



Rabies control in wildlife: the golden jackal (*Canis aureus*) requests for attention – a case study

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ABSTRACT - In Hungary, the rabies control programme with oral bait immunisation of wild carnivores dates back to 1992. Since then, the rules of vaccine placement on bait density has not changed, in spite of drastic expansion of both the carnivore community and the wild boar population in Europe. Though, all these elements of the concerned ecosystem compete for the baits. This case study was based on the accidental finding of vaccine blisters in jackal stomachs during a large-scale investigation on jackals' feeding ecology. The results showed 3.17% (0.57-10.87%) frequency of bait occurrence in jackal specimens harvested during the vaccination term. This finding contradicted previous reports on high bait uptake rate and rabies seroconversion in golden jackals. These results called the attention the need for paradigm shift in management of diseases maintained in a natural reservoir. In the authors' opinion, for reassuring result, multidisciplinary research groups should re-evaluate disease control strategies time and again.

Keywords: golden jackal, multidisciplinary approach, rabies control, zoonotic diseases

INTRODUCTION

In Hungary, the rabies control programme for wild carnivores dates back to 1992 (Forró *et al.*, 2019). Originally, the main target species was the red fox (*Vulpes vulpes*). The immunisation was carried out by oral route of application with bait vaccines. Following the recommendation of the European Union, the bait density distributed on the vaccinated site was 20/km² (Maki *et al.*, 2017; Robardet *et al.*, 2019). Since that time, the carnivore fauna of southeastern Europe has been changed definitely. During the last decade of the 20th century, the golden jackal population of the Balkans began to spread westwards. The assumable reasons of this expansion are alteration in land-use and animal husbandry, warmer winters without deep snow-cover, and the lack of top-down suppression by the grey wolf (*Canis lupus*) (Krofel *et al.*, 2017; Guimarães *et al.*, 2019; Spassov and Acosta-Pankov, 2019). As a result, a very dense golden jackal population established in the lowland habitats of the southwestern part of

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Hungary, as well (*Lanszki et al., 2018; National Game Management Database, 2020*).

Parallely, the wild boar population of this region also went through a notable growth (*National Game Management Database, 2020*). These trends in wild boar numbers were ascribed to a miscellanies of species-specific biological factors (e.g. very high reproduction, phenotypic plasticity and dispersal potential) as well as other changes for instance the lack of apex predators, persistent supplementary feeding, habitat alteration due to human activities and climate changes with mild winters that improved survival (*Massei et al., 2014*).

Studies on evaluation of rabies bait vaccination programmes confirm that non-target species also consume a significant amount of doses distributed on the site. In Europe, 18-42% rabies seroprevalence can be experienced in wild boars (*Dascalu et al., 2019*). Regarding the 100% mortality of rabies caused by wild-type virus, this seroconversion should be due to an extensive uptake of rabies bait vaccines. In an African study, a very similar phenomenon was observed as nearly one third of fishmeal-coated rabies vaccines were consumed by warthogs (*Phacochoerus africanus*) (*Koepfel et al., 2020*).

In order to reach an appropriate vaccination coverage in the target population, bait density should correlate with the number of individuals within the vaccinated area (*Tizzani et al., 2020*). This rule contradicts with the European practice, as the recommended bait density has been 20-30/km² continent-wide for decades (in Hungary 20 baits/km²), in spite of considerable change in size of both the carnivore and omnivore fauna (*Robardet et al., 2019; Tizzani et al., 2020*). Though wild boars are not the target of rabies vaccination campaigns, whereas they cannot contribute significantly to the maintenance of the disease, but regarding the relatively high rabies seroprevalence in the species, they ought to withdraw numerous baits from the real target population. Furthermore, the progressively increasing population of golden jackal also diminishes the per capita baits reachable for carnivores.

This study was a part of a large-scale investigation on the feeding ecology of golden jackal in the south Transdanubian region of Hungary. During the research procedure, plastic blisters of rabies vaccines were found in the stomachs of golden jackals hunted after the vaccination term. This finding called the researchers' attention to the importance of non-target species, what the golden jackal was at the time the rabies control strategy was planned. Though the European rabies control campaign is an unquestionable success story, the presence of potentially competing species might risk the relapse (*Robardet et al., 2019; Tizzani et al., 2020*).

Rabies is a serious, in the lack of post-exposure vaccination, consequently fatal zoonotic disease. Since the middle of the last century, the disease is maintained by a natural reservoir within the sylvatic ecosystem (*Robardet et al., 2019*). Though natural habitats are very complex systems, the multidisciplinary approach with interdependent collaboration of different professionals is still missing at the planning phase of control strategies against wildlife diseases. In this study, we attempted to demonstrate the epidemiological risk of the dense golden jackal population for rabies control in a multi-species ecosystem.

