Western North American Naturalist 65(1), © 2005, pp. 127–130

USE OF COVER AND RESPONSE TO COVER TYPE EDGES BY FEMALE SIERRA NEVADA RED FOXES IN WINTER

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Key words: red fox, Vulpes vulpes necator, *cover, cover type, tracks, Lassen, edge.*

Red foxes (*Vulpes vulpes*) use a variety of habitats across their range, including semiarid deserts, tundra, boreal forests, farmland, and urban areas (Larivière and Pasitschniak-Arts 1996). Within these habitats there is much variation in the use of different cover types among populations of red foxes (Jones and Theberge 1982, Halpin and Bissonette 1988, Theberge and Wedeles 1989, St-Georges et al. 1995). In Maine, red foxes used coniferous stands and open areas more than expected (Halpin and Bissonette 1988). In British Columbia, red foxes used shrub communities more than expected and open areas less than expected (Jones and Theberge 1982). In the Yukon Territory, red foxes used shrub habitats more than forests or open areas (Theberge and Wedeles 1989). Edge habitat, between forest and shrub stands, was important for red foxes in Quebec (St-Georges et al. 1995). Variation in use of cover by this species necessitates population-specific studies of red fox habitat relations for use in conservation and management.

Sierra Nevada red foxes (*Vulpes vulpes necator*; hereafter SNRF) are among the most uncommon and least understood terrestrial mammals in California (Schempf and White 1977, Aubry 1997). The distribution of this subspecies is thought to be from 1370 m to 3500 m elevation in the Sierra Nevada and southern Cascade Ranges, and the greatest densities appear to occur near Lassen Peak (Grinnell et al. 1937, Schempf and White 1977). Although many researchers have studied habitat use of other subspecies of red fox, knowledge of the habitat relationships of the SNRF is lacking. The SNRF was listed as threatened by the California Fish and Game Commission in 1980, and information regarding the use of cover types by this subspecies will be helpful for land managers when assessing the potential impact of habitat conversion (e.g., from timber harvest) on the SNRF. We investigated use of cover types by 2 female foxes during winter by following tracks in snow in the vicinity of Lassen Peak in the southern Cascade Range. We describe the use of cover by these females and also their traveling behavior at cover type edges.

The study was conducted in the Lassen National Forest, in a 30-km^2 area immediately adjacent to the southern entrance of Lassen Volcanic National Park in northern California where elevations range from 1750 m to 2015 m. The study area consists mainly of mixed conifer forests, shrub communities, and meadows.

We followed 9 separate fox trails belonging to 2 female foxes (F1 and F5) in snow for a total of 18.8 km during December 2000 and January 2001. Length of fox trails ranged from 0.92 km to 5.0 km. We used triangulation to locate radio-collared foxes and then snowshoed into the locations and looked for fresh tracks to backtrack and follow.

We used ocular assessment to classify each cover type as forest, shrub, or open. Forest cover was defined as having >40% canopy cover. Shrub cover had <40% canopy cover from trees and ≥20% ground cover by vegetation with woody stems. Open cover had <40% canopy cover and <20% ground cover by vegetation with woody stems. This classification method was modified from Mayer and Laudenslayer (1988).

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To determine cover availability, we followed random transects that were the same length as paired fox trails. We created these transects using a random compass bearing originating from the location where we began following the paired fox trail. The distance traveled through each cover type along fox trails and random transects was paced and converted to meters. All fox trails belonging to a single individual and the associated random transects were pooled. Thus, for both foxes we generated a paired sample of tracks and random transects of identical distances.

We examined traveling behavior at cover edges by classifying tracks that intersected edges as either traveling straight across the edge into the adjacent cover type or altering direction and traveling parallel to the edge. When tracks traveled parallel to the edge, we noted which side of the edge the tracks traveled (i.e., forest side, shrub side, or open side).

The 2 foxes traveled greater distances in forest and lesser distances in open cover than we measured along the paired random transects (Table 1). Shrub cover was not used by F1, and it constituted only 1% of the distance along the paired random transects. Use of shrub cover by F5 was similar to its availability on paired random transects (Table 1).

