

Landscape and Patch Scale Habitat Use by Migratory Black-tailed Deer in the Klickitat Basin of Washington

Abstract

I studied habitat use of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) in the Klickitat Basin of Washington. The habitat mosaic for Klickitat deer consisted of large tracts managed independently by the Yakama Indian Nation, the State of Washington, and two corporate forest-owners. Selection of habitats at the landscape and patch scale was investigated using radiocollared deer. During winter, deer preferred habitats with an overstory dominated or codominated by Oregon white oak (*Quercus garryana*) at both scales of selection. Also during winter, deer selected home ranges with less mixed conifer cover type than available in the background mosaic, but showed some preference for mixed conifer patches within home ranges. Deer occupying mid-elevation home ranges on the Yakama Reservation preferred mature/old-growth and younger, closed-canopy conifer stands at both selection scales during summer. Mid-elevation deer on corporate forestland summer range preferred mature/old-growth stands and open-canopy conifer stands at the landscape scale and the same two habitat classes in reverse order at the patch scale. During summer, deer with high elevation home ranges used habitats in relative proportion to their availability at both selection scales. Habitat conservation for Klickitat deer is complicated by a mixed-ownership mosaic and diverse management approaches. Private land habitat values are important during summer and winter, and conservation may require extensive coordination between public and private resource managers and incentives for private landowners. Conservation of oak-dominated habitat on winter range and mature and old-growth habitat on summer range should be a priority for Klickitat deer managers.

Introduction

Knowledge of a species' habitat affinities is essential to informed management. For example, without basic knowledge of habitat relationships, the consequences of habitat alteration resulting from human land uses cannot be predicted nor can cover types be ranked according to their value. Previous studies have documented some aspects of habitat use for Columbian black-tailed deer (*Odocoileus hemionus columbianus*) in mesic habitats of their range (Brown 1961, Miller 1970, Loft et al. 1984, McNay et al. 1994). However, little is known about black-tailed deer habitat use along the eastern edge of their distribution where the more xeric environment supports different vegetation than in coastal and westslope habitats.

During 1988-94, I studied the ecology of migratory black-tailed deer in the Klickitat River Basin (KRB) along the eastslope of the Washington Cascades. In this paper, I report on habitat use patterns of KRB deer, which were studied in a mixed-ownership landscape managed by the Yakama Indian Nation, the state of Washington, and two large forest products companies.

Conceptually, I addressed habitat relationships at two levels of selection: (1) selection of home

ranges from a background habitat mosaic (landscape-scale selection), and (2) selection of habitat patches within the seasonal home ranges of individual deer (patch-scale selection). Specifically, the following null hypothesis was tested for both wintering and summering KRB deer relative to landscape selection: cover types within deer home ranges were proportional to their availability in a broader habitat mosaic. The null hypothesis tested for wintering and summering KRB deer relative to patch selection was: deer used cover types proportionally to their availability within home ranges.

Study Area

Physiography and Climate

The KRB consists of approximately 350,000 ha of forest and rangeland along the eastern slope of the Washington Cascades (Figure 1). Elevations range from 3,742 m at the crest of Mt. Adams to less than 600 m. The upper basin lays mostly within the 650,000 ha Yakama Indian Reservation. Topographically, the upper basin is characterized by rugged, mountainous country along the Cascade crest that quickly grades into a large, forested plateau. Except for the highly dissected

Klickitat River Canyon, most of this plateau consists of a gently rolling basin that eventually rises to form the Simcoe Mountains along the southern boundary of the Yakama Reservation. Favorable physiographic conditions for wintering deer exist along the lower slopes of the Simcoe Mountains. The lower, southern-most portions of the KRB historically consisted of discontinuous coniferous forest, Oregon white oak (*Quercus garryana*) woodlands, and rangeland. Consid-

erable agricultural and rural development has occurred in the lower reaches of the drainage near the towns of Goldendale and Glenwood.

