

The golden jackal (*Canis aureus*) and the African swine fever pandemic: Its role is controversial but not negligible (a diet analysis study)

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Abstract

Background: In Europe, the African swine fever (ASF) pandemic mostly affects the environmental domain of health, which is a strongly human-impacted ecosystem. However, the current control strategies focus solely on the wild boar and tend to disregard other epidemiologically relevant elements of the ecosystem.

Objectives: This study investigated the potential impact of the golden jackal on the surveillance effort and disease transmission.

Methods: For this reason, the authors analysed the content of 277 stomachs of this canid species within its westernmost inhabitant population, in order to determine the amount of suid remains, disposed.

Results: The findings confirmed that in a densely populated wild boar habitat, the main diet component of jackals was wild boar all the year round. The jackals disposed of 0.3–0.6 kg/km²/day offals that potentially contained suid remains. On the other hand, the scavenging activity removed the most important target objects on which the passive surveillance of ASF should be based.

Conclusions: This study cannot determine whether canid scavengers positively or negatively influence the control efforts; however, the impact of the jackal should not be disregarded. The results warn the necessity of a multidisciplinary approach to complex epidemiological situations within different ecosystems.

KEYWORDS

African swine fever, diet analysis, golden jackal, One Health, wild boar

1 | INTRODUCTION

At first glance, the African swine fever (ASF) pandemic does not appear to be a real One Health challenge due to the pathogen's narrow host spectrum. Nevertheless, on a closer examination, the complexity of the problem becomes unequivocal. Besides animal health, the human and the environmental domains of the health are also concerned. The

central concept of One Health evolved as a multi-sectoral, transdisciplinary collaboration of professionals during disease preparedness and prevention efforts at the human-animal-ecosystem interface (Mackenzie & Jeggo, 2019).

The ASF pandemic has a great impact on human well-being on all continents causing financial loss, or even direct food-shortage. The increasingly deepening poverty impedes the epidemiological

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control efforts in low-income regions (Dixon et al., 2020; Garcia et al., 2020).

Within the European Union, the environmental domain of health is the principal concern. Wild boars spread the infection through the natural ecosystem of Europe. This wildlife reservoir hampers control efforts since human activities can control neither the movement nor the population size of wild animals effectively. Currently, even the size and density of the European wild boar populations are estimated with low precision (EFSA, 2018, 2019). In favour of the European swine industry, the community veterinary authority expects control success from population reduction of wild boars and passive surveillance based on “found dead” animals (Dixon et al., 2020; EFSA, 2018).

Although the wild boar population is a part of a very complex system, the official approach to this disease is roughly simplified. The continent-wide efforts to reduce the population of wild boars are based on the never proven conviction that the spread of ASF in wild boars depends primarily on population density and other phenomena barely impact it. Similarly, the mandatory searching for carcasses relies on the expectation of finding enough dead animals to correctly determine the presence or absence of the disease according to the basic sampling rules of veterinary epidemiology (Pfeiffer, 2002).

These measures disregard the differences between the ecosystems of the continent. For instance, forest cover and the presence of a scavenger species may obstruct the search for carcasses. On the other hand, scavenging may result in both increasing and mitigation of the epidemiological risk by the transportation of potentially contaminated materials and removal of infected carcasses, respectively (Ćirović et al., 2016; O'Bryan et al., 2018; Vicente & Vercauteren, 2019).

Within the southeastern part of Europe, the expansion of the golden jackal (*Canis aureus*) is happening currently. This process began in the second half of the 20th century. Several factors were contributed to this process such as alteration in land-use and animal husbandry, warmer winters without deep snow-cover, and the lack of top-down suppression by the grey wolf (Guimarães et al., 2019; Krofel et al., 2017; Spassov & Acosta-Pankov, 2019). Due to its ecological plasticity, the jackal began to spread to the western part of the continent. The dispersion led to conflicts with farmers and hunters (Guimarães et al., 2019; Lanszki et al., 2018) and caused human health risk as a reservoir of zoonotic diseases such as tick-borne diseases (Sukara et al., 2018), parasitic helminths, and protozoa (Gherman & Mihalca, 2017). By this time, these medium-sized carnivores became the most important scavenger species in the Western Balkans region contributing to the disposal of tons of offal originated from big game species and domestic animals (Ćirović et al., 2016; Lanszki et al., 2018).

