# BAITING RED FOXES IN AN URBAN AREA: A CAMERA TRAP STUDY

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***Abstract:*** Baiting red foxes (*Vulpes vulpes*) is an established method of vaccinating foxes against rabies in rural environments. Furthermore, anthelmintic baiting has been demonstrated to reduce the prevalence of the zoonotic tapeworm *Echinococcus multilocularis* in foxes. The recent invasion of foxes into urban areas on continental Europe represents a considerable health risk that calls for the evaluation of baiting strategies adapted to the urban environment. We investigated bait uptake by urban foxes using camera traps in Zurich, Switzerland. Baits with and without the anthelmintic praziquantel were placed in several arrangements (exposed, covered, buried), at different locations (fox dens, compost heaps, fox tracks) and in different seasons (early summer, summer, winter). Ninety-one of 252 baits (36%) disappeared within 3 days. Most of the baits consumed near cameras were consumed by foxes (44 of 91). The remaining baits were consumed by hedgehogs (*Erinaceus europaeus*), snails (*Arion sp.*), dogs, rodents (*Apodemus sp.*), and unidentified animals. Bait uptake by foxes was significantly higher during summer than winter ($P = 0.022$), and foxes accepted baits most frequently at fox dens during early summer (52.8%). Burying baits reduced bait removal by species other than foxes ($P < 0.01$). For rabies control in urban areas, avoiding contact of nontarget species with the rabies vaccine is particularly important. Greater selection of the fox population can be achieved by distributing baits in winter, burying baits, and choosing sites that are less accessible to nontarget species. However, with anthelmintic treatment, uptake by nontarget species is of lesser importance; hence, the effort to bury the bait is unnecessary.

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In Europe, rabies epizootics substantially reduced red fox densities in the 1960s and 1970s (Breitenmoser et al. 2000). After oral rabies vaccination campaigns, fox populations in some European countries started to recover in the 1980s, and in some areas, fox densities are now higher than before the rabies epizootic (Wandeler et al. 1988, Breitenmoser et al. 2000, Chautan et al. 2000). In addition, foxes started to colonize many European cities (Christensen 1985, Gloor et al. 2001). The situation in continental Europe is now similar to that in Great Britain (Gloor 2002), where urban foxes have been documented for over 60 years (Teagle 1967, Harris 1977), and fox populations occur in higher densities in urban than in rural areas (Harris and Rayner 1986).

In continental Europe, urban foxes living in close contact with humans represent a serious public health risk as foxes transmit 2 dangerous zoonotic diseases: alveolar echinococcosis, caused by the metacestode stage of *Echinococcus multilocularis,* and rabies (Harris et al. 1991, Eckert and Deplazes 1999). Foxes are responsible for most of the environmental contamination with *E. multilocularis* eggs. After oral ingestion of eggs, the parasite can develop in the human liver behaving like a malignant tumor (Ammann and Eckert 1995). In the city of Zurich, 47% of urban foxes are infected with *E. multilocularis* (Hofer et al. 2000). Areas such as public parks, allotments, and private gardens have been shown to be contaminated with fox feces containing *E. multilocularis* eggs (Stieger et al. 2002). The high prevalence of *E. multilocularis* in foxes in urban areas suggests that an evaluation of possible intervention strategies is needed. The delivery of baits containing the anthelmintic praziquantel successfully reduced *E. multilocularis* prevalence in the red fox population in rural areas of Germany and Japan (Schelling 1997, Tackmann et al. 2001, Tsukada et al. 2002). Up to now, this control strategy has not been evaluated in urban areas.

