United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-555
October 2002

Adjusting for Radiotelemetry Error to Improve Estimates of Habitat Use

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Abstract

Findholt, Scott L.; Johnson, Bruce K.; McDonald, Lyman L.; Kern, John W.; Ager, Alan; Stussy, Rosemary J.; Bryant, Larry D. 2002. Adjusting for radiotelemetry error to improve estimates of habitat use. Gen. Tech. Rep. PNW-GTR-555. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 14 p.

Animal locations estimated from radiotelemetry have traditionally been treated as error-free when analyzed in relation to habitat variables. Location error lowers the power of statistical tests of habitat selection. We describe a method that incorporates the error surrounding point estimates into measures of environmental variables determined from a geographic information system. We estimated a bivariate ellipsoidal probability density for errors surrounding radio collars placed at 20 random sites. This probability density of errors was used to construct probability-weighted estimates of environmental variables. Computer simulations indicated that slope, sine and cosine of aspect, and canopy cover at radiotelemetry locations differed from probability-weighted estimates of those variables ($P \leq 0.031$). However, these differences were based on large sample sizes ($n \geq 305$) and were probably too small to influence power of statistical tests of habitat selection. The frequency with which soil, plant community, and canopy cover types were correctly classified with simulated radiotelemetry point estimates increased with increasing patch sizes ($P \leq 0.005$). Our method could be used to assess how accurately environmental variables can be determined across extremes of habitat and topography and the spatial scale at which analyses retain adequate power. It also could be used with other radiotelemetry systems, including those based on global positioning system technology, if sufficient locations are obtained to describe their probability distribution.

Keywords: Automated tracking, error neighborhood, habitat selection, LORAN-C, Oregon, principal components analysis, radiotelemetry location error, Starkey.

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Introduction

Habitat studies require accurate estimates of an animal's location to correctly measure habitat variables (Nams 1989, White and Garrott 1990). Accurate estimates are especially important when the study area contains a mosaic of small habitat patches. Although errors have been recognized in both aerial (Garrott et al. 1987, Harrington et al. 1987) and triangulation (Hupp and Ratti 1983, Lee et al. 1985, Springer 1979) radiotelemetry methods, these errors are often ignored when determining environmental characteristics of estimated locations (Saltz 1994).

The main effect of error in the estimates of radiotelemetry locations is lower power of statistical tests of habitat selection (White and Garrott 1986, 1990). Ad hoc solutions (Rotella and Ratti 1992) and statistical procedures (Samuel and Kenow 1992) may improve estimates of habitat use when misclassification is probable for radio location by triangulation. In this paper, we describe a new method to assess the accuracy of measurements of environmental variables (e.g., elevation, slope, distance to roads) associated with automated animal telemetry system (AATS) location estimates. Our objectives were to (1) develop an empirical method for calculating the probability distribution of an animal's location given a LORAN-C radiotelemetry point estimate (hereafter point estimate), (2) describe how to use this probability distribution to incorporate environmental variables in a geographical information system (GIS) with radiotelemetry error neighborhoods (hereafter error neighborhood), and (3) assess whether point or error neighborhood estimates provide more accurate estimates of environmental variables, and therefore habitat use.

We conducted research on a portion of the Starkey Experimental Forest and Range (Starkey) located on the Wallowa-Whitman National Forest, about 35 km southwest of La Grande in Union County, Oregon. In 1989, an AATS was deployed at Starkey that uses time differences (TDs) of retransmitted LORAN-C radio navigation signals that are differentially corrected to compute locations of radio-collared animals (Dana et al. 1989, Findholt et al. 1996, Johnson et al. 1998). A TD is the difference in time of arrival of two LORAN-C signals, one from the master station, and one from a secondary station. Estimated locations of Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) and mule deer (*Odocoileus hemionus* Rafinesque) from the AATS, when coupled with environmental variables and mapped in a GIS database, enable researchers to analyze distributions of these species in relation to intensive timber management, cattle grazing, vehicle traffic, and hunting (Bryant et al. 1991, Johnson et al. 1991, Rowland et al. 1997). We enclosed the 10 102-ha study area with a 2.4-m fence to restrict movement of elk and deer. Elevation in this area ranges from 1120 to 1500 m. Vegetation is a mosaic of forest stands and grasslands, and soils are derived from basalt and pumicite (Strickler 1965). Forest stands are dominated by ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). Grand fir (*Abies grandis* (Dougl.) Forbes) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) occur on the northern aspects. Rowland et al. (1997) provide a detailed description of Starkey.

