to include not only lethal measures

but also restriction of the food sources in the habitats (e.g., BINO et al. 2010), adhering to the current trends for wildlife welfare.

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