Den site selection and utilization by the red fox in Hokkaido, Japan

Kohji URAGUCHI¹ and Kenichi TAKAHASHI²

Hokkaido Institute of Public Health, Sapporo 060-0819, Japan
Fax. +81-11-736-9476, e-mail. ura@iph.pref.hokkaido.jp, e-mail. takaken@iph.pref.hokkaido.jp

Abstract. Den site selection and den use by the red fox, Vulpes vulpes, were studied on the Nemuro Peninsula, eastern Hokkaido, Japan. Certain physical variables of 144 fox den sites were compared with those of 236 randomly selected control locations. The red foxes on the Nemuro Peninsula clearly preferred to den on slopes in woodlands near open spaces and streams. The seasonal pattern of den utilization was studied from June 1986 to May 1987. Red foxes used dens mainly during the period from January to June. Since this period coincides with the gestation, parturition and cub rearing periods of the red fox, it was confirmed that the red fox’s den was fundamentally a breeding site. Almost all dens were observed each spring from 1986 to 1996 to establish whether they were used for breeding or not, and it was found that the number of fox families was stable during this decade.

Key words: den, Hokkaido, red fox, habitat selection, Vulpes vulpes.

Habitat selection is a reflection of a species’ environmental, ecological and physiological requirements. For the red fox, Vulpes vulpes, den sites are very important because the cubs are born there and because they are reared there while still juveniles. Therefore, foxes might be expected to exercise some preference when choosing locations for their dens. Although many studies have described fox den characteristics in different habitats (e.g., Scott and Selko 1939, Storm et al. 1976, Roman 1984, Zhou et al. 1995), there have been few quantitative studies on den site selection by red foxes (Nakazono and Ono 1987, Meia and Weber 1992).

Information on den site preferences, and on the number of breeding dens being used in a given area, are useful for understanding both the habitat evaluation being made by red foxes for reproduction, and any trends in their population dynamics. Furthermore, such an understanding is helpful in the development of control measures against zoonoses transmitted by red foxes.

In this study, we describe the habitat factors associated with dens that we detected by comparing certain variables from den sites with those of control sites, and we also describe the utilization pattern of fox dens in Hokkaido, Japan.
STUDY AREA

The study area (73.0 km²) is located in the central part of the Nemuro Peninsula in eastern Hokkaido. The area is composed of low rolling hills with about twenty streams in small eroded valleys with steep slopes. The highest point was only 55 m above sea level. The study area consisted of a mosaic of pastures (43.6%), grasslands (24.7%), woodlands (20.7%) and residential areas (11.0%). The pastures consisted largely of *Phleum pratense* which was cultivated for pasturage and hay-making. The grasslands were dominated by *Sasa nipponica*, Gramineae spp. and *Artemisia montana*. The woodlands were principally located along the banks of streams and were dominated by broad-leaved deciduous trees such as *Quercus nipponica*, *Alnus hirsuta* and *Betula ermanii*. There were also small woodlots of *Abies sachalinensis*. The climate of this area is cool: the mean February temperature is −5.3°C and the mean August temperature is 17.1°C. It usually snows from late December to March, and the average yearly precipitation is 1,035 mm (National Astronomical Observatory 1996). The human population of this area was about 30,000, 95% of whom lived in two residential areas. There were some fishing ports along the sea coast, and 54 dairy farms were scattered through the area.

METHODS

The field work for this study was conducted from 1986 to 1996, however forty-eight fox dens had already been located before the main field study began as a result of questioning farmers and from field inspections made during 1984 and 1985 (Kondo pers. comm.). Since this preliminary information suggested that there were few dens in pastures, we searched for fox dens in grasslands and woodlands mainly during May and June 1986. Because most of the woodlands in this area were located along streams, almost all stream banks were inspected. Stream banks were usually surveyed by one observer traversing upstream along one bank and downstream along the other. In open areas, such as grassland slopes, binoculars were also used.

Most dens observed in Hokkaido consist of tunnels with a diameter of some 20 cm excavated by the foxes themselves. Although rabbits, *Oryctolagus cuniculus*, and badgers, *Meles meles*, dig tunnels in this size range elsewhere, hence leading to some difficulties of identification (Cowan 1991, Roper 1992), neither rabbits nor badgers are found in Hokkaido. Raccoon dogs, *Nyctereutes procyonoides*, possibly use such tunnels as their dens, but few individuals occur in this study area (Kondo pers. comm.). Therefore, we regarded all excavated tunnels with a diameter of circa 20 cm as fox dens.