Methods

Method Development

We developed methods to estimate the probability density of LORAN-C radiotelemetry locations from experimental data. Forty radiotelemetry collars were tested to ensure proper functioning. Differentially corrected global positioning system (DGPS) locations were obtained in Starkey at 20 random sites with a Trimble Pathfinder receiver.[1] Two radio collars were placed in an upright position at each site to simulate the position of a standing animal. We used two radio collars per site to assess whether radiotelemetry error varied among collars at the same sites. From 27 October through 3 November 1992, all 40 radio collars were located systematically by using the AATS, once every 40 minutes, 24 hours each day; this provided about 300 attempted locations per radio collar. We determined the differences between the DGPS location for each site and the point estimates to obtain estimates of error in meters. One collar failed during this trial and was omitted from the analysis.

Radiotelemetry locations from stationary collars were treated similarly to locations obtained during studies of animals at Starkey. Locations were corrected for mean bias based on the DGPS locations of the sites (Findholt et al. 1996). We discarded locations when they did not have the required number of TDs (three or four) or when TDs did not meet minimum threshold values for signal strength, signal-to-noise ratios, or geometric dilution of precision (Dana et al. 1989). Positions that contained cycle slips also were discarded from the data set (Rowland et al. 1997). The number of successful observation attempts from each collar varied from 26 to 152 ($\overline{x}$ = 107, *SE* = 5.2).

We estimated the probability that a particular pixel contained the true location of a radio collar for each 30-m pixel near the home pixel. Each of the 39 radio collars received equal weight because we did not want any unique environmental conditions that yielded acceptable TD conditions to have undue influence on the magnitude or direction of corrections. Consequently, when less than 152 successful locations were obtained for a given collar, a simple random sample was drawn (with replacement) from the locations for that collar to complete a set of 152 locations. The sampling process generated 5,928 locations with balanced representation from each collar. Relative errors of all 5,928 radiotelemetry locations from the 39 collars were pooled.

We assumed that the bivariate probability density function was elliptical in shape based on the observed pattern of LORAN-C location errors. The major and minor axes of this ellipse were calculated from the eigenvalues and eigenvectors of the covariance matrix of the observed error distribution (Mardia et al. 1979). The major axis was in the direction of the eigenvector corresponding to the largest eigenvalue, and the ratio of major:minor axis lengths was given by the ratio of the eigenvalues. A (1-β)100 percent confidence ellipse was defined by the equation $\boldsymbol{x}^T A \boldsymbol{x} = c$ where A is the covariance matrix of the location errors, $\boldsymbol{x}^T$ is a bivariate vector of locational errors, and c is a constant. A (1-β)100 percent confidence ellipse for the true location is estimated by finding the smallest constant c, such that (1-β)100 percent of the errors are contained by the ellipse. The calculations were performed by using MATLAB (Mathworks, Inc. 1995).

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Probability weights for pixels in each error neighborhood were determined by counting the number of locations found in each pixel within the (1-β)100 percent confidence ellipse. We assumed that the shape of the ellipse would be similar for all known locations, and therefore probability weights were estimated from the pooled 5,928 radiotelemetry locations.

We conducted a basic exploratory analysis to test the appropriateness of using a single elliptical probability density to describe the radiotelemetry error polygon for Starkey. We estimated the angle of orientation and the ratio of the major to minor axis lengths for each radio collar by using only the observed locations without bootstrap resampling. All the axes were plotted on a single graph to allow visual assessment of variation among collars. We investigated any irregularities by comparing estimates from both collars at the same location. These comparisons were displayed graphically. We tested for differences among locations by using one-way analysis of variance (ANOVA) with one or two observations per location. This analysis was conducted with all radio collars except the one anomalous radio collar. We analyzed directional data to estimate a 95 percent confidence interval for the mean angle of orientation of the major axis (Mardia 1972).

