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SHORT COMMUNICATION

# Feasibility of oral rabies vaccination campaigns of young foxes (*Vulpes vulpes*) against rabies in summer

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**Abstract** Oral vaccination of foxes (*Vulpes vulpes*) against rabies has been shown to be highly effective. Several baiting strategies to increase vaccination coverage of the target population have been developed. For example, to increase the vaccination coverage of the young fox population before dispersal an additional summer vaccination campaign has been suggested. The effectiveness of such a campaign was evaluated using field data on home range size and shape of young foxes and a simulation model for aerial bait distribution. The results indicated that the limited ranging behaviour of the young fox population during the summer months severely reduced bait accessibility and consequently such an additional vaccination campaign would be very cost-ineffective.

**Keywords** Home-range · Baits · Accessibility

Oral vaccination of foxes (*Vulpes vulpes*) against rabies has shown that the concept of vaccinating free-roaming wildlife against an infectious disease by the oral route is not only feasible but also a very cost-effective control method. At present, large areas of Europe and North-America have been freed from terrestrial wildlife rabies through distribution of vaccine baits. Since the first field trial in Switzerland in 1978 baiting strategies have been constantly improved or adapted to local situations. Unfortunately, baiting strategies have not always taken the behavioural ecology of the main target species into consideration (Vos 2003). For example, to increase the relatively low vaccination coverage of young foxes in some areas, it has been suggested that an (additional) summer vaccination campaign be conducted. This proposal led to the implementation of such campaigns in several countries, adding considerable costs to the often already restrained budgets. Trewhella et al. (1991) showed that during late spring and early summer adult foxes located and consumed the distributed baits more often than cubs, indicating that such summer vaccination campaigns were not able to induce effectively the desired results; an increased vaccination coverage of the young fox population. Actually, Masson et al. (1996) demonstrated that the distribution of vaccine baits during summer was not very efficient in terms of a subsequent reduction in rabies incidence.

A possible explanation for this lack of efficiency is the difficulty in reaching the young foxes in summer baiting campaigns due to their reduced ranging behaviour (Robertson et al. 2000). The aerial baiting strategies presently used are not adapted to target such small areas, and therefore many of these young animals will not have access to the baits distributed (Johnston and Tinline 2000). However, these arguments have never been verified with experimental and/or field data. Therefore, we investigated the feasibility of a vaccination campaign targeted at the young fox population during the summer months by estimating the number of baits dropped within the home ranges of young foxes.

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To estimate the number of baits to which the individual young foxes would have access, we used telemetry data of a field study in a Dutch coastal region for the size and shape of the home ranges and a simulation model for bait distribution. From 1980 to 1984 foxes were radio-collared in the Noordhollands Dune Reserve near Castricum, northwest of Amsterdam, the Netherlands. The adult fox density including non-territorial animals was two to three foxes per square kilometer and the overall fox density including cubs amounted to six foxes per square kilometer (Mulder 1988). Average group territory size was 167.5± 38.8 ha. Several young foxes ($n$=36) were caught and fitted with radio collars during the study period. In late spring and summer these animals were located intermittently, mostly during the day in their lying up places. However, some were also followed irregularly during the night. Home range size (95% Minimum Convex Polygon) was calculated with Arcview. The obtained radio telemetry data from a single animal could not be pooled for the entire summer period. This was because the activity range of the animals changed during this period; with increasing age most animals roamed over increasing larger areas. Furthermore, due to translocation of the den site in late spring and/or early summer when the young foxes were followed home range size and location of the young foxes could suddenly change drastically. Therefore, the home ranges were calculated on a monthly basis from May till August. For one individual the data from 2 months were pooled because of the limited number of fixes available, and for two animals a month was divided into two 2-week periods, while many fixes were obtained from these two animals. For a detailed description of this study and the material and methods used, see Mulder (1988).

Unfortunately, not all estimated home ranges of the young foxes gave a reliable picture of the true home range of the individual concerned. Reliability depends not only on the total number of fixes but also on the proportion of active fixes. The inactive fixes mostly obtained during the day only give an indication of the (generally few) favoured lying up places that are sometimes located in a very restricted area of the home range. Hence, it was decided to use only the data from the young foxes where more than 40% of the total fixes used for the estimation of the home range size were active ones recorded during the night. Furthermore, at least 25 total fixes for every home range had to be available. Based on these criteria the available data set was reduced to 16 home ranges of eight animals (Table 1). The number of baits dropped within the 16 selected home ranges was calculated using a simulation model for the baiting strategies as suggested by the European Union: In case of a low fox density, 25 baits per square kilometer dropped along flight lines 500 m apart, and in case of a high fox density 30 baits per square kilometer dropped along flight lines only 300 m apart (European Commission 2002). For the model, a homogeneous distribution of the baits along the flight lines were considered and not a more targeted approach where baits are dropped by helicopter or hand at locations assumed to be favoured by foxes. The home ranges were placed at random within a virtual study area (1,000 ha) in which the