Annual precipitation ranges from nearly 180 cm to approximately 20 cm, depending on elevation and distance from the Cascade Mountains. Precipitation is strongly seasonal with most falling during winter and spring. Mean annual snowfall measured in nearby Yakima, Washington, 1964-94, was 61.2 cm (National Oceanic and Atmospheric

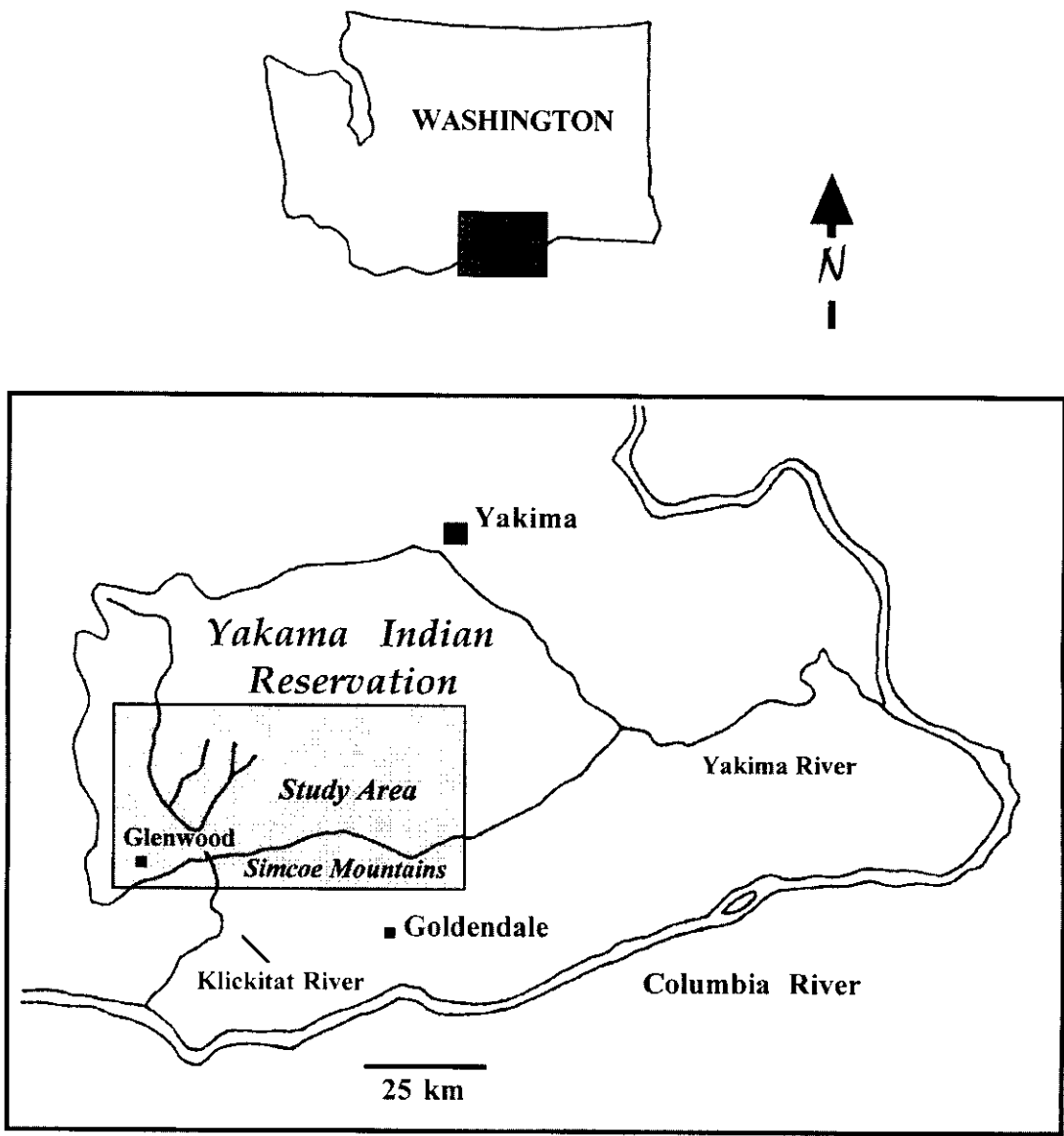


Figure 1. Location of the Klickitat Basin and Yakama Indian Reservation, Washington.

Administration [NOAA] 1994). During this study (1988-94), annual snowfall was below this long-term mean during the winters of 1988-89, 1989-90, 1990-91, 1991-92, and 1993-94 (NOAA 1994). Annual snowfall exceeded the 1964-94 mean during winter 1992-93 and was the second highest snowfall recorded since 1910.

Vegetation

Habitats of the upper Klickitat are primarily alpine and subalpine communities dominated by mountain hemlock (*Tsuga mertensiana*), Pacific silver fir (*Abies amabilis*), and subalpine fir (*A. lasiocarpa*) associations (John et al. 1988). Mid-elevation mixed-conifer stands are dominated by western hemlock (*T. heterophylla*), grand fir (*A. grandis*), and Douglas-fir (*Pseudotsuga menziesii*). Lower elevation forests are typically dominated by ponderosa pine (*Pinus ponderosa*) associations. The forest/rangeland ecotone is characterized by mixed ponderosa pine/Oregon oak stands or pure Oregon oak woodlands.

