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Fox bait consumption and camera trapping in agricultural areas in eastern Hokkaido, Japan

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The red fox (*Vulpus vulpus*) is found throughout much of the northern hemisphere and most of Australia and has a broad range of habitats, from deserts to arctic tundra (e.g., Saunders et al. 1995). In Japan, this animal is common in Hokkaido, Honshu, Shikoku, and Kyushu islands (e.g., Uruguchi 2009). On Hokkaido Island (Fig. 1), red foxes transmit the dangerous zoonotic disease, alveolar echinococcosis, caused by the metacestode stage of *Echinococcus multilocularis* (e.g., Yamashita and Kamiya 1997; Hokkaido Institute of Public Health 2011). This disease is widespread in the northern hemisphere (Eckert et al. 2001; Soulsbury et al. 2010). Red foxes are the principal definitive hosts in the natural environments and the main infection source for humans. In recent years, the infection rate among red foxes in Hokkaido is around 40% (Takahashi et al. 2005; Nonaka et al. 2006). Therefore, it is important to evaluate the intervention strategies, especially as the administration of anthelmintics to red foxes in Hokkaido.

Baiting foxes with the anthelmintic praziquantel successfully reduced *E. multilocularis* prevalence in red foxes in Germany and Switzerland (Schelling et al. 1997; Tachmann et al. 2001; Hegglin et al. 2003; Romig et al. 2007). In Hokkaido, small scale trials of baiting foxes with praziquantel were carried out in Koshimizu (Tsukada et al. 2002), Nemuro (Takahashi et al. 2002), Otaru (Nonaka et al. 2006) and Kutchan (Hokkaido Government 2007). Tsukada (2005) suggested that red foxes might prefer natural foods to artificial foods, as long as they can obtain natural foods from their environment. The red fox diet varies seasonally and regionally, including small mammals, birds, insects, fruits and carcasses of large mammals (Yoneda 2005; Uruguchi 2008, 2009). To establish an effective baiting method, it is important to identify seasonal differences in bait consumption by red foxes and other animals. The Tokachi District of Hokkaido is representative of Japan's agricultural areas.

As red foxes frequently appear in agricultural areas, it is important to provide them with fox bait containing the anthelmintic praziquantel. In agricultural area, many other animals such as domestic dogs, domestic cats, weasels and crows may also consume the bait. When other animals frequently consume the bait, it becomes difficult to evaluate its effect. For more effective baiting, it is important to identify the animals using the fox baits. Since the environment of agricultural areas changes due to harvesting and planting activities, it would be needed to evaluate the fox bait's seasonal effectiveness. We used automatic digital cameras with infrared sensors to obtain this fundamental information on fox bait consumption by animals in an agricultural area. We examined seasonal differences in numbers of animals (including red foxes) occurring at baiting sites in the Tokachi District and seasonal differences in bait disappearance by red foxes and other animals.

Methods

Study area and site

This study was conducted in the agricultural areas of Kawanishi, Obihiro City, Tokachi District in eastern Hokkaido, Japan (43°84'97.09"N, 143°16'55.93"E, see Fig. 1). Average temperature and precipitation are 6.5°C and 920.4 mm, respectively (Japan Meteorological Agency, <http://www.jma.go.jp/jma/menu/report.html>). We selected Kawanishi as the study area because 46 red foxes were actually captured as pests in 2009 (Obihiro City Government, personal communication).

Baiting and camera trapping

In the study area, a transect line for about an 8-km along a road was established, following the methods of the previous baiting activities (Hokkaido Government 2007). Along this line transect, 10 baiting sites were

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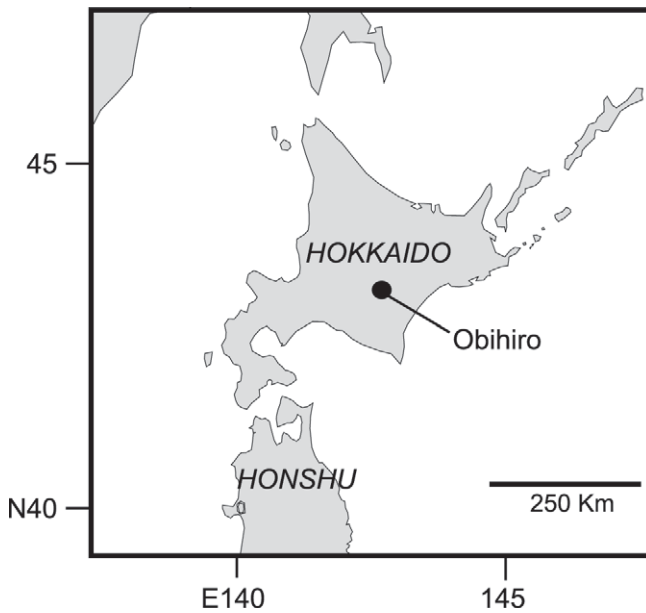