**Table 1** Home range size (ha) of young foxes during the summer months, the percentage of overlap with their mother and minimum number of foxes ($N$) known to have access to this particular home range area

| | Animal | Sex | Period | Home range (ha) | Overlap (%) | Number ($N$) | Total fixes | Active fixes | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number | Percent% |
| 1 | Elsje | F | May | 21.50 | 23.0 | 8 | 32 | 13 | 42 |
| 2 | Peter | M | May | 18.12 | 19.4 | 8 | 26 | 10 | 43 |
| 3 | Ellen | F | June 1st part | 40.75 | 29.2 | 4 | 64 | 45 | 82 |
| 4 | Wieger | M | June 1st part | 43.75 | 31.4 | 4 | 86 | 57 | 86 |
| 5 | Peter | M | June | 34.00 | 36.4 | 8 | 53 | 27 | 53 |
| 6 | Elsje | F | June | 22.00 | 23.6 | 8 | 46 | 20 | 46 |
| 7 | Ellen | F | June 2nd part | 14.50 | 10.4 | 4 | 113 | 74 | 79 |
| 8 | Wieger | M | June 2nd part | 27.25 | 19.5 | 4 | 116 | 83 | 78 |
| 9 | Kleintje | F | July | 26.50 | 23.2 | 11 | 110 | 47 | 73 |
| 10 | Peter | M | July | 27.12 | 29.0 | 8 | 37 | 14 | 42 |
| 11 | Wieger | M | July | 12.63 | 9.1 | 4 | 29 | 18 | 69 |
| 12 | Koot | M | July – August | 36.75 | 39.8 | 6 | 29 | 12 | 43 |
| 13 | Kleintje | F | August | 80.50 | 38.6 | 11 | 140 | 100 | 93 |
| 14 | Mieke | F | August | 96.00 | 41.2 | 6 | 72 | 47 | 71 |
| 15 | Walter | M | August | 29.13 | 23.1 | 4 | 41 | 20 | 54 |
| 16 | Peter | M | August | 34.00 | 36.4 | 8 | 70 | 44 | 72 |

The number of active fixes and the percentage of active fixes in relationship to the total number of fixes used to estimate the home range (MCP) are also shown exact location of each individual bait dropped was determined. These locations are fixed depending on the baiting strategy used, flight line distance and bait density. For randomisation purposes, the home ranges were rotated around the centroids, as well as by random selection of the centroids coordinates within the virtual study area as long as the complete home range falls within the virtual study area. The number of baits positioned within the home range, shown as convex polygons, can simply be determined by using algorithms (Sedgewick 1992). For every home range and baiting strategy the simulation model ran 10,000 times using JAVA (SUN Microsystems) to make sure that every possible flight route was covered. Especially for very small areas, the angle at which the airplane enters the vaccination area has a great impact on the number of baits distributed within the home ranges; sometimes the home ranges are not reached at all.

The results of the simulation model are shown in Table 2. On average, in only three of 16 home ranges more than ten baits were dropped when 25 baits per square kilometer were distributed with flight lines 500 m apart. The baiting strategy suggested for areas with a high fox density gave somewhat better results, but still in most home ranges ten or less baits were dropped.

When baits are distributed within a home range of a fox, it does not implicate automatically that this particular animal has also guaranteed and exclusive access to these baits. Some baits are dropped at locations within the home ranges that are not regularly visited by the territory owner or are distributed at ‘inaccessible’ sites. Furthermore, the fox shares its territory with many non-target species that actively compete with the fox for the baits, e.g. wild boar, mustelids, rodents, corvids, domestic animals like dog and cat, etc. Hence, a surplus of baits must be distributed to guarantee that sufficient foxes have access to at least one bait to reach a vaccination coverage that will interrupt the chain of infection. To quantify the surplus needed is almost impossible because this does not only depend on the number of foxes present but also on the density of the major bait competitors. It was assumed that the number of baits had to be 10–15 times greater than the number of animals targeted (Linhart 1993). The results of the simulation model indicate that most young foxes in this particular population do not have access to sufficient baits (a minimum of ten baits per animal). Increasing bait density has only a limited positive effect on the number of accessible baits.