MATERIALS AND METHODS

This study was the part of an investigation on the feeding ecology of the golden jackal. It was carried out between 2014 and 2018 within the characteristic habitats of the species in Baranya and Somogy Counties in the southwestern part of Hungary. The total area of the two counties is 10,495 km². The habitats were characterised with a diverse landscape structure, e.g. mosaic lowlands and wet grassland valleys covered some half of the territory. The local population of this mesopredator is rapidly expanding. At the beginning of our sample collection period, the golden jackals' hunting bag of the study site was 1,102 individuals; which increased continually and reached 3,589 by the end of our investigation. The data concerning jackals' population originated from the official *Hungarian Game Management Database (2020)*.

The jackal specimens assigned for investigation were whole stomachs collected by hunters. All harvested jackals were legally hunted in the framework of the wildlife managers' approved annual hunting plan. After the hunting event, the organs (n=226) were sent to the laboratory and frozen as soon as possible. After thawing in a fridge, the stomachs were opened along the great curvature and the whole content was emptied into a plastic tray. The humid components were sorted by forceps. Besides real diet components, the indigestible items of stomach contents, such as stones, inorganic wastes, soil and the jackals' own hair, were also measured.

The occurrence of the vaccine blisters was investigated separately in specimens from the vaccination periods (April and October of each year) and outside these two months. We determined the apparent frequency of vaccine sheath occurrence among the feed items as the number of stomachs with vaccine remains divided by the total number of investigated stomach specimens. The true frequency of occurrence (CI 95%) was calculated with adaption of the method described by *Reiczigel (2003)* for calculation of the true prevalence in epidemiology.

RESULTS

During the five years of the investigation period, 226 stomach specimens underwent an analysis, of which 63 originated from April or October, the term of oral vaccination of wild carnivores against rabies. Outside the vaccination period, we did not detect any remnants of rabies vaccines. Among the 63 specimens, harvested during the vaccination campaigns, two contained plastic blisters of the applied vaccines. In one of the stomachs, we found one blister. This specimen was got just after the placement of the baits. In the other stomach, which was harvested two weeks after the vaccine distribution, we found three blisters (*Figure 1*). The frequency of blisters' occurrence proved 3.17 % (0.57-10.87%) and 0% (0.00-2.30%) within the vaccination period and outside it, respectively.

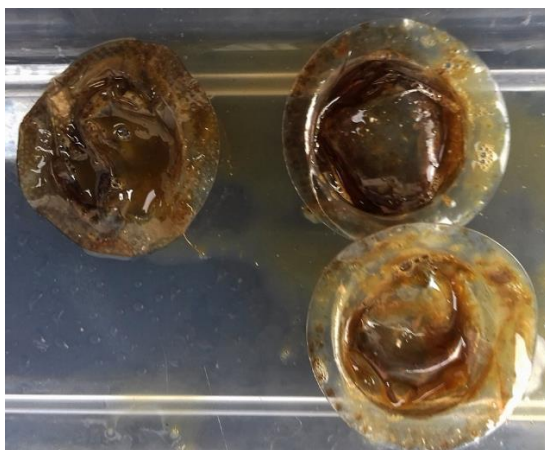


Figure 1
Found vaccine blisters from a golden jackal stomach

DISCUSSION

In this study, of 63 jackals hunted during the vaccination period, two were caught out with vaccine blisters in the stomach. This frequency of occurrence contradicted the observations in southwestern Europe, which reported a very high (90%) rate of bait uptake in golden jackals (*Bedeković et al., 2019*).

On the other hand, the finding of multiple uptake is thought-provoking. Considering official bait density (20 pieces/km²), for three baits, the jackal had to comb 15 ha area exhaustively. In this case, it is presumable that distribution of baits between the target individuals is certainly not even. This fact highlights

that some individuals may remove much more vaccines from the site than they ought to do for their appropriate immunisation. Whereas this phenomenon was supposed to be due to an ethological adaption to a seasonal food source, its impact is hardly estimated at population level.

The size of the European golden jackal population is still growing. The exact numbers cannot be estimated but the results of different studies can be summarised as an average of 2-3 family groups/10 km². The average group generally consists of a breeding pair and their offspring (*Lanszki et al., 2018; Wernink et al., 2019; Kowalczyk et al., 2020*). Whereas roughly the half of the total area (cca. 5,000 km²) is appropriate for establishment of a reproducing jackal population, some 1,000-1,500 family groups should form the total population of the south Transdanubia. By data of *Moehlman and Hayssen (2018)* it is assessed the average group size is around 2.5. Based on these data the calculated number of golden jackals could be between 2,500 and 3,750. Regarding to the recent hunting bag (3,589 jackals), this data need correction.