We cross validated to further determine if using a single error neighborhood across Starkey was valid. The test was conducted for nominal probabilities of 0.8, 0.9, 0.95, and 0.99. An 80-percent error neighborhood is that set of pixels surrounding and including the home pixel such that the sum of the probability weights equals 0.80. Other error neighborhoods are defined similarly. Radiotelemetry locations associated with one of the 39 radio collars were removed from the data set, and the error neighborhood was estimated by using locations from the remaining 38 collars. This confidence ellipse was tested against locations from the excluded collar by counting the number of locations falling inside the new error neighborhood. We expected that for a nominal 95-percent error neighborhood, about 95 percent of the locations for each collar would fall inside the confidence ellipse. This procedure was repeated for each collar giving an observed proportion of samples in the ellipse for each radio-collar and at each nominal probability level. A chi-square goodness-of-fit test (Zar 1974) was applied within each nominal probability level to test the null hypothesis that the telemetry error distribution can be described by a single bivariate ellipsoidal probability density.

The probability weight for a particular 30-m pixel was influenced by the precise location of an observation within the home pixel. Consequently, the 30-m pixels were divided into thirty-six 5- by 5-m pixels. Then, 80 and 95 percent weight matrices were calculated for surrounding 30-m pixels conditioned on the subpixel in which an observation was recorded. Subunits (5 by 5 m) were selected because DGPS locations were assumed to be within 5 m with 95 percent confidence (Findholt et al. 1996). This technique resulted in 36 sets of probability weights for each confidence level.

Method Testing

We generated 4,191 random universal transfer Mercator coordinates within Starkey to determine whether point or error neighborhood estimates could more accurately describe an animal’s habitat. We obtained, with GIS, the values for environmental variables from the 30-m pixels containing the random points. A 30-m pixel was chosen because most environmental variables could not be determined accurately in an area less than 30 by 30 m. For a thorough discussion of environmental variables in the Starkey habitat database, including how they were determined and their accuracy, see Rowland et al. (1998). Continuous variables used were elevation, slope, sine and cosine of aspect, and distance to nearest road. Discrete variables used included canopy cover, plant community type, and soil type. The random sites were considered exact locations (i.e., true animal locations) when we were obtaining values of environmental variables. We used the known probability distribution of radiotelemetry locations to obtain simulated locations of LORAN-C radiotelemetry point estimates at each random site. This was accomplished by randomly selecting points with replacement from the 5,928 location errors that formed the probability distribution of radiotelemetry locations and adding the location error to the true location. We determined the 80- and 95-percent error neighborhoods around the home pixel containing the simulated LORAN-C point estimates. Next, we calculated values of environmental variables at the simulated radiotelemetry points and from the 80- and 95-percent error neighborhoods. Finally, we subtracted the value of each continuous environmental variable at the "true animal location" (i.e., random site) from our simulated point and error neighborhood estimates. We used mean absolute deviations as a measure of accuracy for each method. For the discrete variables, the category chosen for the point estimate was the one found in the home pixel, and for the 80- and 95-percent error neighborhoods, we used the category most frequently represented as the estimate. We divided Starkey into three canopy cover classes (forage, <40 percent canopy cover; marginal cover, 40 to 70 percent canopy cover; satisfactory cover, >70 percent canopy cover) based on Landsat classification; the resulting mean patch size was 2.9 ha. Mean patch size at Starkey for 15 plant community types was 14.6 ha; mean patch size of 20 soil types was 20.4 ha.

Error neighborhoods for a simulated LORAN-C location may overlap the boundary of Starkey when an animal location is adjacent to the fence and thus assign positive probability to pixels that could not possibly contain the radio; i.e., an unadjusted error neighborhood will contain pixels outside Starkey. To resolve this bias, error neighborhoods were calculated by computing the weighted averages for only those pixels inside the fence.