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Because foxes were absent from urban areas at the time of the rabies epizootic, cities were considered effective barriers for the spread of rabies when developing control strategies (Steck et al. 1980). Now, in Europe, rabies vaccination campaigns must include urban habitats (Bacon and Macdonald 1981, Baker et al. 2001). The density of foxes susceptible to rabies must be reduced below a specific threshold value (0.25–1.0 foxes/km$^2$) to stop the transmission of the disease (Anderson et al. 1981). In urban areas with >10 adult foxes/km$^2$, achieving these densities is difficult (Trewhella et al. 1991). Empirically, vaccination rates of 50–80% (using tetracycline markers as a measure for bait uptake) were sufficient to eliminate the disease in medium to high fox densities (Zanoni et al. 2000). Yet, the development of very effective and selective baiting strategies for urban foxes is of major interest.

An effective baiting strategy is characterized by high bait acceptance of the target species and low bait acceptance of nontarget species (Guthery and Meinzer 1984). In urban areas, dogs, cats, and wild mammals, such as stone martens and raccoons (*Procyon lotor*), can reach high abundances and may compete for baits (Hadidian et al. 1989, Andelt and Woolley 1996) and, hence, reduce the effectiveness of the baiting strategy. Different food supplies for foxes can alter the attractiveness of baits and reduce bait acceptance in urban habitats (Wandeler 2000). Also, requirements for baiting strategies for control of rabies or *E. multilocularis* differ. The live attenuated and recombinant rabies vaccines used for oral immunization carry the risk of residual pathogenicity. Consequently, contact of nontarget species with rabies vaccine should be prevented (Rosatte et al. 1992, Wandeler 2000). Because the anthelmintic praziquantel represents no risk for urban wildlife, pets, or urban dwellers (Sweet 1987), the inadvertent treatment of nontarget species presents minimal risk. Contrary to the rabies baits that contain vaccine blisters, the anthelmintic praziquantel is homogenously distributed in the bait matrix. Therefore, partial consumption of baits by invertebrates or other small animals hampers proper dosage of the active agent if the baits are not taken by the foxes within a short time.

Field evaluations of bait uptake traditionally have been undertaken by checking individually marked baits for disappearance, or by searching for a biomarker that was added to the baits in target and nontarget animals (e.g., Guthery and Meinzer 1984, Olson et al. 2000). The identification of tracks yields only limited information in areas with high numbers of different animal species (e.g., Wolf et al. 2003). Baiting studies based on the use of biomarkers are very labor intensive and require large sample sizes of target and nontarget animals. In contrast, the evaluation of bait uptake using camera traps is a non-invasive control method that yields detailed data regarding bait competition between different species under different conditions.

Our objectives were to (1) quantify bait acceptance by urban foxes, (2) investigate bait competition by other urban species, (3) determine factors affecting bait uptake by urban foxes, and (4) document loss of bait mass for nonremoved baits.

## METHODS

### Study Area

We conducted our study in Zurich, the largest city in Switzerland, with about 1 million inhabitants. The actual community of Zurich has 362,000 inhabitants and covers 92 km$^2$, consisting of 53% urban area, 24% forest, 17% agricultural area, and 6% water (Statistical Department of the City of Zurich 2000). The experiments were carried out in the developed areas of Zurich including private gardens, allotments, industrial areas, and cemeteries.

### Urban Wildlife

Foxes have reached a high density in the urban area of Zurich with >10 adults/km$^2$ (Gloor 2002). They are mainly organized in family groups of >2 adults. Home ranges generally are small (100% minimal convex polygon of mean seasonal home-range size: females 28.8 ± 22.7 ha [SD], males 30.8 ± 11.0 ha) with a large overlap among members of a family group (Gloor 2002).

Nontarget species that potentially compete for baits, including hedgehogs, domestic cats, and dogs, exceed the population density of foxes (Table 1). Zurich has few stray cats and dogs (S. Gloor, unpublished data), and people usually walk their dogs on leashes.