All dens were marked on a 1: 50,000 map, and numbered in the order that they were found. At each site, we measured a series of variables which were considered likely to be associated with dens, as in previous studies (Zhou et al. 1995, Scott and Selko 1939, Roman 1984, Nakazono and Ono 1987, Meia and
Weber 1992). These variables included: 1) habitat type within 10 m of the primary entrance, 2) the number of entrances, 3) eight grade directions of the slope of the primary entrance, 4) the angle of the slope on which the primary entrance was located, 5) the distance to the nearest open space (non-wooded area which was more than 10 m in diameter), 6) the distance to the nearest source of water, 7) the distance to the nearest dwelling house, and 8) the distance to the nearest road.

The occurrence of red fox dens within habitats versus the relative availability of habitats, determined from vegetation maps was tested using the G-test for goodness of fit (Sokal and Rohlf 1981). On the Nemuro Peninsula, even if foxes were to excavate dens in pastures, they would soon be destroyed, because the pastures are harvested by tractor every summer and autumn, and are plowed every three to five years. Two fox families that made their dens in residential areas during this study were immediately turned out or captured by city officers as pests. We, therefore, regarded pastures and residential areas as unsuitable habitat for denning by red foxes, and have excluded them from further discussion of den site selection by foxes on the Nemuro Peninsula.

To ascertain which habitat factors influenced den site selection by red foxes, variables from den sites were compared with control sites within grasslands and woodlands. Five hundred control locations were marked randomly on a 1 : 25,000 map; the 264 control sites that fell within pastures or residential areas were excluded from the analysis leaving 236 control sites within grasslands and woodlands. Distances to the nearest house and road were measured from maps, and the distance to the nearest open space was measured from aerial photographs. Because the direction and angle of a slope and the distance to the nearest source of water were difficult to measure from either maps or aerial photographs, 80 of the 236 control sites were chosen randomly and visited using a hand-held GPS receiver (GPS45, GARMIN INTERNATIONAL) and the variables of the sites were measured directly.

The habitat surrounding fox dens and habitat availability were compared using a $4 \times 2$ G-test of fitness. The mean values of the angle of the den slope and four kinds of distances for both den sites and control locations were compared using the two-tailed Mann-Whitney U-test. The frequencies of eight grade directions of the slope in the two samples were compared using an $8 \times 2$ G-test of independence (Sokal and Rohlf 1981). Repeating individual statistical tests increased the chance of type I errors. To compensate for this, we took the standard probability of $p \leq 0.05$ and divided it by the total number of tests ($n = 6$) looking for differences in physical variables between den sites and control locations (Ortega 1987). Consequently, the conservative significance level ($p \leq 0.008$) was used.

Dens were defined as either a) unoccupied, b) occupied but without cubs, or c) occupied with cubs (breeding dens) based on the presence of signs found during monthly visits from June 1986 to May 1987. The distinction between dens with or without cubs was based either on the direct observation of cubs, or on the presence of absence of conspicuous marks indicating their presence,
i.e., polishing of excavated soil by cubs moving in the out of the den, fecal remains, and signs of play such as flatten grasses.

From 1988 to 1996, dens were usually observed just once a year in spring in order to check the breeding status of the fox population. As the peak of fox parturition occurs from late March to late April in Hokkaido (Abe 1974), and because juveniles usually begin to emerge from the dens when about six weeks old, that is during May (Lloyd 1980), we mainly observed dens during the latter half of May.

Red foxes are susceptible to even slight disturbance, and often move their juveniles from one den to another (Sargeant 1975, Storm et al. 1976, Lloyd 1980, Stubbe 1980, Nakazono and Ono 1987) making it difficult, therefore, to distinguish between natal dens and to which juveniles have been moved (rearing dens). In this paper, therefore, we have used the term "breeding den" to include both natal and rearing dens. Given the risk of disturbing the foxes and causing them to move by observing them, adjacent dens were always observed on the same day so as to avoid double-counting litters.

A single vixen and her cubs might use several breeding dens, hence the number of breeding dens used did not equate to the number of families. In this study, the minimum distance from a breeding den to an adjacent family was assumed to be 500 m because 12 out of 15 known den translocations involved movements of less than 500 m from the original den as indicated by radio-tracking and tag observation (Uraguchi unpublished). Dens within 500 m of each other were regarded, therefore, as belonging to one family, and all other dens were assigned to different families.