Fig. 1. Locality in Hokkaido, Japan, where red foxes are baited in the present study.

established at 500–1,000 m intervals.

We used fox baits designed for red foxes (Takahashi et al. 2010): 15 g (44 mm × 44 mm × 15 mm) pellets made of palm oil, vegetable fats and oils and fish meal. Since our purpose was not to treat foxes for *E. multilocularis*, we did not add anthelmintic praziquantel to the bait. Five pellets were put on a wooden board (450 mm × 300 mm × 2.5 mm). One board was placed on ground at each baiting site. One automatic digital camera with infrared sensor (FieldnoteDS6010, Marifu Co. Ltd.) was set about 3 m apart from each board. Automatic cameras were fixed on tree trunks or stakes at 150–170 cm in height. From May to October 2010, baits and cameras were set in each baiting site for seven days each month. Due to heavy snow, we did not test during winter (November–April). To maintain experimental condition, we replaced pellets with fresh every day, using a total 350 pellets each month. When we replaced new pellets, the number of disappeared pellets was also recorded.

Data analyses

We recorded all animal species photographed by the camera traps. Since it was difficult to identify each individual, we counted the total number of photographs made by each camera traps, but not number of individuals. We did not count any photograph made within 5 min of a previous photograph, unless it was of a different

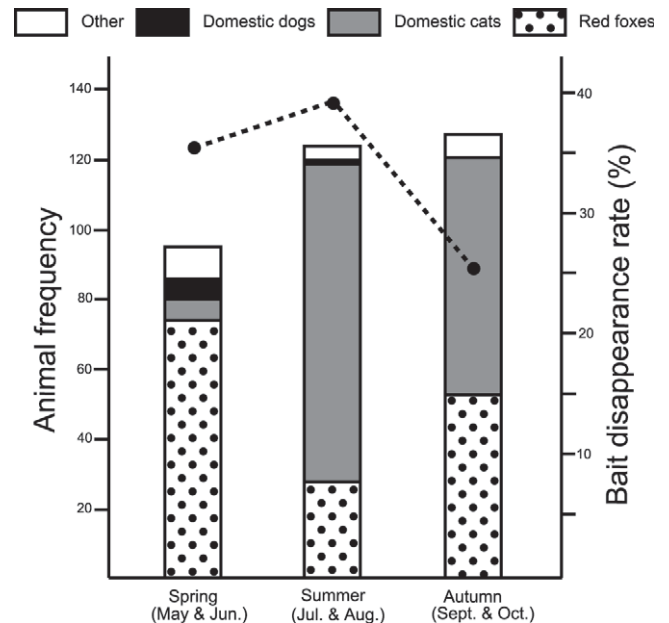


Fig. 2. Seasonal change in animals photographed by camera-traps from May to October 2010 in Kawanishi, Obihiro City, Tokachi District, Hokkaido, Japan. Dotted line is seasonal change in bait disappearance rate.

species. We compared captured number of photographs among animal species among seasons: spring (May and June), summer (July and August), and autumn (September and October) with a χ^2 test. A value of $P < 0.01$ was considered statistically significant. Disappearance rates of pellets were calculated for each season.