Statistical Analyses

We used a general linear model (GLM) completely randomized block design ANOVA to determine whether point estimates or error neighborhoods (80 and 95 percent) provided the most accurate estimates of values of continuous environmental variables. This was accomplished by testing for differences by using all 4,191 random sites throughout Starkey and from a subset of 332 sites in riparian areas (i.e., within 100 m of major streams) from the original 4,191. We evaluated riparian areas because they were the most diverse topographically and contained a variety of habitat types. In the ANOVA, the "treatments" were the three different methods (point estimates, 80- and 95-percent error neighborhoods) and the "blocks" were the individual random sites. When significant differences were detected, we used a Student-Newman-Keuls multiple comparison range test. Chi-square tests of homogeneity were used to test whether the proportion of correctly classified categories of discrete variables varied with radiotelemetry point or error neighborhood estimates for all random sites and sites in riparian areas. We used regression analysis to test for relations between patch size and the proportion of correctly classified canopy cover, soil, and plant community types at simulated radiotelemetry point estimates. SAS (SAS 1985) was used for statistical analyses (level of significance, $\alpha = 0.05$).

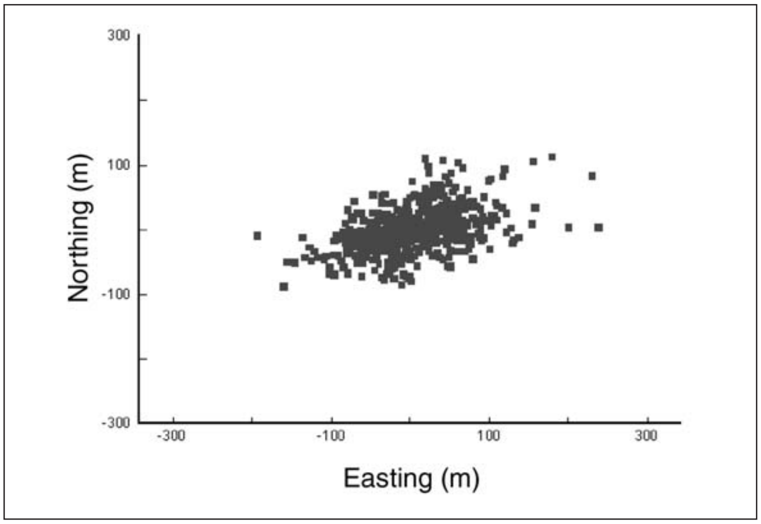

Figure 1—Error distribution of bias-corrected locations from 39 collars resulting from the LORAN-C automated animal telemetry system at the Starkey Experimental Forest and Range, northeast Oregon.

Determining Values of Environmental Variables from Radiotelemetry Error Neighborhoods

We used the following equation to estimate weighted values of continuous environmental variables (V_w) for 80- and 95-percent error neighborhoods:

$$V_W = \frac{\sum_{i=1}^{n} \left(W_i \times V_i \right)}{\sum_{i=1}^{n} W_i} ,$$

where

W_i = relative probability weight of the 30- by 30-m pixel,

V_i = value of the continuous environmental variable for the pixel, and

n = the number of pixels in the array that corresponds to error neighborhood size.

We chose the category with the largest sum of relative probability weights to obtain the estimate for a discrete variable with error neighborhoods. Programs used to estimate values of environmental variables from error neighborhood estimates and GIS were written in Borland PASCAL (Borland International 1994).

Results

Statistics

The spatial distribution of the combined radiotelemetry location errors was nearly elliptical in shape with maximum frequency at the center of the ellipse (fig. 1). Major and minor axes of the error ellipse for each radio collar are plotted in figure 2. Axis orientation for all but one collar ranged from 0° to 34° north of east with one collar (number 175) having its major axis oriented 72° north of east. The error distribution for this anomalous collar and for collar 154, also at the same location, were plotted