**RESULTS**

1. **Den site selection by red fox**

A total of 161 fox dens were found in the study area by May 1996. The defining variables of 144 of those dens were recorded (the remainder were either destroyed by man or collapsed naturally). One hundred and twenty-eight, out of the 144 dens (88.9%), consisted of tunnels excavated by the foxes themselves, while the remaining 16 dens were artificial (underfloors of abandoned houses or warehouses, and under concrete debris). One den was found in pasture land, although systematic searching was not conducted in this habitat.

Table 1. A comparison between the habitats of red fox den sites and habitat availability in a study area on the Nemuro Peninsula (n=140).

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Deciduous forest</th>
<th>Coniferous forest</th>
<th>Mixed forest</th>
<th>Grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent available</td>
<td>40.0</td>
<td>4.5</td>
<td>1.0</td>
<td>54.5</td>
</tr>
<tr>
<td>Observed number (%) of dens*</td>
<td>77 (55.0)</td>
<td>5 (3.6)</td>
<td>5 (3.6)</td>
<td>53 (37.9)</td>
</tr>
<tr>
<td>Expected number of dens</td>
<td>56.0</td>
<td>6.3</td>
<td>1.4</td>
<td>76.3</td>
</tr>
</tbody>
</table>

*Excepted four dens that were situated pastures or under the floors of houses. 

\[ G = 20.8, d.f. = 3, p < 0.005. \]
Table 2. Mean values (±SD) of physical variables of fox den sites and control sites within woodlands and grasslands on the Nemuro Peninsula.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Den sites</th>
<th>n</th>
<th>Control sites</th>
<th>n</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of slope (°)</td>
<td>32.5 (±15.2)</td>
<td>107</td>
<td>15.9 (±14.4)</td>
<td>80</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Nearest stream (m)**</td>
<td>85.6 (±134.9)</td>
<td>144</td>
<td>185.9 (±260.0)</td>
<td>80</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Nearest open space (m)**</td>
<td>18.7 (±20.7)</td>
<td>87</td>
<td>33.4 (±35.0)</td>
<td>85</td>
<td>0.0003*</td>
</tr>
<tr>
<td>Nearest house (m)</td>
<td>408.7 (±248.6)</td>
<td>144</td>
<td>366.3 (±271.8)</td>
<td>236</td>
<td>0.0251</td>
</tr>
<tr>
<td>Nearest road (m)</td>
<td>276.1 (±212.8)</td>
<td>144</td>
<td>283.8 (±217.5)</td>
<td>236</td>
<td>0.8517</td>
</tr>
</tbody>
</table>

*p ≤ 0.008
**Comparison between den site and control site within forests.

Red fox den sites were not distributed randomly according to habitat availability. Dens were found more often than expected in woodlands and less often than expected in grasslands (Table 1). Furthermore, dens within woodlands were located significantly closer to open spaces than were control locations within woodlands (p = 0.0003, Table 2). In our study area, most of the open spaces close to dens were grasslands. Fox dens were also located significantly closer to water sources (usually a stream), and on steeper slopes than the control sites. Den sites and control locations did not differ significantly in their distance from either the nearest house or the nearest road. The direction that slopes on which dens were located faced were recorded at 111 den sites and at 69 control locations. Dens occurred more frequently on slopes facing west and south-west and less often on slopes facing east or south-east than control locations, but this difference was not significant (G = 15.4, d.f. = 7, p = 0.03). The average number of entrances per den for 140 dens was 3.5 ± 3.6 (mean ± SD, range 1–36).

Five physical variables of 20 dens used for breeding more than five times during the 11 year study were compared with those of 21 dens that were never used for breeding during the same 11 years. There was surprisingly no significant difference between them (Table 3).

2. Seasonal patterns of den utilization

Although fox dens were utilized all year around, the proportion of dens utilized varies seasonally (Fig. 1). The percentage of dens utilized decreased during July, and remained low until December, then increased again during January, and remained high until June. Dens occupied by cubs were found from April onwards, but most of them were observed during May, June and July.