Also, the young fox targeted shares its home range with its parents, littermates and, in case of family groups, other family members. In this study, for each juvenile fox there were at least three to ten other adult and juvenile foxes in the family group present. This further reduces the changes that a young fox will encounter and find a bait and it becomes very unlikely that a summer vaccination campaign using one of the two selected baiting strategies would result in a very high vaccination coverage of the young fox population.

It is difficult to generalize these results. Little is known about the relationship between home range size of parents and that of their offspring. Robertson et al. (2000) estimated the activity areas of cubs in an urban area in England. They found extremely small areas: May—1.3 ha; June—2.0 ha;

**Table 2** Number of baits dropped within the selected home ranges for the two baiting strategies using the simulation model (strategy A: bait density—25 baits/km$^2$, flight lines 500 m apart; Strategy B: bait density—30 baits per square kilometer, flight lines 300 m apart)

| | Animal | Period | Strategy A | | | | Strategy B | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | SD | Min. | Max. | Mean | SD | Min. | Max. |
| 1 | Elsje | May | 5 | 2.0 | 0 | 10 | 7 | 1.0 | 4 | 13 |
| 2 | Peter | May | 5 | 2.0 | 0 | 9 | 6 | 1.0 | 2 | 10 |
| 3 | Ellen | June 1st part | 10 | 2.0 | 4 | 16 | 14 | 1.4 | 7 | 18 |
| 4 | Wieger | June 1st part | 11 | 2.1 | 7 | 17 | 15 | 1.4 | 11 | 20 |
| 5 | Peter | June | 8 | 1.4 | 5 | 14 | 11 | 14 | 7 | 16 |
| 6 | Elsje | June | 5 | 1.7 | 0 | 10 | 7 | 1.3 | 4 | 12 |
| 7 | Ellen | June 2nd part | 4 | 1.9 | 0 | 9 | 5 | 1.0 | 2 | 9 |
| 8 | Wieger | June 2nd part | 7 | 1.7 | 2 | 12 | 9 | 1.3 | 4 | 14 |
| 9 | Kleintje | July | 7 | 1.9 | 0 | 11 | 9 | 1.3 | 5 | 14 |
| 10 | Peter | July | 7 | 2.0 | 0 | 11 | 9 | 1.3 | 6 | 15 |
| 11 | Wieger | July | 3 | 1.9 | 0 | 11 | 4 | 1.3 | 0 | 9 |
| 12 | Koot | July — August | 9 | 1.7 | 4 | 16 | 12 | 1.4 | 7 | 17 |
| 13 | Kleintje | August | 20 | 2.5 | 13 | 27 | 27 | 1.7 | 20 | 32 |
| 14 | Mieke | August | 24 | 1.8 | 18 | 30 | 32 | 1.8 | 26 | 38 |
| 15 | Walter | August | 7 | 1.1 | 4 | 12 | 10 | 1.2 | 5 | 13 |
| 16 | Peter | August | 9 | 1.4 | 6 | 14 | 12 | 1.1 | 6 | 16 |

July—5.6 ha, and August—8.9 ha. Also, the home ranges of the parents were much smaller than in the fox population we examined. Under these extreme circumstances, almost all cubs would not have access to any of the baits distributed. In other areas where the adult foxes have much larger home ranges, the young foxes may also roam over a much larger area than we found.

However, the spatial activity of young foxes may also be limited by physical constraints and is most likely not directly proportional to the home range size of their parents. Robertson et al. (2000) found that just before dispersal in August cubs were moving over areas comparable in size to their parents. In our study area, young foxes still only utilized less than 50% of their mothers' range during this month. Hence, it seems more reasonable to suggest that vaccination campaigns targeted at the young fox population should not be implemented before September. The recommendation of the European Commission (2002) to vaccinate preferably early June is therefore strongly discouraged; most young foxes simply cannot be reached during this period with conventional aerial bait distribution.

A more efficient way to reach the young fox population is by placing baits at the entrance of the fox den in early summer or at the rendezvous sites through summer (Breitenmoser et al. 1995; Robertson et al. 2000). However, the locations of only a minority of the dens and rendezvous sites will be known in any region. Only after an intensive search can these sites be located. The topography of the area can severely hinder such a search, especially in mountainous areas with a high forest cover. It can be concluded that aerial oral rabies vaccine bait distribution campaigns targeted at the young fox population in the period May to August will most likely not reach the desired goal of a high vaccination coverage of this subpopulation.

Such campaigns can better be postponed till September when the juvenile foxes can be reached much easier. This would coincide with the period that in most countries the annual vaccination campaign in autumn is planned. Therefore, a vaccination campaign in early autumn would be the most cost-effective approach to reach both the adult and juvenile fox population.

## Declaration

The activities, including the capture and handling of the animals required for obtaining the presented data, complied with current applicable laws in the Netherlands.

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