Another possible way to estimate the population size is based on the hunting bag and the approximate hunting rate. In Hungary, the latter was calculated to be 23% (*Banea et al., 2018*). Considering this value, our study sights can carry more than 15,000 jackals. The truth should be between the two values, as it is suggested by other studies, which estimate relatively high density among suitable conditions in the lack of competition (*Singh et al., 2016*). This is characteristic solely for some core jackal habitats of the southwestern part of Hungary, while outside these spots, the occurrence of the species is sporadic.

In any case, the south Transdanubian jackal population is recognisable in both size and density. Thus, the number of carnivore individuals per area recently exceeds more times the original population, which the bait density of the anti-rabies campaign was planned for (20 baits/km² distributed twice a year). When this bait density was determined, the golden jackal was only a rare visitor in this part of Europe (*Krofel et al., 2017; Lanszki et al., 2018; Spassov and Acosta-Pankov, 2019*) and the fox population was controlled by endemic rabies (*Smith and Wilkinson, 2003*).

Based on the above-mentioned population calculations and our finding on frequency of bait occurrence in stomachs, the estimated number of baits consumed by jackals should be between 20 and 1,650. This interval is very wide, however neither the lower nor the upper value supports the reported 90% uptake rate in golden jackals (*Bedeković et al., 2019*).

Regarding the benefits of rabies control for the fox population, it cannot be ruled out that a very important one of the causes led to the population expansion in golden jackal is the same. When the naturally migrating golden jackals met the rabies-free zone of the continent without any real limiting factors, then the size and density of the population began to increase rapidly. Due to its ecological plasticity, the jackal began to spread to the western part of the continent, creating conflicts with farmers and hunters and causing human health risk as a reservoir of zoonotic diseases (*Lanszki et al., 2018; Guimarães et al., 2019; Balog et al., 2021*). 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 offals originated from big game species and also domestic animals (*Ćirović et al., 2016; Lanszki et al., 2018*).

The recent situation in Europe can be described with a huge carnivore community, which is competing with omnivores for rabies oral baits surrounded by rabies endemic areas. It is far from simple and appears to harbour serious danger in terms of rabies control. Though the eradication of the disease from the continent seems to go on successfully (*Korou et al., 2016; Bedeković et al., 2019; Robardet et al., 2019*), it is very probable that even the number of carnivores profusely exceeds the distributed baits. This situation is aggravated by the wild boars and other omnivore species that remove the majority of baits. The high seroprevalence of rabies in a dense wild boar population, as it was detected in different parts of the continent, should be the result of high uptake rate (*Dascalu et al., 2019*).

Based on dog studies, a 70% of annual vaccination coverage is suggested to be appropriate for control of rabies in a concerned population. This rate of immunisation can prevent even the non-vaccinated part of the population between two mass vaccination campaigns (*Sánchez-Soriano et al., 2020*). But first of all, we have to know how many individuals mean that 70%? For this reason, large-scale standardised methods will be needed for the main target species, both red fox and golden jackal.

It is worth investigate the bait choice of the two species. A study, carried out in Africa, found that fishmeal covering the recently applied oral rabies vaccines is not preferred by jackals, moreover omnivorous species, such as suids and corvids, can consume the majority (62%) of baits (*Koeppel et al., 2020*).

Besides the obstruction of rabies control efforts, wild boars' bait uptake will result in a food-safety concern. These oral rabies vaccines contain tetracycline biomarker, which is deposited in the bones and teeth of the animals. Thus, the uptake rate can be assessed based on the detection of tetracycline in the tooth

specimen of the foxes hunted to check the success of the mass vaccination. Tetracycline is a type of antimicrobials, which can occur in the muscle tissues of the wild boars taken the bait up. This phenomenon was confirmed in Poland, where 37% of the investigated wild boar carcasses (N=144) contained tetracycline residues due to a previous vaccination campaign in their habitat (*Gajda et al., 2018*).

Consequently, the European rabies control program is threatened by a lot of factors, of which some seem to lack epidemiological relevance. We should have appropriate knowledge on bait preference, feeding ethology and ecology of both golden jackal and red foxes. We should find out how we can reduce the bait uptake of wild boars. For this, we need detailed experiences of feeding habits of this species. In an African study, the warthog, another suid species, proved to avoid chicken head or beef meat baits (*Koepfel et al., 2020*). These are small elements of a big puzzle and all these features are very important for the success. An endemic maintained in a natural ecosystem can be hardly managed without the professionals of the concerned fields of science. In the case of rabies control, multidisciplinary research groups of ecologists, ethologists, animal nutritionists, hunting professionals and mathematicians are needed to re-evaluate ongoing strategies to get a reassuring result.

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