Our study was conducted within the habitat of the westernmost resident breeding population of the golden jackal (Krofel et al., 2017; Spassov & Acosta-Pankov, 2019). During the investigation, the area possessed an ASF free status. Therefore, the offal obtainable on-site originated from natural mortality or inadequate hunting waste management. Based on previous experiences (Ćirović et al., 2016; Lanszki et al., 2018), we hypothesised that the scale of the golden jackal's scavenging activity might be so abundant as it can decrease the success rate of searching for wild boar carcasses. On the other hand, resident

jackals may mitigate the risk of viral survival in the environment by the removal of carcasses. By this study, we would like to call attention to the need for a holistic approach to a complex ecosystem health problem, like ASF in wild boars. We suppose that the application of One Health principles provides new insights into the driving forces of the ASF epidemic (Iglesias et al., 2018).

2 | MATERIALS AND METHODS

The investigation was conducted between 2011 and 2018. The study area was assigned as the whole territory of Somogy County (6065 km²) in the southwestern part of Hungary. The human population density is low (50 heads/km²). Most of the people live in the four biggest cities of the county as a result of excessive countryside abandonment. The forest covers 29.6% of the area. The mosaic-structured lowlands, which are typical golden jackal habitats, characterise some half of the territory. The local population of this mesopredator is rapidly expanding. At the beginning of our sample collection period, the annual number of hunted golden jackals was 426 individuals, which increased continually and exceeded 2000 by the end of our investigation.

The wild boar population of the county is the densest in Hungary with an annual hunting bag over 16,000 hunted wild boars nowadays. The growth has been continual during the last two decades, with more than 20% increase during the study period. We considered the number of hunted wild boars as an indicator of the population size based on the findings of Nores et al. (2008). This study determines that intensive hunting management removes approximately 30% of the breeding wild boar population without relevant influence on population size or density. The official number of “found dead” wild boars in the county decreased from 375 to 167 between 2011 and 2018. The data concerning the game population originated from the official Hungarian Hunting Database.¹

The jackal specimens assigned for investigation were whole stomachs collected by hunters. All harvested jackals were legally hunted within the framework of the wildlife managers' approved annual hunting plans. Following the hunting event, the organs were sent to the laboratory and frozen as soon as possible. After thawing, the stomachs were opened along the greater curvature, and the entire content was emptied onto a plastic tray. The humid components were sorted by forceps and weighed with 0.1 g accuracy.

The animal remains were identified by anatomical characteristics of the bones and viscera or by hair morphology based on the works of Teerink (1991) and Tóth (2015). In the case of ungulates, we attempted to define the species of the prey. Other animal remains were categorised as carnivores, rodents, wild birds, reptiles and amphibians, fish, insects and worms, and poultry. The plant components were classified as silage, fruits, cereals, oilseeds, grasses, dicotyledonous plants, and leaf litter. In the case of human communal waste, we separated indigestible materials from food waste. Other components, such as the

¹ See: National Game Management Database. <http://www.ova.info.hu/vgstat.html>.

jackals' hair, stones, rabies vaccine sheaths, and wild boars' feeding place soil, were also measured. Wild boars' feeding place soil was identified by its characteristic pickle and boars' odour and grain content.

The stomach content data were sorted into two groups according to the harvesting seasons. The period from November to February was classified as cold season, which is the main hunting season of wild boars, and the rest of the year was appointed as the warm season. We calculated the frequency of occurrence (FO), percentage of the total biomass (BM%), importance value (IV) and percentage of importance value (IV%) for all feed items in both seasons (Frackowiak & Gula, 1992):

$$IV_i = \frac{FO_i \times BM_i \%}{100} \quad (1)$$

Furthermore, importance was expressed in percentage by the following equation:

$$IV_i \% = \frac{IV_i}{\sum IV} \times 100 \quad (2)$$

Based on IV%, food items were classified into the following three categories: a dominant item strongly characterises the diet ($IV\% \geq 10\%$); an ordinate item contributes significantly to the nutritional demand of the jackals, though to a lesser degree than dominant items ($1\% \leq IV\% < 10\%$); a subordinate item occurs infrequently and not contributing significantly to the diet ($IV\% < 1\%$).