3. Annual change in the number of breeding dens

The numbers of breeding dens and the numbers of families (estimated by the use of the 500 m criterion) were calculated each year from 1987 to 1996, though not from 1986 because the sample size that year was too small (Table 4). The number of the breeding dens was 22–41 and the estimated number of families was 20–31. There were no significant differences between successive
Table 3. Mean values (± SD) of physical variables at dens used for breeding more than five times (n = 20) and dens never used for breeding (n = 21) during the 11 years from 1986 to 1996 on the Nemuro Peninsula.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Breeding dens</th>
<th>Non-breeding dens</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of slope* (°)</td>
<td>36.3 (±11.0)</td>
<td>29.6 (±15.4)</td>
<td>0.402</td>
</tr>
<tr>
<td>Nearest stream (m)</td>
<td>85.0 (±148.7)</td>
<td>114.9 (±178.0)</td>
<td>0.657</td>
</tr>
<tr>
<td>Nearest open space (m)</td>
<td>16.3 (±19.5)</td>
<td>15.5 (±23.5)</td>
<td>0.408</td>
</tr>
<tr>
<td>Nearest house (m)</td>
<td>406.3 (±175.3)</td>
<td>419.3 (±222.2)</td>
<td>0.927</td>
</tr>
<tr>
<td>Nearest road (m)</td>
<td>248.8 (±148.1)</td>
<td>238.9 (±185.9)</td>
<td>0.676</td>
</tr>
</tbody>
</table>

*For this variable only, the sample size for breeding dens was 19, and that for non-breeding dens was 18.

years in either the numbers of breeding dens used or the estimated number of families, however, the number of breeding dens fluctuated more than the estimated number of families, and their trends were not always consistent with each other.

Eighty-two dens were observed every year from 1986 to 1996. Of these 82, 61 (74.4%) were used for breeding at least once during the 11 year study. One den was used 11 times, three were used nine times each, and six were used eight times for breeding. These estimates are considered to be lower than actuality, because most dens were visited only once a year from 1988 onwards, thus breeding activity may have been missed.

Fig. 1. Monthly variation in the proportion of dens occupied during the period from June 1986 to May 1987. ■: dens with cubs, □: dens without cubs. The number below each column represents the number of dens observed.
Table 4. The number of breeding dens and estimated families. Expected numbers were calculated from the ratio of the average number of breeding dens and families to the average number of observed dens.

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of observed dens</th>
<th>No. of breeding dens</th>
<th>Expected no. of breeding dens</th>
<th>No. of families</th>
<th>Expected no. of families</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>106</td>
<td>27</td>
<td>28.9</td>
<td>20</td>
<td>21.8</td>
</tr>
<tr>
<td>1988</td>
<td>104</td>
<td>32</td>
<td>28.4</td>
<td>25</td>
<td>21.4</td>
</tr>
<tr>
<td>1989</td>
<td>113</td>
<td>36</td>
<td>30.9</td>
<td>22</td>
<td>23.2</td>
</tr>
<tr>
<td>1990</td>
<td>114</td>
<td>34</td>
<td>31.1</td>
<td>22</td>
<td>23.4</td>
</tr>
<tr>
<td>1991</td>
<td>114</td>
<td>29</td>
<td>31.1</td>
<td>22</td>
<td>23.4</td>
</tr>
<tr>
<td>1992</td>
<td>118</td>
<td>22</td>
<td>32.2</td>
<td>21</td>
<td>24.3</td>
</tr>
<tr>
<td>1993</td>
<td>117</td>
<td>41</td>
<td>31.9</td>
<td>29</td>
<td>24.1</td>
</tr>
<tr>
<td>1994</td>
<td>122</td>
<td>32</td>
<td>33.3</td>
<td>25</td>
<td>25.1</td>
</tr>
<tr>
<td>1995</td>
<td>133</td>
<td>27</td>
<td>36.3</td>
<td>24</td>
<td>27.3</td>
</tr>
<tr>
<td>1996</td>
<td>131</td>
<td>40</td>
<td>35.8</td>
<td>31</td>
<td>26.9</td>
</tr>
</tbody>
</table>

Average 117.2 32.0 (27.3%) 24.1 (20.6%)

\[ d.f. = 9 \]

\[ G = 10.8, \ p > 0.1 \]

\[ G = 3.4, \ p > 0.9 \]

**DISCUSSION**

Although red foxes are able to make their dens in various environments such as in woodlands, grasslands, plowed fields, pastures, dunes, among rocks and residential areas (Sheldon 1950, Nakazono 1970, Sargeant 1972, Abe 1974, Storm et al. 1976, Harris 1977, 1981, Macdonald and Newdick 1982, Roman 1984, Nakazono and Ono 1987), in this study area, their dens were strongly associated with relatively steep slopes near streams and open spaces in woodlands. The question remains open as to why they prefer these areas rather than others for denning.