### Baits

We used commercially available baits (fuchs–Köder® and Lock-Köder für Füchse, Impfstoffwerk Dessau Tornau GmbH, Rosslau, Germany) weighing 13.5 g with a matrix consisting of a mixture of fat and animal meal comparable to the matrix of the widely used rabies vaccine bait Rabifox® (Impfstoffwerk Dessau Tornau GmbH, Rosslau, Germany). One type of bait (fuchs–Köder®) in addition contained 50 mg of

Table 1. Estimated number of animals, number of animals found dead, and number of animals shot per year in Zurich (92 km$^2$), Switzerland, during 1992, 1999, and 2000.

| Species | Year | No. animals | No. dead | No. shot |
|---|---|---|---|---|
| Red fox | 1999 | 600–1,000[a] | 127[b] | 100[b] |
| Domestic cat | 2000 | 20,000[c] | NI[d] | NI |
| Domestic dog | 1999 | 6,500[e] | NI | NI |
| Hedgehog | 1992 | 2,300–4,700[f] | NI | NI |
| Stone marten | 1999 | NI | 11[b] | 17[b] |
| Badger | 1999 | 140[b] | 9[b] | 0[b] |
| Carrion crow | 1999 | NI | NI | 287[b] |

[a] Estimation according to Gloor (2002).
[b] Game sanctuary report of the city of Zurich 1999/2000 (Waldamt der Stadt Zürich 2000).
[c] Estimated by a Swiss pet food producer (EFFEMS, U. Müller, personal communication).
[d] No information available.
[e] Dog tax of Zurich (data 2000).
[f] Report of Department for Public Areas of the City of Zurich (Bontadina et al. 1993*a*).

praziquantel (Droncit® Bayer AG, Leverkusen, Germany).

## Camera Traps

Camera traps were built by the Theodor Kocher Institute (University of Bern) and consisted of a compact camera (BRAUN Trend DX AF 3 and AF-C, 35mm, auto-focus), 2 passive-infrared motion sensors, and an electronic control, all mounted in a solid waterproof plastic box. Camera traps recorded the date and time of each exposure. The camera system was programmed (PBASIC interpreter and A BASIC-Stamp; Parallax, Inc., Rocklin, California, USA) to be dependent on the activation of the motion sensors and an external trigger device and the implemented clock.

We placed each bait about 3 m from the camera trap. Baits were linked with a 10-cm, loosely fixed plastic band with the camera trigger device, which released the camera independently from the motion sensor. We attached a small piece of reflector foil to the plastic band and were therefore able to assess the bait presence on each picture (Fig. 1). The program for the camera traps permitted the following picture types:

(1) *Removal Photo.*—Bait removal closed an electric circuit and triggered the camera trap 3 times at 8-sec intervals. To ensure the identification of the bait consumer, 3 additional pictures were taken if the movement sensors were activated. We defined the first picture that identified the bait consumer as the "removal photo" (Fig. 1). The other pictures were excluded from analyses.

(2) *Movement Photo.*—The activation of both movement sensors triggered the camera trap. We defined the resulting pictures as "movement photos." After 1 movement photo, the camera was blocked for 15 min from taking further movement photos (but not removal photos). The number of movement photos was limited to 8 pictures/24 hr to save footage (Fig. 1).

(3) *Opportunity Photo.*—For every picture, we assessed whether the photographed animal had access to the bait or if bait already had been removed. Accordingly, we classified all movement photos taken before the bait was removed and all removal photos as opportunity photos.

We defined bait acceptance as the number of removed baits divided by the number of opportunity photos expressed in percentages.

## Experimental Design

We selected 24 different sites in the urban area (private gardens, allotments, industrial areas, cemeteries) and installed 2 camera traps 10–20 m apart at each site. We placed a bait containing praziquantel in front of 1 camera and a bait without praziquantel in front of the other to assess the influence of praziquantel on the attractiveness of the baits (variable = type of bait). Because prebaiting can improve bait acceptance of some species (e.g., Tietjen and Matschke 1982, Sugihara et al.