Nonforested habitats include abundant wet meadow and subalpine park areas in the upper KRB and widespread xeric meadows and shrubfields at lower elevations. Rangeland habitats are dominated by perennial grasses such as bluegrasses (*Poa* spp.) and fescues (*Festuca* spp.) and discontinuous shrub overstories dominated locally by sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and shiny-leaf ceanothus (*Ceanothus velutinus*).

Habitat Management

About 200,000 ha of the KRB is within the Yakama Reservation. Boise Cascade Corporation owns approximately 30,000 ha of mid-elevation forest in the KRB, and Champion International Corporation owns an additional 38,000 ha of KRB forest land, most in the western part of the drainage. Additionally, the Washington Department of Natural Resources manages approximately 19,000 ha of state forest land south of the Yakama Reservation. Reservation lands in the KRB provide summer range, whereas state and private lands south of the reservation provide a mix of summer and winter range.

Commercial forest management is the dominant land use in the KRB. Yakama Reservation forests have been managed using uneven-aged management for several decades; clearcutting on

the reservation has historically been rare (McCorquodale et al. 1997). Clearcutting and intensive selective harvesting has been more extensive on corporate and state-owned timberlands in the KRB. Other land uses include cattle grazing, common on both reservation and corporate timberlands, and agricultural development in the lower Klickitat.

Deer winter range in the lower Klickitat consists of a series of south-facing breaks along the Klickitat River canyon. These open slopes rise steeply from extensive forest stands along the river. As the breaks grade into the lower Simcoe plateau, these openings give way to oak woodlands, and eventually to extensive pine forest as distances from the river and elevations increase. Forest cover, both coniferous and deciduous, is extensive on some portions of the Klickitat winter range.

Methods

Marking and Telemetry

Deer were captured using collapsible Clover deer traps (McCullough 1975) and a hand-triggered, 21 m x 21 m drop net (Ramsey 1968, Conner et al. 1987). Trapping was conducted after the close of recreational hunting seasons, and typically occurred between mid-December and late-February. Traps were dispersed throughout the winter study area in all major cover types to avoid biasing the collection of habitat use data. A sample of adult deer captured each year received radiocollars (MOD-500, Telonics, Inc., Mesa, Arizona). Although I did not use a formal randomization protocol, I attempted to spread radiocollars throughout the winter study area, thus avoiding the oversampling of specific matriline. Most radios were placed on adult female deer, but some were placed on adult males. Radios transmitted at 148-150 Mhz and had an estimated two to three year battery life.

Radiocollared deer were relocated weekly during spring, summer, and fall, and approximately twice monthly during winter. Relocations were obtained from a Cessna 182 or Citabria aircraft fitted with two strut-mounted directional antennas. Aerial tracking protocol generally followed that of Gilmer et al. (1981). Coordinates for aerially-relocated deer were determined using a Geographic Positioning System (GPS) unit mounted on the aircraft's instrument panel.

Coordinates obtained from the GPS unit were converted from latitude and longitude to Universal Transverse Mercator (UTM) coordinates using a computer algorithm (Dodge et al. 1986). Periodically, GPS accuracy was tested by collecting coordinates for known locations.

Movements and Home Range Estimation

Seasonal home ranges (100% minimum convex polygon [MCP]) for radiocollared deer were estimated with PROGRAM HOME RANGE (Ackerman et al. 1989). Minimum Convex Polygon estimates were used to facilitate habitat analyses because they were nonparametric, required few assumptions, and were simple to map using a Geographic Information System (GIS). My interest in home ranges was primarily to define sampling units for habitat questions. Inter-year seasonal home range overlap for deer that were tracked for more than one year was considered evidence of home range fidelity. Inter-year relocation data were pooled for seasonal home range estimation in cases where home range fidelity was documented. Seasonal home ranges were estimated only for deer with at least 10 seasonal relocations.

Habitat Use Relationships

Preliminary observations suggested that KRB deer summered in a diverse array of cover types in environments ranging from subalpine to oak/shrub-steppe ecotone. During winter, however, deer in the KRB regularly concentrated in a narrow range of habitats. Because of this, the analytical strategy differed for summer and winter deer habitat use data.