Den sites on steep slopes, as found during our study, may well be advantageous because of their good drainage. Some previous studies have also demonstrated that many fox dens are to be found in well-drained soil (e.g., Scott and Selko 1939, Sheldon 1950, Roman 1984), and most dens have been found on slopes with gradients of 5-10% or more (Scott and Selko 1939). On the Nemuro Peninsula, the angle of the slopes on which primary den entrances were located were relatively steep (mean±SD=32.5±15.2°). Such den site selection may have been related to the fact that the soil of the study area consisted largely of Gleyic Cumulic Andosols which are badly drained (Hokkaido National Agricultural Experiment Station 1985). Slopes may be advantageous for denning for other reasons in addition to drainage. Digging and the removal of soil may be easier, for example, and on steep slopes perhaps rain and snow are less likely to fall into the dens.

Goszczyński (1989) described forests as primary shelter for foxes and for raising their young. Woods may also serve to provide shelter for juvenile foxes. In the present study area, however, fox dens within woodlands were situated closer to open spaces than were control sites within woodlands indicat-
ing that open areas are also important for them. Nakazono and Ono (1987) suggested that juvenile foxes require substantial amounts of sunshine for normal growth. Marginal sites in woodlands might be preferable both for sheltering and for providing sunning opportunities for juveniles.

Although many fox dens were situated near streams, we do not believe them to be essential for drink water, because adult foxes are able to find water to drink in many situations. Moreover since one den, located 300 m away from a stream, was used for breeding four times during five years, a stream does not seem necessary for juveniles to drink at either. The Nemuro Peninsula experiences many foggy days during late May and June when young foxes are being raised in the breeding dens. It is more than likely that the cubs are able to obtain sufficient water by licking leaves wet with fog and from the food provided by their parents. There is a tendency for steeper locations to be closer to a source of water (Fig. 2), thus the reason why many dens were situated near streams was probably the result of the foxes' preference for well-drained, steeper slopes.

No difference was found in five physical variables between breeding and non-breeding dens. During the course of this study, we were unable to evaluate the impact of disturbance by other animals, especially humans and stray dogs, on fox breeding, because it was difficult to express quantitatively. Disturbance is, however, considered an important variable affecting selection and

![Diagram](image_url)

**Fig. 2.** The relationship between the angle of slope and the distance to the nearest water source of 80 control locations.
utilization of fox den sites (Storm et al. 1976, Harris 1977, 1981). One reason why no difference was found between breeding and non-breeding dens might be because of the absence of any measure of this "disturbance" factor in our analysis.

In the Nemuro area, fox dens were mainly used during the period from mid winter to early summer, a tendency also reported for the red fox in Kyushu, southern Japan (Nakazono and Ono 1987). In Hokkaido, fox mating peaks from late January to mid February followed by a peak in parturition from late March to late April (Abe 1974). The period during which dens were used most intensively in the Nemuro area corresponded, not surprisingly, with the period of mating, parturition and rearing of cubs, confirming that dens are fundamentally breeding sites for the red fox. Of interest, therefore, is the fact that about half of the dens occupied were not used for rearing cubs during the later winter and early spring period, and 11-17% of dens were used even during the period from August to December, though not for breeding. Since few of the signs typical of frequent use such as polishing of excavated soil were observed, these dens might have served just as temporary retreats (Nakazono and Ono 1987).

The density of families estimated using the 500 m criterion was 0.27–0.42 families/km², and was stable over a period of 10 years. There have been few studies on the density of fox families in Japan, however, the density in Nemuro was clearly higher than in either Yabe, Kyushu (0.18 families/km², Nakazono and Ono 1987) or in Koshimizu, Hokkaido (0.24 families/km², Abe 1974). Some studies in southern Sweden, central Europe and England have indicated that where vole densities are high, then fox populations became socially regulated stable and dense. The relatively high and stable density of fox families on the Nemuro Peninsula is probably due to the high density of voles in the area (Saitoh and Takahashi 1998) and the richness of alternative food, such as organic waste from fisheries and from dairy farms (Kondo et al. 1986).

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