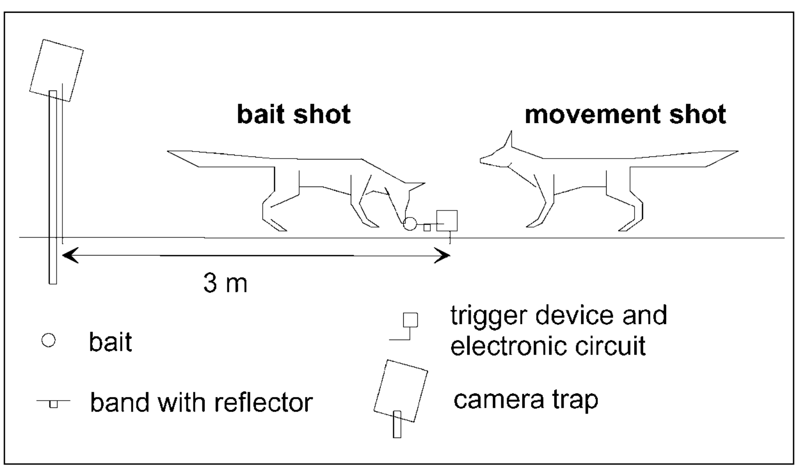


Fig. 1. Arrangement of camera trap, trigger device, and bait (bold: type of picture) in Zurich, Switzerland, 1999–2000.

1995), new baits were placed at all baiting sites after 3 and 6 days (variable = bait number). We removed traps after 9 days. Every time a bait was replaced, we changed the method of placement: 2 baits were placed openly exposed, 2 baits were covered with surrounding material, and 2 baits were slightly buried in the soil (variable = method of placing). The 6 possible sequences of the 3 methods of placement were randomly allocated to the different sites of each location type (fox den, compost heap, fox track). Paired baits at 1 site (i.e., with/without praziquantel) were always placed with the same placement method. Following this scheme of bait distribution, we placed 6 baits at each site within 1 9-day period (2 bait types [with/without praziquantel] × 3 methods of placing [openly exposed, covered, buried]).

The 24 different baiting sites comprised 12 fox dens with cubs, 6 compost heaps, and 6 fox tracks. We placed the baits at 6 of the 12 fox dens during early summer (6 Jun–30 Jul; 6 × 6 baits) and at the remaining 18 baiting sites during summer 1999 (20 Jul–27 Aug), winter 2000 (25 Jan–3 Mar), and summer 2000 (2 Jul–27 Aug; 18 × 6 baits during each period). To evaluate a possible influence of the camera traps on bait uptake rates, the baits delivered during summer 2000 were placed without camera traps and the disappearance rate was compared with the data from summer 1999.

We used the data from summer 1999 and winter 2000 to investigate the effect of the independent factors "location type," "season," "type of bait," "bait number," and "method of placing" on bait uptake of foxes. Additionally, we analyzed whether burying the baits reduces bait uptake by animals other than red foxes. To investigate differences of bait removal at fox dens during the breeding season, we compared bait uptake at the 6 fox dens from early summer 1999 and the 6 fox dens from summer 1999.

### Statistical Analyses

We performed statistical analyses with SPSS-PC (Norusis 2000). To avoid pseudoreplication, the experimental unit for statistical analyses was not the data collected for a single bait, but the data collected at 1 site for the 6 baits delivered within 9 days. Correspondingly, removal rate of baits was calculated for every statistical unit separately. Furthermore, at each baiting site, we calculated the mean loss of mass for baits not removed within 9 days.

We investigated differences between unpaired data by Mann-Whitney *U*-tests to compare 2 categories and Kruskal-Wallis tests to compare >2 categories (dependent variable: removal of 0, 1, 2, 3, 4, 5, or 6 baits). We analyzed differences between paired data with Wilcoxon tests to compare 2 categories (dependent variable: removal of 0, 1, 2, or 3 baits) and Friedman tests to compare >2 categories (dependent variable: removal of 0, 1, or 2 baits). Critical significance levels were Bonferroni corrected according to Rice (1989), taking into account multiple tests on the same dataset.