Results

Our automatic cameras took 155 photos of foxes, 164 photos of domestic cats, 7 photos of domestic dogs, 3 photos of weasels (*Mustela* spp.), 2 photos of Eurasian red squirrels (*Sciurus vulgaris*), 2 photos of Siberian chipmunks (*Tamias sibiricus*), 3 photos of murids, 8 photos of crows (*Corvus* spp.), 1 photo of a Japanese tit (*Parus minor*), and 1 photo of an Eastern turtle dove (*Streptopelia orientalis*). Based on these results, we categorized animals into four groups: foxes, domestic cats, domestic dogs, and others. Red foxes were photographed at 9 baiting sites, although its frequency varied seasonally. Proportions of animal species photographed by camera traps were significantly different between spring and summer ($\chi^2 = 98.61$, $df = 3$, $P < 0.001$) and between summer and autumn ($\chi^2 = 50.96$, $df = 3$, $P < 0.001$) (Fig. 2). In spring, 77.9% of photographs were

of red foxes. In summer, domestic cats were most frequently photographed (73.4%) and the proportion of red fox photographs markedly decreased (22.6%). In autumn, proportions of red fox and domestic cat photographs were 41.7% and 52.8%, respectively. Domestic dogs were photographed only in spring and summer at low frequencies (6.3% and 0.8%, respectively). Domestic cats, domestic dogs, and others were photographed at 10, 2, and 7 baiting sites, respectively. Red foxes and domestic cats were photographed at nine sites, but only two sites photographed both red foxes and domestic cats.

The total fox bait disappearance rate was 33%. Fox bait disappearance rates for each bait site ranged from 11% to 76%. Seasonal disappearance rates were 36% in spring, 38% in summer, and 26% in autumn (Fig. 2).

Discussion

Our camera traps photographed red foxes at the baiting sites. Also, fox baits disappeared at the baiting sites (Fig. 2). Therefore, delivery of bait containing the anthelmintic praziquantel may be effective for reducing *E. multilocularis* prevalence in the red fox population in this agricultural area. Our camera traps also photographed domestic cats and dogs. This means that these domestic animals and red foxes have overlapping ranges. Domestic dogs and cats are also definitive hosts of *E. multilocularis*, although infected domestic cats rarely shed the eggs (e.g., Uruguchi 2008). When infected with *E. multilocularis*, domestic dogs could be a serious source of infection.

Red foxes most frequently occurred at the baiting sites in the spring (Fig. 2). Tsukada et al. (2002) reported that red foxes in Koshimizu, eastern Hokkaido more frequently ate bait (fish sausage) in the spring rather than in summer. In spring, after the snow melts, red foxes may not be able to obtain many natural foods, such as insects and fruits. They may lead them to use bait instead of natural foods.

In the sub-urban areas of Sapporo, domestic cats were rarely photographed by automatic cameras, showing that they do not consume fox bait made of fish meal (Takahashi et al. 2003, 2010). Hegglin et al. (2004) reported that domestic cats in Switzerland did not consume fox bait. The bait used by Takahashi et al. (2003, 2010) and Hegglin et al. (2004) is essentially same as that used in our study, however, during the summer, our cameras frequently photographed domestic cats and the baits also disappeared at the baiting sites (Fig. 2).

If domestic animals did consume the bait, there would have been little left for red foxes to eat. To avoid competition for fox bait by domestic animals and red foxes, it is important to consider the presence of domestic cats and dogs in areas with red foxes. Our camera traps also photographed murids, weasels, squirrels, and birds. We found rodents tooth marks on some pellets. Murids and squirrels may have been attracted to the bait. As their numbers were few, it would not be necessary to consider their effect on baiting the red foxes.

Although the highest fox bait disappearance rate was in summer (Fig. 1), we were not able to determine which animals photographed by automatic cameras actually ate the bait. The disappearance rates did not always indicate directly that the animal had consumed the pellet. For instance, Abe (1971) and Kondo and Shiraki (2012) reported that the red fox does not prefer *Sorex* species, i.e., red foxes removed the dead body of *Sorex*, but did not eat it. Because of prey selection by carnivores, it was difficult to connect disappearance with consumption by any animals in this study. Some fox baits may have been removed but not eaten by the carnivores. Automatic camera data and bait disappearance rates (Fig. 2), however, may indirectly indicate that red foxes most frequently used the bait in spring and domestic cats most frequently used the bait in summer.

Fox bait consumption by animals such as red foxes and domestic cats may vary with season. To maintain the effects of anthelmintic praziquantel, it is important to consider way to provide bait to foxes in different seasons. To ensure ongoing treatment of red foxes in all seasons, we should consider ways to deliver the bait and other types of bait, especially bait palatable to red foxes, but unpalatable to domestic cats. In the present study, we did not consider environmental factors of baiting sites, such as vegetation and distances from rivers, buildings, and roads. Further studies should identify the most suitable micro-habitats for delivering bait.

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