During winter, the proportional composition of home ranges and the proportional use of cover types by radiocollared deer were examined in a GIS environment (ArcInfo®). Statistical testing of habitat use hypotheses was based on rank testing using the methods of Johnson (1980) and Friedman (1937). The 2 methods differ subtly. The Johnson method is based on the difference in the ranks of used and available habitats across all individuals. In contrast, in the Friedman approach, the difference in the proportions of available and used habitats is calculated for each individual and these computed differences are then ranked within individuals. Rank-testing approaches had two distinct advantages over other methods: (1) small

errors in estimating habitat availabilities were inconsequential, and (2) by maintaining individual-level telemetry data the problems associated with pooling data from different individuals was avoided (Alldredge and Ratti 1986). However, these methods still facilitate inference about population-wide patterns of resource selection (Alldredge and Ratti 1986).

I assumed that all radiocollared deer on the core winter study area had the opportunity to select (landscape scale) from the same array of available habitat components. Therefore, landscape-scale winter habitat availabilities were determined within a digitized ArcInfo® polygon that roughly corresponded to a composite winter home range of radiocollared deer, and the area of various cover types within the composite winter home range was determined using GIS.

For winter landscape-scale analyses, each deer's home range polygon was digitized using GIS, but each was enlarged by a 100 m buffer because of the way individual relocations were treated (described in next paragraph). The relative area of different cover types within individual home range polygons and within the previously-described composite winter home range polygon were then compared.

Winter deer use (patch-scale) was sampled using an ArcInfo® coverage created from winter deer telemetry locations. A relocation coverage for each deer was created by adding a 100 m circular buffer to all telemetry relocations. Each relocation was subsequently treated as a 3.14 ha circular habitat use plot centered on the original telemetry location. By using this approach, I recognized telemetry and mapping errors associated with each relocation. I also hypothesized that deer perceive and select habitats as patches rather than as points. The deer-use coverages were then modified by intersecting the buffered relocations, resulting in a final coverage of winter use for each individual. Habitat proportions were then compared between the winter use coverages and the buffered home range polygons of individual radiocollared deer according to the method of Johnson (1980).

In contrast with winter, during summer, deer were widely dispersed in a broad array of habitat associations. To prevent use of diverse mosaics by individual deer from obscuring patterns of resource selection on summer range, I classified

radiocollared deer into one of two discrete "ecogroups": (1) deer that summered at mid-elevations, primarily in habitats within ponderosa pine and mixed-conifer forest associations, and (2) deer that summered at high elevations (>1,370 m), primarily within moist mixed-conifer associations and subalpine habitats of the true fir and mountain hemlock forest associations. Patterns of resource selection were evaluated independently for these two ecogroups. The analysis of summer habitat use by Klickitat deer was further stratified by analyzing summer deer use of reservation lands separate from deer use of corporate lands outside of the reservation. The justification for this was the historical difference in KRB forest management approaches wherein uneven-aged management was applied on reservation lands and even-aged management predominated on adjacent state and private lands.

Digitized coverages of buffered point relocations and individual home range polygons for summering deer were created similarly to those for wintering deer. Evaluations of patch-scale habitat selection followed the same conceptual approach as that employed for winter analyses, except that hypothesis testing was based on the method of Friedman (1937). I used this method instead of the Johnson (1980) approach for summer deer use because tied ranks resulting from non-use of some components were a problem with some deer during summer, and the Friedman (1937) technique largely eliminated tied ranks.

Evaluations of landscape-scale selection on summer range differed slightly from that employed for winter use, because deer were not geographically concentrated within a narrow range of environments during summer. Therefore, the assumption that all deer were selecting home ranges from the same background mosaic during summer did not seem appropriate. I selected habitat adjacent to each individual deer's summer home range polygon as representing the background habitat mosaic from which home ranges were selected. Habitat availabilities were determined within a 3 km buffer adjacent to the respective 100% MCP home range, and habitat composition within home range polygons and within the 3 km buffer zones were compared to assess landscape scale selection. The Friedman (1937) method was also used to evaluate use of cover types at the landscape scale for the reasons described above.

Results

Capture and Marking

During 1988-94, radiocollars were placed on 69 deer (56 adult females and 13 adult males). The 69 radiocollared deer were collectively relocated 3,152 times. The number of radiocollared deer tracked each year varied from 16 (1989) to 44 (1991). GPS error averaged $29.8 \text{ m} \pm 4.8 \text{ m}$ (1 SE) during accuracy tests. Actual tracking error was estimated to be <200 m for most relocations based on tracking of mortalities and test transmitters. Therefore, tracking system error (relocation error + GPS error) was estimated to average <250 m and rarely exceed 350 m.