## RESULTS

### Bait Acceptance

We observed 252 baits with camera traps for 3 days and nights and collected 1,376 pictures. The main activity at the baiting sites was by cats, foxes, and various birds (Table 2). Ninety-one baits (36.1%) disappeared within 3 days, and about half of these were removed by foxes (Table 2). The other baits were consumed by hedgehogs, dogs, mice, and snails. We were unable to identify species for 9 baits removed. Because 7 of these baits were removed without the trigger device, we treated these baits as being removed by species other than fox for further analyses.

In 278 pictures of birds, including blackbirds (*Turdus merula*, $n = 251$), domestic chickens (*Gallus gallus*, $n = 17$), 1 carrion crow (*Corvus corone*), and various songbirds ($n = 9$), no picture showed a bird manipulating the bait or observing it from a close distance. Cats, stone martens, and badgers (*Taxidea taxus*) often sniffed at the baits, though these species never removed any bait.

Bait acceptance (no. of removed baits/no. of opportunity photos) by dogs (17.4%) was the same as by foxes (17.1%; Mann-Whitney *U*-test: $Z = -0.44$, $P > 0.1$). Bait acceptance by hedgehogs (37.0%) was significantly higher than by foxes (17.1%; Mann-Whitney *U*-test: $Z = -2.3$, $P = 0.022$).

### Factors Affecting Bait Uptake

Bait uptake by foxes during summer 1999 and winter 2000 did not differ significantly among fox dens (4.2 ± 1.8% [SE]), compost heaps (22.2 ± 9.4%), and fox tracks (8.3 ± 4.3%; Kruskal-Wallis: $n = 18$ baiting sites, $\chi^2 = 3.2$, df = 2, $P = 0.201$). However foxes removed significantly more baits in summer (18.5% ± 6.3%) than in winter (4.6 ± 2.6%; Wilcoxon test: $n = 18$ bait sites, $Z = -2.3$, $P = 0.022$). The factors "type of bait," "bait number," and "method of placing" had no significant effect on bait removal by foxes. Other species removed significantly less buried baits (6.9 ± 3.4%) than covered (22.2 ± 5.3%) and exposed baits (29.2 ± 7.4%; Friedman test: $n =$

Table 2. Number of movement photos, opportunity photos, removed baits (no. of removal photos, no. of removed baits with evidence for a certain species, and percentage of removed baits), and derived bait acceptance in Zurich, Switzerland, 1999–2000.

| | | | Removed baits[a] | | | | |
|---|---|---|---|---|---|---|---|
| Species | Movement photos | Opportunity photos | Removal photos | Evidence | Total | % Total | Bait acceptance (%) |
| Fox | 373 | 258 | 44 | 0 | 44 | 48.4 | 17.1 |
| Domestic cat | 525 | 431 | 0 | 0 | 0 | 0.0 | 0.0 |
| Domestic dog | 71 | 46 | 8 | 0 | 8 | 8.8 | 17.4 |
| Hedgehog | 79 | 46 | 14 | 3[b] | 17 | 18.7 | 37.0 |
| Stone marten | 32 | 27 | 0 | 0 | 0 | 0.0 | 0.0 |
| Badger | 18 | 12 | 0 | 0 | 0 | 0.0 | 0.0 |
| Birds | 278 | 278 | 0 | 0 | 0 | 0.0 | 0.0 |
| Snail | NR[c] | NR | NR | 9[d] | 9 | 9.9 | NR |
| Rodent | NR | NR | NR | 4[e] | 4 | 4.4 | NR |
| Not identified | NR | NR | 2 | 7 | 9 | 9.9 | NR |
| Total | 1376 | 1098 | 68 | 23 | 91 | 100.0 | NR |

[a] 23 baits disappeared although the trigger was not removed. Species were identified according to movement photos and traces.
[b] Several opportunity photos of hedgehogs with contact to the bait.
[c] Not recorded.
[d] A lot of snail mucus and no indication of other species.
[e] Several opportunity photos with rodents just near the bait.