The proportion of the empty stomachs between the two seasons was compared by Chi-squared test, while in the case of the average content biomass and the mean weight of the dominant items, the Wilcoxon–Mann–Whitney rank-sum test was used for comparison.

The probability level of $p < 0.05$ was accepted in all statistical tests. For analysis, we applied R statistics software version 3.6.1.

During ecosystem service calculation, the golden jackals' average daily intake of food is 850 g (Ćirović et al., 2016). For lack of precise monitoring data on the Somogy County jackal population, we calculated the approximate size of the investigated population by the hunting bag data of the year 2018 (2069 hunted individuals) combined with the recently known Hungarian control rate of 0.23. Banea et al. (2018) calculated this control rate value as a ratio between the number of hunted individuals and the estimated size of the breeding population. The daily amount of feed components potentially containing suid remains was calculated from the estimated total biomass using the feeding ecological data gained from the stomach content analysis.

3 | RESULTS

During 8 years, we collected 277 stomach specimens. Most of them ($N = 210$) were derived from the warm seasons. The total biomass of the stomach contents originated from the cold and the warm seasons were 5866.4 and 25371.3 g, respectively. During the two seasons, the proportion of the empty stomachs (28.4% cold, 22.4% warm) and the average stomach content (87.6 g cold, 120.8 g warm) did not differ significantly.

The IV calculation revealed that the red deer and wild boar remains were the most important diet components in both seasons. During the cold season, unidentifiable big game tissues got dominance, while fish had almost the same role ($IV\% = 9.4\%$). Rodents, insects and worms, and fruits became important in the spring. The low relevance of food wastes remained constant throughout the year (Table 1).

For the most two important food sources, wild boar and red deer, there were no significant differences between the FO, the BM%, and the consumed mean BM during the two seasons. The IV% of unidentifiable big game and fruit items exceeded 10%. The unidentifiable big game appeared to be more important during the cold than the warm season. Notwithstanding, the seasonal difference between the FO, the BM%, and the mean consumed BM did not prove significant. The fruit dominated in the warm season. Its mean BM showed statistical dissimilarity between the two seasons.

Based on the number of hunted golden jackals (2069) and the control rate of 0.23 determined by Banea et al. (2018), we calculated that the approximate population size was almost 9,000 in the final year of our investigation. Considering the estimated jackal population of the study area and the average daily intake of feed, the golden jackals consumed 7.65 t/day feed in Somogy County during the final year of the investigation period. Through their feeding activity, the jackals disposed of approximately 2.28 t/day wild boar remains 0.93 t/day unidentifiable big game tissues and 0.43 t/day food waste during the cold season. The amounts of feed components for the warm season were calculated as 1.42 t/day wild boar remains, 0.45 t/day unidentifiable big game tissues, and 0.10 t/day human food waste. Thus, 0.6 and 0.3 kg/km²/day animal by-products potentially containing suid remains were removed from the ecosystem in the cold and warm seasons, respectively.

4 | DISCUSSION

This study investigated the proportion of wild boar remains and human food waste in the diet of golden jackals in the southwestern part of Hungary, where ASF has not gone to endemic yet. Based on the literature, these two components of the diet were defined as the most hazardous ones concerning the ASF pandemic (Chenais et al., 2019; Oļševskis et al., 2016). According to the previous experience on the sanitary role of the golden jackal (Ćirović et al., 2016), we hypothesised that the expanding population of this mesopredator might interfere with surveillance efforts for early detection of ASF.

As a result of our diet analysis, the big game remains, primarily wild boar and red deer, were demonstrated to be the most important feed components of golden jackals within the study area. In comparison across the seasons, the importance value of these items seemed higher during the main hunting season of big games. Notwithstanding, the statistical analysis could not confirm the seasonally higher consumption of big games during the cold season. This finding is in accordance with the results of Lanszki et al. (2018), who found that total removal of hunting offal from a hunting site did not reduce the percentage of the big game remains in the diet of the inhabitant golden jackal population.