Home Ranges

Of the 69 deer radiocollared, three died during their winter of marking without providing enough data to estimate home ranges. Of the remaining 66 deer, nine were non-migratory residents of the lower KRB where winter trapping was conducted. Resident deer were excluded from the habitat analyses because the study objectives focused on migratory deer behavior. Among migrants, the requisite number of relocations were obtained to justify estimating seasonal home ranges for 43 adult female deer during summer and 31 adult females during winter. For females, the mean number of relocations used to estimate summer and winter home ranges was 34.1 and 21.0, respectively. Summer home ranges were also estimated for eight migratory, adult males from a mean number of 22.4 relocations. Too few males were tracked to allow comparisons of habitat use between the sexes, so data from males and females were pooled for habitat analyses. Data on home range sizes and other movement parameters have been published elsewhere (McCorquodale, *in press*).

Habitat Use Relationships

Winter Habitat Relationships

Mean differences between ranks of use and availability of cover types in the background habitat mosaic during winter suggested that deer selected home ranges with more oak woodland habitat than the background mosaic (Table 1); this cover type was significantly preferred ($P < 0.05$) over all other cover types at the landscape scale. Deer home

TABLE 1. Results of winter cover-type use analyses based upon rank testing (Johnson 1980) for radio-collared Klickitat Basin black-tailed deer.

Cover Type	Available (ha)	Mean Use Deviation ^a	Preference Rank ^b
Landscape Scale			
Open	2,085.6	- 0.12	3 ^{cd}
Oak Woodland	1,482.3	- 1.08	1 ^{cd}
Pine / Oak	4,017.2	- 0.60	2 ^{ab}
Mixed Conifer	4,577.5	1.80	4 ^{abf}
Patch Scale			
Open	36.37	0.36	4 ^{ade}
Oak Woodland	34.12	-0.20	1 ^c
Pine / Oak	141.81	-0.04	3 ^d
Mixed Conifer	64.87	-0.12	2 ^e

^aAverage deviation of ranks [use - availability] for all radiocollared deer.

^bOverall rank of preference [1 = most preferred] [ranks denoted by shared superscript are significantly different, $P < 0.05$].

ranges also contained less mixed conifer habitat than the background mosaic during winter. Within radiocollared deer winter home ranges, moderate selection, evidenced by negative mean use deviations between the availability and proportional use of patches, was noted for oak woodland, mixed conifer, and pine/oak. Significant selection ($P < 0.05$) was not detected among these cover types, but all three were preferred over nonforested habitat patches.

Summer Habitat Relationships

The null hypothesis that deer used cover types proportional to their availability was rejected for mid-elevation ecogroup deer on reservation and nonreservation lands at the landscape scale ($T_2 = 3.23$, $T_2 = 3.43$, $P < 0.10$). Similarly, selection of habitat patches within home ranges was nonrandom for mid-elevation ecogroup deer on both reservation and nonreservation summer ranges ($T_2 = 5.29$, $T_2 = 3.08$, $P < 0.10$). At the landscape scale, home ranges of mid-elevation deer on tribal lands generally contained more mature/old-growth stands and younger, closed-canopy conifer stands than background mosaics (Table 2). At the patch scale, these deer also preferred mature/old-growth and younger, closed canopy conditions relative to nonforested and open-canopy stands (Table 2).

TABLE 2. Results of summer cover-type use analyses based upon ranks of differences between use and availability (Friedman 1937) for mid-elevation ecogroup, radiocollared Klickitat Basin black-tailed deer summering on Yakama Reservation land ($n=18$).

Cover Type ^a	Mean Availability	Ranks Sums (U-A) ^b	Preference Rank ^c
Landscape Scale			
Open / shrub	0.08	57.0	4 ^{ab}
Open conifer	0.07	48.0	3
Closed conifer	0.18	39.0	2 ^c
Mature / Old growth	0.67	37.0	1 ^d
Patch Scale			
Open / shrub	0.05	54.0	3.5 ^d
Open conifer	0.06	54.0	3.5 ^{ab}
Closed conifer	0.24	41.5	2 ^{cd}
Mature / Old growth	0.65	30.5	1 ^{ef}

^aOpen / shrub = non-forested; open conifer = $\leq 39\%$ canopy closure (CC); closed conifer = $\geq 40\%$ CC, < 9 in. dbh; mature / old growth = $\geq 40\%$ CC, > 9 in. dbh.