18 bait sites, $\chi^2 = 13.5$, df = 2, $P < 0.01$; Fig. 2). In addition, baits at the 6 fox dens in early summer were removed more frequently by foxes (52.8 ± 15.8%) than baits at the 6 fox dens in summer (5.5 ± 3.5%; Mann-Whitney *U*-test: $n = 12$ bait sites, $Z = -2.2$, $P = 0.026$). Hedgehogs and snails consumed baits only during early summer and summer and not during winter.

## Baits not Removed

Of the 252 baits monitored with camera traps, 162 baits (64.3%) remained after 3 days. Many of these baits showed a reduction in mass. Usually snails and occasionally other invertebrates (e.g., ants, isopods) were found directly on the baits and/or mucus of snails and signs of rodent teeth were visible. This indicated that the loss of mass mainly can be attributed to snails and rodents.

We recorded remaining baits at 16 baiting sites during summer 1999 as well as during 2000 winter. The mean mass reduction of these baits was significantly more pronounced during summer (18.7 ± 4.4% [SE]) than during winter (2.4 ± 1.1%; Wilcoxon test: $n = 16$ baiting sites, $Z = -3.0$, $P < 0.01$). Burying the baits reduced bait consumption by small animals, such as rodents and snails, compared to covered and exposed baits (Friedman-test: $\chi^2 = 8.7$, $P = 0.013$). This effect was most pronounced in summer when the mean loss of bait mass was 6.4 ± 3.1% for the buried baits, 25.0 ± 7.1% for the covered and 46.0 ± 8.9% for the exposed baits.

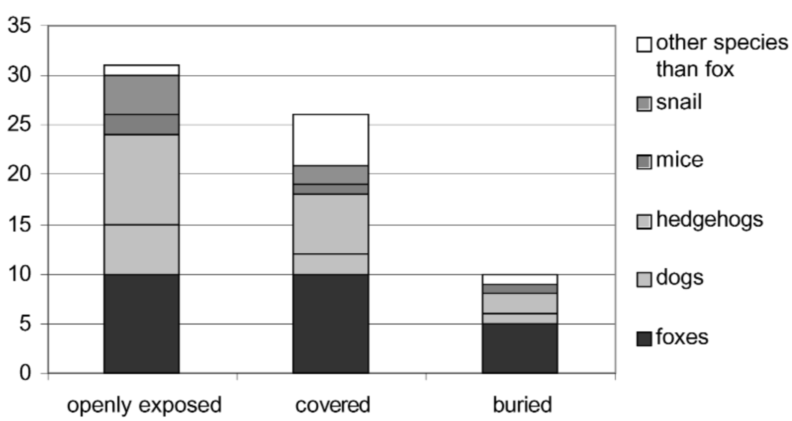


Fig. 2. Number of exposed, covered, and buried baits that were removed by different species in Zurich, Switzerland, 1999–2000. Number of delivered baits during summer 1999 and winter 2000: openly exposed, $n = 72$; covered, $n = 72$; buried, $n = 72$. Species determination was not achieved for all removed baits. Viewing the movement photos and looking at evidence at the baiting site we assigned these baits to the category "removed by other species than fox."

## Effect of Camera Traps

Overall removal rate of baits was 46.2 ± 6.9% (SE) at sites with camera systems and 75.0 ± 5.9% at sites without cameras, which is significantly different (Wilcoxon test: $n = 18$ baiting sites, $Z = -2.7$, $P < 0.01$). This different removal rate was observed at fox dens (removal rate with camera trap: 38.9 ± 14.7%; without camera trap: 83.3 ± 10.5%) and at fox tracks (with camera trap: 38.9 ± 9.4%; without camera trap: 77.8 ± 10.2%). At compost heaps, the bait removal rate with camera traps (61.1 ± 11.1%) was similar to the removal rate without camera traps (63.9 ± 10.0%).