Foxes that came to forests from another cover type (n = 13) moved straight into forests (Table 2). Foxes that came to open cover from forests (n = 21) altered direction and followed the edge (Table 2). These foxes followed the edge on the forest side (n = 17) more often than on the open side (n = 4). In one case a fox came from shrub to open cover and moved straight into the opening.

Although statistical analyses were not performed due to the small sample size, the 2 foxes in this study appeared to use forest more and open cover less than the availability of these cover types. Behavior of the foxes at cover edges also suggested a preference for forest cover because in all cases they crossed directly into the forest rather than following the edge. When foxes traveling in forest came to open cover, they showed a behavioral avoidance of the opening by altering their traveling direction and following the edge. In addition, after making turns to avoid openings, they traveled on the forest side of the edges more often than on the open side. All of these results suggest that the foxes were selecting forest and avoiding open cover. This is consistent with several other studies that found red foxes used wooded areas more than expected (Cavallini and Lovari 1991, Adkins and Stott 1998) and avoided open habitats (Jones and Theberge 1982, Theberge and Wedeles 1989, Adkins and Stott 1998).

Other studies have concluded that red foxes may use coniferous forests during winter because snow is not as deep in these habitats (Henry 1980, Halpin and Bissonette 1988). Although we did not measure snow depth, limited evidence suggests that snow depth may have influenced traveling behavior. In 5 separate instances on 2 fox trails, foxes traveled in cross-country ski tracks or snowshoe tracks for 748 m (range 19–430 m). The snow in these tracks was probably harder than the surrounding snow, and foxes may have traveled in them to avoid sinking into deep snow. Traveling in coniferous forests during winter may be another mechanism used by foxes to avoid deep snow.

Jones and Theberge (1982) found that red foxes in British Columbia avoided open areas and noted that these habitats may not meet their intrinsic need for cover from weather and other predators. Competition between coyotes (*Canis latrans*) and red foxes has been reported often, and coyotes have been observed to chase and kill red foxes (Dekker 1983, Sargeant and Allen 1989). In several studies red foxes were found to avoid coyotes, possibly to reduce competition and harassment (Major and Sherburne 1987, Sargeant et al. 1987, Harrison et al. 1989). Forests probably provide better cover than open habitats for hiding and escaping. Thus, the patterns of cover use we observed may be a reflection of the need of red foxes for cover from larger predators such as coyotes.

Because of the difficulty of finding and observing SNRF, we were able to obtain data from only 2 foxes. However, our sample of 2 foxes represents the only information on habitat use by SNRF to date and thus should be useful in developing further studies and conservation plans for this subspecies. Further studies are needed with larger sample sizes and statistical analyses to validate these results and investigate possible differences in cover use between genders. The snow-tracking technique could be combined with extensive vegetation sampling along fox trails and random

TABLE 1. Distance (m) and proportion of the distance measured along Sierra Nevada red fox tracks and paired random transects through forest, open, and shrub cover types in Lassen National Forest, CA, in winter 2000–2001.

Fox ID number	Forest		Open		Shrub		Total
	m	Proportion	m	Proportion	m	Proportion	m
F1	6714	0.98	133	0.02	0	0.00	6847
Random	5624	0.82	1143	0.17	80	0.01	6847
F5	10,994	0.92	218	0.02	748	0.06	11,960
Random	9124	0.76	1783	0.15	1053	0.09	11,960

TABLE 2. Reactions of red foxes upon coming to cover edges, characterized as either moving straight into the adjacent cover or turning and following the edge during winter 2000–2001.

Fox ID number	To open		To shrub		To forest	
	Straight	Turn	Straight	Turn	Straight	Turn
F1	0	7	0	0	2	0
F5	1	14	7	7	11	0
Totals	1	21	7	7	13	0

transects to provide specific information about SNRF habitat requirements. If SNRF do select forests and avoid open habitats, some silvicultural practices (e.g., large-scale clear-cutting) may negatively impact habitat for this subspecies. Therefore, understanding the habitat features (canopy closure, basal area, etc.) of forests selected by SNRF would be useful when potential forest management strategies are considered for the region.

Lassen Volcanic National Park (NPS) and Lassen National Forest (USDA-FS) provided vehicles, office space, and other equipment for this project. The California Department of Fish and Game issued permits authorizing capture and telemetry on the state-threatened Sierra Nevada red fox.

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Received 15 December 2003
Accepted 20 July 2004