^bSum of ranks of differences in use and availability percentages for all radiocollared deer.

^cOverall rank of preference [1 = most preferred] [ranks denoted by shared superscript are significantly different, $P < 0.10$].

Mid-elevation ecogroup deer summering on private forest land also selected home ranges with more mature/old-growth than available in background mosaics; this cover type was preferred over all other cover types (Table 3). Summer home ranges of these deer also generally contained more open-canopy conifer stands than the background mosaics. Deer in this ecogroup appeared to select home ranges with less nonforested habitat than was typical of background mosaics. Within the summer home ranges of these deer, preference was noted for open-canopy conifer habitat and mature/old-growth, and non-overstory habitat patches were neither preferred nor avoided relative to other cover types ($P > 0.10$).

The home ranges of radiocollared, high-elevation ecogroup deer contained cover types in similar proportion to their availability in background habitat mosaics ($T_2 = 0.42$, $P > 0.50$) (Table 4). Likewise, use of cover type patches was relatively proportional to their availability in high elevation deer summer home ranges ($T_2 = 1.68$, $P > 0.25$) (Table 4).

TABLE 3. Results of summer cover-type use analyses based upon ranks of differences between use and availability (Friedman 1937) for mid-elevation ecogroup, radiocollared Klickitat Basin black-tailed deer summering on corporate timberlands (n = number of radioed deer in analysis).

Cover Type ^a	Mean Availability	Ranks Sums (U-A) ^b	Preference Rank ^c
Landscape Scale (n=10)			
Open / shrub	0.04	33.0	4 ^{ac}
Open conifer	0.33	21.0	2 ^{cf}
Closed conifer	0.07	28.0	3 ^b
Mature / Old growth	0.56	18.0	1 ^{adg}
Patch (n=15)			
Open / shrub	0.04	38.5	3
Open conifer	0.38	28.0	1 ^c
Closed conifer	0.06	44.5	4 ^{dc}
Mature / Old growth	0.52	29.0	2 ^e

^aOpen / shrub = non-forested; open conifer = < 40% canopy closure (CC); closed conifer = ≥ 40% CC, < 9 in. dbh; mature / old growth = ≥ 40% CC, > 9 in. dbh.

^bSum of ranks of differences in use and availability percentages for all radiocollared deer.

^cOverall rank of preference [1 = most preferred] [ranks denoted by shared superscript are significantly different, *P* < 0.10].

Discussion

Analytic Approach

I used seasonal home ranges, estimated from telemetry, to define sampling frames for landscape and patch scale habitat selection questions. Home range estimation has been discussed extensively in the literature (Van Winkle 1975, Samuel et al. 1985, Worton 1987, 1989). It is known that estimates of home range size are affected by model assumptions, treatment of outliers, and sample sizes (Van Winkle 1975, Worton 1987, Seamon and Powell 1996). Obviously other methods would have yielded somewhat different estimates of home range size and shape. Although MCP home range estimates are sensitive to outliers, they require few distributional assumptions (Ackerman et al. 1989). Likewise, many probabilistic models perform poorly unless sample sizes are larger than those used to estimate seasonal use areas of deer in this study (Worton 1989). Given the trade-offs between home range models, sample-size constraints, and the need to simply identify an objectively-determined sampling frame for habitat questions I had framed, I believe my use of MCP estimates was a reasonable approach.

TABLE 4. Results of summer cover-type use analyses based upon ranks of differences between use and availability (Friedman 1937) for high-elevation ecogroup, radiocollared Klickitat Basin black-tailed deer (n=8).

Cover Type ^a	Mean Availability	Ranks Sums (U-A) ^b	Preference Rank ^c
Landscape Scale			
Open / shrub	0.16	19.0	2
Open conifer	0.21	22.0	3.5
Closed conifer	0.20	17.0	1
Mature / Old growth	0.43	22.0	3.5
Patch scale			
Open / shrub	0.14	23.0	3
Open conifer	0.20	24.0	4
Closed conifer	0.19	14.0	1
Mature / Old growth	0.47	19.0	2

^aOpen / shrub = non-forested; open conifer = ≤ 39% canopy closure (CC); closed conifer = ≥ 40% CC, < 9 in. dbh; mature / old growth = ≥ 40% CC, > 9 in. dbh.

^bSum of ranks of differences in use and availability percentages for all radiocollared deer.