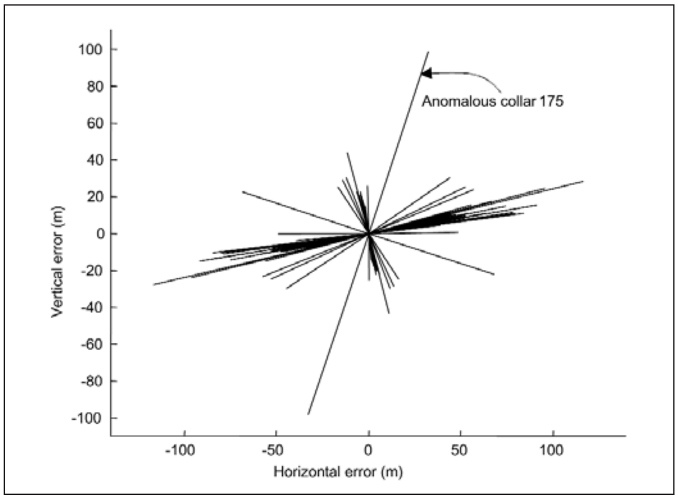

Figure 2—Plot of major and minor axes of error distribution estimated from each radio collar. Notice that collar 175 stands out anomalously from the group, whereas the remaining collars are consistent.

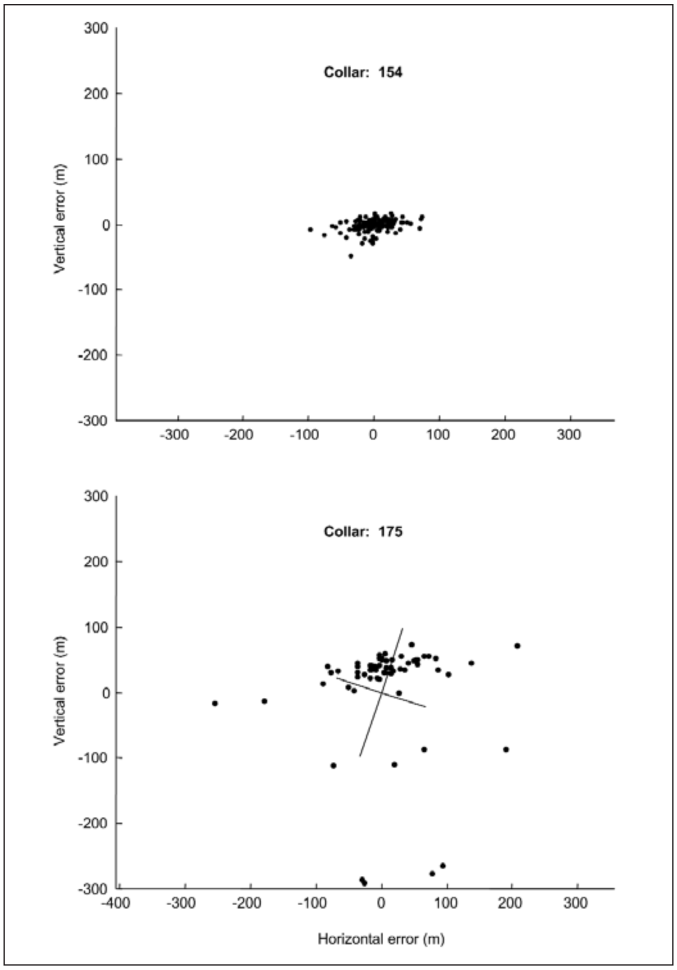

Figure 3—Comparison between error distribution of collar 154 and collar 175. Both collars are from the same location within the Starkey Experimental Forest and Range in northeast Oregon.

in figure 3 for comparison. The angle of orientation and ratio of major to minor axis lengths were similar across all 20 locations (*P* > 0.7). We removed collar 154 from the analysis to determine whether collar 175 biased results and found that angles of orientation and ratios of principal axes were still similar across all 20 locations (*P* > 0.4). The average angle of orientation was 13.0° (95 percent confidence interval: 10.6° to 15.3°), and the average ratio of major to minor axis lengths was 3.7 (95 percent confidence interval: 3.2, 4.1).

The average observed coverage probabilities for each nominal probability level were greater than the nominal level (table 1). The chi-square goodness-of-fit test did not indicate a lack of fit for nominal probability levels of 90 percent or greater. The observed coverage probabilities more closely matched the nominal levels as the nominal level increased. The poorest fit was for the 80 percent nominal level, with an average observed coverage of 90 percent, a minimum of 55 percent, and maximum of 100 percent.