TABLE 1 Seasonal diet composition of golden jackal ($N = 277$)

Feed-item	November–February ($N = 67$)				March–October ($N = 210$)			
	N_i	BM	IV	IV%	N_i	BM	IV	IV%
Red deer	6	1227.7	2.6	15.2 ^D	24	5754.8	3.3	22.9 ^D
Fallow deer	0	0.0	0.0	0.0	3	165.9	0.0	0.1
Roe deer	0	0.0	0.0	0.0	1	257.7	0.0	0.0
Wild boar	15	1749.1	9.3	54.2 ^D	35	4719.3	4.0	27.4 ^D
Unidentifiable big game	8	712.5	2.0	11.8 ^D	18	1481.9	0.7	4.4
Wild birds	0	0.0	0.0	0.0	14	504.3	0.2	1.2
Rodents	2	17.3	0.0	0.1	36	159.07	1.4	9.5
Carnivores	0	0.0	0.0	0.0	7	788.9	0.1	0.9
Reptiles and amphibians	0	0.0	0.0	0.0	3	39.3	0.0	0.0
Fish	10	457.1	1.6	9.4	13	1056.8	0.3	2.3
Insects and worms	1	1.0	0.0	0.0	24	1062.1	0.6	4.2
Cattle	0	0.0	0.0	0.0	1	964.2	0.0	0.2
Sheep/goat	3	13.8	0.0	0.1	3	358.6	0.0	0.2
Domestic pig	0	0.0	0.0	0.0	1	85.9	0.0	0.0
Poultry	1	4.5	0.0	0.0	3	202.6	0.0	0.1
Human food waste	3	329.2	0.4	2.0	4	341.2	0.0	0.2
Indigestible communal waste	1	12.7	0.0	0.0	4	37.6	0.0	0.0
Silage	2	181.0	0.1	0.8	3	217.6	0.0	0.1
Fruits	1	206.9	0.1	0.4	38	3125.5	2.9	19.7 ^D
Cereals	2	130.0	0.1	0.5	11	636.4	0.2	1.2
Oil seeds	1	148.2	0.1	0.3	3	187.2	0.0	0.1
Grasses	4	68.8	0.1	0.6	28	779.6	0.5	3.6
Dicotyledonous herbs	2	49.7	0.0	0.2	1	4.2	0.0	0.0
Leaf litter	2	54.1	0.0	0.2	8	94.7	0.0	0.1
Wild boars' feeding place soil	4	502.8	0.7	4.2	10	815.7	0.2	1.4
Stones	0	0.0	0.0	0.0	2	0.9	0.0	0.0
Jackals' hair	0	0.0	0.0	0.0	6	82.9	0.0	0.2
Rabies vaccine sheath	0	0.0	0.0	0.0	2	8.5	0.0	0.0
Empty stomach	19				47			

Note: Superscript D denotes dominant food item.

Abbreviations: BM, biomass in grams; IV, importance value; IV%, the percentage of importance value; N_i , number of stomach with the concerned item.

On the other hand, our study was not confined to one hunting site but a whole county with a 6065 km² area. Thus, the confusing effect caused by different offal management of the adjacent areas biased our results less. Nevertheless, both studies suggest that big game consumption of golden jackals slightly depends on human-provided offal.

With its 10–11 kg weight, the golden jackal cannot play a significant role in the population control of big game species (Klare et al., 2010). Jackals as mesopredators can feed on prey less than 45% of their body mass (Temu et al., 2016). Therefore, large ungulate remains in the stomach content could be originated predominantly from scavenging. Considering the amount of wild ungulate remains detected in jackals' stom-

achs, it is probable that the natural mortality of dense big game populations in Hungary is greater than officially reported to the Hungarian Hunting Database. Thus, the official population estimation also underestimates the real population size. Our assumption is also supported by the decreasing number of officially “found dead” wild boars despite the continually growing hunting bag. Although this contradictory phenomenon could occur in line with the population explosion of golden jackals, it could be hypothesised that the missing carcasses end up in the jackals' stomachs.