^cOverall rank of preference [1 = most preferred] [ranks denoted by shared superscript are significantly different, *P* < 0.10].

Rank testing methods for studying animal preference for habitats have many desirable features (Allredge and Ratti 1986). However, reducing data to ranks reduces the resolution of some information available regarding animal use. These methods also may obscure distinctive patterns of certain individual animals. It was apparent in this study that some deer had home ranges centered on specific habitat features such as a clearcut, a shrub-field, or a riparian zone that did not always emerge as important population-level habitat features. The methods of Friedman (1937) and Johnson (1980) are clearly designed to yield inference that is weighted towards common patterns among all animals as opposed to individuals. Although it is interesting to note prominent individual patterns, managers should emphasize the maintenance of habitat conditions that are predictably used by most individuals. Thus, I recognize that the analytical approach I employed may have obscured some habitat selection behaviors. However, I believe the methods were appropriate for yielding insight into important population-level patterns.

The rank testing methods I employed also produced a ranking of habitats from least to most

preferred, even when differences between the rankings were not statistically significant. Although trends may be suggested in some non-significant relationships, I attempted to clearly flag those rank differences that were significant and emphasize significant relationships in the results and following discussion.

Winter Habitat Relationships

In contrast with the background habitat mosaic during winter, radiocollared deer appeared to select home ranges with more nonforested, oak, and oak/pine fringe habitat. These cover types are generally associated with lower elevation, xeric environmental settings in the KRB. Deer also selected winter home ranges with less mixed conifer habitat than was locally available. Within the general vicinity of the winter trapping area, extensive mixed conifer cover was typically associated with higher elevation uplands and cold air sinks. Winter deer home ranges were, therefore, associated with cover types that predictably received less snow, more radiant energy, and had more open canopies. In such settings, deer would find energetically less demanding winter habitat and more accessible forage. Acorns, a source of energy and nutrients during critical winter months, were also relatively easily obtained beneath oak canopies.

Within winter home ranges, radiocollared deer also demonstrated selection for oak, oak/pine, and mixed conifer patches relative to nonforested components. Although home ranges contained less mixed conifer habitat than the background mosaic, radiocollared deer appeared to selectively use mixed conifer patches within their winter home ranges. As previously noted, it seems likely that the bulk of the mixed conifer cover type in the vicinity of the winter concentration area was associated with unfavorable wintering macrohabitat; however, when conifer stands did occur close to more preferred macrohabitats such as extensive oak and oak/pine habitat, deer readily used mixed conifer stands for cover.

During winter, oak-dominated habitat patches appeared to provide preferred foraging settings for deer. Forage within oak-dominated habitats included acorns and sub-shrubs; during the severe winter of 1992-93, deer were also noted foraging extensively on arboreal lichens that were common in oak stands. High trapping success in

oak-dominated stands relative to other cover types also suggested habitats with a strong oak component were preferred by wintering deer.

Suring and Vohs (1979) found that Columbian white-tailed deer (*O. virginianus leucurus*) preferred habitat components providing substantial cover and forage over components providing either alone. Likewise, this intuitive preference of deer for habitat structure meeting multiple ecological needs was suggested by Loft and Menke (1984) for wintering black-tailed deer in northern California. Coniferous forest ecotone habitat in the KRB (i.e., oak and oak/pine habitat) probably provided both quality forage and cover relative to open habitat components and extensive closed-canopy mixed conifer stands, which provided either primarily forage or cover alone.

Summer Habitat Relationships

Mid-elevation, summer deer habitat on the Yakama Reservation is managed primarily using uneven-aged silviculture, whereas on corporate timberlands in the KRB, a mix of even-aged and uneven-aged management has historically been used. This difference in management has led to substantial differences in the structure of post-logging conifer stands. GIS analyses indicated that deer summering on tribal land had a greater area of mature and old-growth and small-diameter, closed-canopy conifer habitat available in both background and home range habitat mosaics relative to deer summering on private land. Open-canopy conifer habitat and clearcuts were more abundant on managed private lands than on tribal lands.