Estimates of sine and cosine of aspect were more accurate with radiotelemetry points than with error neighborhood estimates at all random sites and the subsample of sites from riparian areas (table 2). By contrast, estimates of slope were improved with error neighborhood estimates (table 2). Canopy cover was correctly classified more often with error neighborhood estimates than point estimates at all sites (table 3). No differences were found between point and error neighborhood estimates (*P* > 0.05) for elevation, distance to roads, plant community type, and soil type. As patch size increased, the frequency that soil, plant community, and canopy cover type were classified correctly also increased (fig. 4).

Discussion

The error distribution of radiotelemetry locations is elliptically shaped and is similar throughout Starkey for properly functioning radio collars. We found that with the exception of radio collar 175, the distribution of the angle of orientation and the ratio of major to minor axis lengths were similar for all 20 locations throughout Starkey. Radio collar 175 appeared to generate an error distribution much different than the other radio collars at the same location. We suspect that this particular collar may have been damaged.

Results of cross-validation analyses and chi-square goodness-of-fit tests also provided evidence that the error distribution was similar across Starkey and that a single error neighborhood was appropriate, especially for nominal probability levels of 0.9 or greater. The observed coverage probability of the error neighborhood tended to be greater than or equal to the target nominal probability for each nominal level. A positive bias was associated with the technique, but the magnitude of the bias tended to decrease with increasing nominal levels. For a given radiotelemetry location, some pixels were given higher probability of inclusion in the sample than their actual probability. This resulted in more conservative inferences in resource selection studies. In particular, when selection was observed with error neighborhood correction methods, the statistical significance of effects was likely to be higher (lower probability values) than the estimated significance level. When the nominal level of a test of significance was set at 0.05, we may, in practice, have been testing at a lower probability level.

Table 1—Summary statistics for observed coverage probability based on cross-validation analysis for nominal probability levels of 80, 90, 95, and 99 percent

Nominal probability level	Minimum	Maximum	Average	Chi-square	*P*[a]
0.80	0.55	1.0	0.90	98.80	<0.001
.90	.74	1.0	.94	22.90	.97
.95	.80	1.0	.97	7.08	>.99
.99	.88	1.0	.99	1.41	>.99

[a] Based on chi-square goodness-of-fit tests.

Note: Frequency distribution = 38 for all analyses.

Table 2—Absolute mean differences between values of continuous environmental variables at radiotelemetry points, 80- and 95-percent error neighborhoods (E.N.), and true values at the Starkey Experimental Forest and Range, northeast Oregon

Variable	*n*	Point	80% E.N.	95% E.N.	*F*	*P*[a]
All sites:						
Elevation (m)	4,191	5.6	5.5	5.6	2.23	0.108
Aspect—						
cosine	4,191	.21A	0.22A	.22B	11.37	<.001
sine	4,191	.25A	.26B	.26C	20.30	<.001
Slope (%)	4,191	3.9A	3.5B	3.6B	47.29	<.001
Distance to roads (m)	4,191	40.6	40.9	41.1	1.93	.145
Sites ≤ 100 m class 1 streams:						
Elevation (m)	332	8.9	8.8	8.9	.53	.591
Aspect—						
cosine	332	.29A	.33B	.34B	11.28	<.001
sine	332	.29A	.32B	.33B	3.99	.019
Slope (%)	332	8.4A	7.3B	7.4B	8.25	<.001
Distance to roads (m)	332	40.7	41.9	42.1	1.92	.1480

Means in the same row with dissimilar letters are different (Student-Newman-Keuls multiple comparison range test, $P \leq 0.05$).

[a] *P* values are based on general linear model completely randomized block design analysis of variances.

Table 3—Proportion of canopy cover, plant community, and soil types correctly classified using radiotelemetry points and 80- and 95-percent error neighborhoods (E.N.) at the Starkey Experimental Forest and Range, northeast Oregon

Variable	*n*	Point	80% E.N.	95% E.N.	X^2	*P*
All sites:						
Canopy cover[a]	2,742	74.2A	76.9B	76.7B	6.93	0.031
Plant community	2,720	77.2	78.6	78.8	2.25	.324
Soil type	2,742	76.7	76.8	76.9	.04	.981
Sites ≤ 100 m class 1 streams:						
Canopy cover	307	65.2	68.4	69.7	1.55	.461
Plant community	305	75.7	79.3	77.7	1.14	.564
Soil type	307	69.7	68.4	68.7	.13	.936

[a] Proportion of correctly classified sites with dissimilar letter is different (chi-square test of homogeneity).