## DISCUSSION

### Evaluation of Camera Traps

In contrast to Gürtler and Zimen (1982), our data suggests that the installation of camera traps lowered the bait removal rate (46% with camera traps, 75% without camera traps). This difference could also be explained by simple annual variations. However, an ongoing study on the effect of distributing praziquantel-containing baits gives further evidence that bait removal generally is lowered by the presence of a camera trap (D. Hegglin, unpublished data). Harris and Knowlton (2001) demonstrated that coyotes (*Canis latrans*) visited scent stations more frequently in familiar than in unfamiliar environments. Such site-specific avoidance behavior could explain the lower bait removal rates in the presence of a camera trap at fox dens and tracks, which are familiar sites for foxes, but not at compost heaps.

We assume that the lower removal rate at baiting sites with camera traps was caused mainly by reduced bait acceptance of foxes, known to be very suspicious animals compared to the other species living in the city. Consequently, our results can be interpreted as minimal bait removal rates by foxes.

### Bait Uptake by Different Species

Our study found foxes to be the main bait consumers. The most important competitors for baits in urban habitat were dogs and, surprisingly, rodents, snails, and hedgehogs. In rural areas of Italy, Belgium, Luxembourg, and Germany, the removal rate of similar types of baits was considerably lower than in our control experiment (baits without camera traps) and ranged between 18 and 42% (Linhart et al. 1997). Hedgehogs reach considerably higher population densities in urban compared to rural areas (Bontadina et al. 1993*b*, Zingg 1994). This or the high density of urban foxes (Gloor et al. 2001) could explain the high bait disappearance rate found in our study. The substantial loss of bait mass caused by rodents and snails during the summer highlights the importance that foxes find unburied baits within 1 or 2 days.

Domestic cats can be major competitors for rabies baits (Roscoe et al. 1998). In Brooklyn, New York, USA, Calhoon and Haspel (1989) recorded densities of free-ranging domestic cats of up to 4.9 individuals/ha, which was >10 times the population density for urban foxes (Harris and Rayner 1986, Baker et al. 2000). The large number of movement photos of domestic cats indicates the high abundance of free-ranging cats in the city of Zurich, though they never removed baits. This indicates the significance of utilizing baits that are not attractive to bait competitors.

Based on the interest in the baits that martens and badgers exhibited, these species may also occasionally accept baits. Nevertheless, these 2 species were photographed much less frequently than foxes (Table 2), and they are unlikely to be strong bait competitors due to their low relative population densities (Table 1).

Regardless of the high number of different bait competitors in urban environment, a follow-up study has demonstrated that urban foxes can effectively be baited. In the city of Zurich, the frequency of *E. multilocularis* eggs was significantly lower in fox feces recovered from praziquantel-baited areas compared to control areas (Hegglin et al. 2003).

## MANAGEMENT IMPLICATIONS

Our results indicate that urban foxes accepted the delivered baits and that most baits were consumed by this species. However, hedgehogs, dogs, snails, and rodents were important competitors for baits. For an efficient and selective baiting strategy for urban foxes, we provide the following recommendations:

(1) Baits should be slightly buried to increase the proportion consumed by red foxes.

(2) Bait distribution during winter prevents bait uptake by hedgehogs and snails.

(3) Baiting places should be selected where domestic dogs have no or restricted access.

(4) Selecting particular location types and baiting periods (e.g., fox dens during early summer) can increase the uptake rate of baits.

(5) A short pre-baiting period does not increase the uptake of baits by foxes.

(6) Praziquantel does not impair the uptake of baits by foxes. Hence, a combination of a rabies vaccine and praziquantel in 1 bait should not lower the efficiency of an oral vaccination campaign against rabies.

Many baits will not be consumed by foxes. In urban areas, for safety reasons, managers would therefore be advised to tag the sites where the rabies vaccination baits are placed and collect baits that do not disappear within a few days. Baits containing only praziquantel represent no risk for urban inhabitants, free-ranging pets, or urban wildlife (Sweet 1987), and the effort to bury them is unnecessary.

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