In these conditions, the success of passive surveillance based on “found dead” wild boars is at least questionable. Regarding the previous

reports that describe a slow rather than sudden transmission of ASF in wild boar populations, moderate growth in natural mortality caused by the disease might not be noticed at first (Olševskis et al., 2016; Sánchez-Cordón et al., 2019; Schulz et al., 2019). The hiding behaviour of diseased wild boars also hampers the detection of perished animals (Morelle et al., 2019). During our study, even the excessive increase of hunting offal in winter months could not cause a significant change in the diet composition of the jackals. At the emergence of ASF, a smaller increase in animal remains can disappear due to scavenging activity. With a very strong preference to meat-eating, canid mesopredators can find animal originated feed sources in the wilderness rather effectively and rapidly (Koeppel et al., 2020; Sarkar et al., 2019).

For medium-sized mammal scavengers with moderate bite force, the access to meat from fresh carcasses requires a great deal of effort (Christiansen & Wroe, 2007; Damasceno et al., 2013; Wroe et al., 2005). In general, these scavengers enter the dead body at the perianal region or from the abdominal side where the collagen fibre content of the skin is lower than it is in the other anatomical regions (Lotan, 2000; Meyer et al., 1982; Yang et al., 2015). Despite their limited ability to penetrate the skin of an adult wild boar, mesocarnivores can remove most of the soft tissues in few weeks post-mortem (Keyes et al., 2020; Lotan, 2000; Probst et al., 2020). Considering the fact that deathbeds of wild boars have limited visibility for humans, the period needed for skeletonization is rather short to succeed in surveillance (Morelle et al., 2019).

On the other hand, this potentially contaminated material might not vanish only from the surveillance system but also from the transmission cycle. A study on scavengers confirmed that canid species are the most active visitors of wild boar carcasses. Their beneficial characteristic is that they feed on the spot, and they take only small pieces of meat less frequently (Probst et al., 2019). The intensive meat searching activity and voracity of jackals prevent wild boars from cannibalism, which is a very rare phenomenon in this suid species (Probst et al., 2017).

In golden jackal, as a species that evolutionarily adapted to scavenging, the grooming activity is very strong (Gashe & Yihune, 2020). Our findings also supported this fact, whereas, between March and October (when the shedding seasons happen), the jackals' hair proved to be a subordinate item of the stomach content. Through this comfort behaviour, predators and scavengers can decrease the contamination level of their body surface (Hart & Hart, 2018). Moreover, the golden jackal possesses strong territoriality; thus, the resident population is unlikely to contribute to the excessive transmission of ASF (Gupta et al., 2016; Moehlman & Hayssen, 2018; Trbojević et al., 2018). In this context, the presence of a dense jackal population can support the risk mitigation during epidemics maintained by wild ungulates (O'Bryan et al., 2018).

The elements of the ecosystems concerning ASF should be evaluated from the viewpoint of their epidemiological role. The identification of factors that potentially mitigate or enhance transmission is a cornerstone during risk level evaluation of a certain ecosystem (Machalaba et al., 2017; Mackenzie & Jeggo, 2019). In this process, carnivore species have merit. Besides scavenging, large carnivores, such as wolves, may pose as a mortality factor for wild boar (Mori et al., 2017).

In this case, predation can reduce the length of the infective period as febrile viraemic boars are killed more probably than healthy individuals (Tanner et al., 2019).

Similar to golden jackals, wolves may also disrupt control activity by removing the best targets for passive surveillance. For this reason, the epidemiological role of species other than wild boars should also be evaluated from ecosystem to ecosystem. A panacea that works in every situation does not exist.

5 | CONCLUSION

This study suggested the role of the golden jackal in ASF control to be ambivalent. On the one hand, the scavenging activity might interfere with surveillance efforts by the elimination of the potential samples from the site. On the other hand, the advantageous effect of carcass disposal was determined in detail. The presence of carnivores is only one of the ecosystem services that may have a relevant impact on viral survival and disease transmission in an ecosystem concerned by ASF.

The increasing body of knowledge in the field of ecology should enforce the paradigm shift in the control strategy against diseases maintained by wildlife. An ecosystem is rather a complex space to be approached simply and uniformly. In these conditions, the interdependence of potential stakeholders responsible for certain aspects of wild boar health and management should be appreciated. The adaption of the One Health approach can be a promising method to ensure an optimal outcome of control efforts. This study highlighted the potential in a rather ecological than veterinary epidemiological analysis of the various factors that can influence the course of an epidemic at the human-animal or livestock-wildlife interface.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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