Mid-elevation deer summering on tribally managed lands used non-forested and open-canopy conifer habitat less than expected in the absence of selection at the home range and habitat patch scale. On an uneven-aged, managed landscape, such habitats were typically associated with xeric site conditions or stands that were harvested heavily during previous entries. Although open-canopy habitat is often generalized as being forage-producing habitat with considerable value to wild ungulates, radiocollared, mid-elevation, reservation deer displayed little selection for open-canopy or nonforested habitat. Although black-tailed deer have been generalized as an ecotone species (Witmer et al. 1985), empirical data have been variously supportive of (Hanley 1983) and

contrary to (Kirchhoff et al. 1983) this hypothesis, depending on climatic and other environmental features of study areas. In my study, the use of aerial diurnal point locations may have undersampled deer involved in major crepuscular foraging bouts. However, my approach of using a 3.14 ha habitat use plot centered on the point relocations did not detect any widespread affinity for openings or open-canopy stands among radiocollared deer. It is likely, however, that smaller openings were inadequately mapped, and GIS-based analyses may have subsequently underestimated use of these smaller openings by radiocollared deer.

Radiocollared deer preferentially used mature and old-growth habitat at a landscape scale regardless of whether they summered on reservation or corporate timberlands. On corporate land, mature/old-growth was ranked as the second most-preferred habitat at a patch scale, although it was significantly preferred only over young, closed-canopy stands. Mature and old-growth forest habitat has been shown to provide preferred summer habitat for black-tailed deer, despite the generalization that mature, closed-canopy forests provide little ungulate forage (Kirchhoff et al. 1983, Loft et al. 1984, Hanley et al. 1989). Parker and Robbins (1984) experimentally determined an upper critical environmental temperature of 25 C° for summering mule deer. Older, closed-canopy forest stands in the Klickitat may have provided an energetically favorable thermal environment for summering deer during the warm, dry summers characteristic of the eastern slopes of the Cascade Range.

Apparent preference for open-canopy conifer stands on corporate timberlands attests to the adaptability of black-tailed deer, a generalist herbivore. During this study, logging occurred in the home ranges of a few radiocollared deer, and previously logged habitat occurred in several deer home ranges. In general, active logging temporarily displaced deer to parts of their home range beyond the logging disturbance. To my knowledge, no deer abandoned a home range already documented by radiotelemetry because of logging. Because home range fidelity was strong, it appeared deer coped with habitat change mediated by logging.

Site fidelity among deer, especially females, complicates the interpretation of management-

induced change on habitat quality. For example, it is difficult to determine whether a deer with logged habitat in their home range selected the home range because of, or in spite of, management-induced features, because their fidelity to a female home range tradition is so strong (McCorquodale, *in press*). Deer with home ranges perturbed by management may have had matrilineal fidelity to the site before the habitat alteration. Ultimately, habitat value should be defined not simply by preference behavior, but by the influence of habitat on individual fitness. Longer term data on survival and reproductive success for deer with known home range traditions and experimentally-controlled habitat change would be required to rigorously test hypotheses of this nature. Neither this nor any previously published study has yielded such hypothesis testing.

Management Implications

The seasonal habitat mosaic for KRB deer includes limited public land, unlike the scenario for many western big game populations. During summer, KRB deer primarily depend on habitat provided by the Yakama Indian Reservation and corporate timberlands. Winter range, a limiting factor for many western big game populations, is predominantly provided by state and private land in the KRB.

Because Klickitat deer, a resource owned collectively by both the tribal and nontribal public, depend heavily on privately-owned and managed land, long-term habitat conservation is an important concern for managers. Historically, managers of public wildlife resources have had greater control over habitat management on public lands than on private lands. Likewise, federal environmental laws applicable to federal public lands often have more limited applicability on private lands.

In the last several decades, considerable low elevation deer habitat has been converted to agricultural and rural development. During this study, new home building continued within the winter study area. Continued habitat conversion or development in the lower KRB can only further reduce the winter carrying capacity of this area and increase the relative impact of periodically severe winters on deer survival (McCorquodale, *in press*). Similarly, decades of fire suppression in the lower Klickitat has led to encroachment of

ponderosa pine into areas once dominated by nearly pure oak stands. Winter habitat maintenance and enhancement should remain a high priority for Klickitat deer managers. Given the importance of privately-owned deer winter range, cooperative agreements providing an incentive for large landowners to conserve winter deer habitat values may be required to achieve long-term habitat conservation objectives.

Habitat use by Klickitat deer suggested considerable affinity for older forest stands on summer range. Thus, retention of some older, mid-elevation forest stands across the landscape in the more xeric portions of black-tailed deer range should also be a management priority. Winter habitats with a strong oak component appeared to have substantial value to deer in this region as evidenced by predictable preference among a large sample of radiocollared deer. Oak/pine ecotone habitats may require manipulations such as pre-

scribed fire to maintain a strong oak component in the face of natural succession.

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