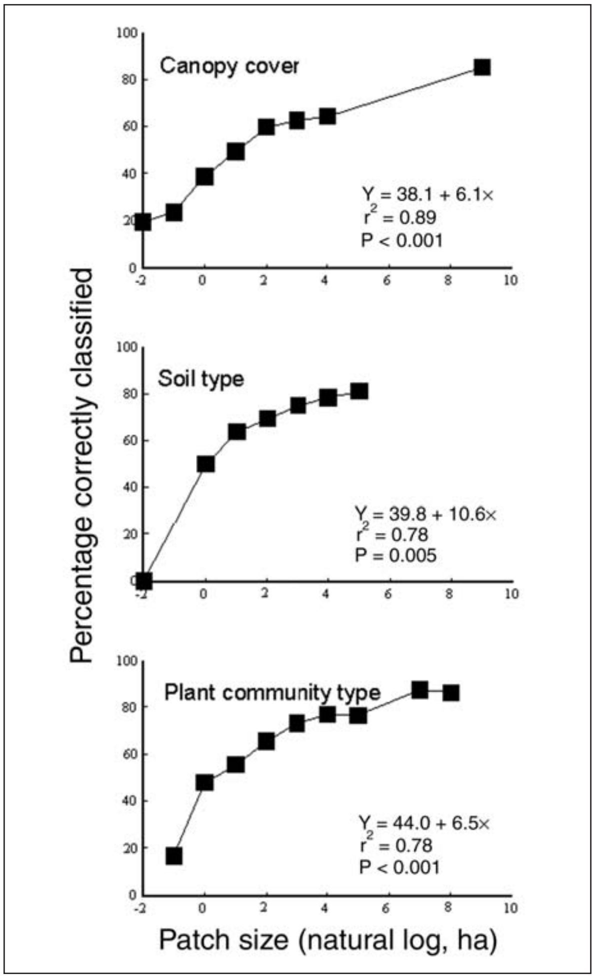

Figure 4—Relation between patch size of canopy cover type, soil type, and plant community type and proportion of correctly classified patches with simulated LORAN-C radiotelemetry point estimates. Number of classes used for each variable was canopy cover (3), soil type (20), and plant community type (15).

We recognize that selection of 80- and 95-percent error neighborhoods was arbitrary. For large error neighborhoods ($\geq$ 80 percent), weighted averages and most probable classes are expected to be similar. We could have used an error neighborhood of 100 percent although this may have allowed for significant influence from outliers that may have been present. Further research should investigate development of selection criteria for error neighborhood size.

Our results indicated that values for environmental variables calculated from error neighborhood estimates were the same as those from point estimates. Although statistically significant differences existed between point and error neighborhood estimates for some variables, we believe that these differences were an artifact of large sample sizes ($n \geq 305$) and not biologically meaningful. Also, we believe differences found between point and error neighborhood estimates were too small to influence power of statistical tests of habitat selection by elk, deer, and cattle. When a point estimate is obtained at Starkey, we are 90-percent confident that it is within a 3.1-ha area (Findholt et al. 1996). However, it is more likely that the location is near the center of the area than the perimeter. Based on the error associated with locations from the AATS at Starkey and the environmental heterogeneity existing within the study area, overall point and error neighborhood estimates of environmental variables did not differ. Thus at Starkey, the power of statistical tests of habitat selection is not influenced by point or error neighborhood estimates.

Our ability to estimate some continuous variables and correctly classify discrete variables declined at sites within riparian areas. This probably was due to the increased habitat heterogeneity and topographical variability of areas near streams. Mean patch sizes of categorical variables in riparian areas were canopy cover (0.4 ha), plant community type (1.9 ha), and soil type (8.8 ha). Although patch size influenced whether the classes of discrete variables were classified correctly (fig. 4), other factors (e.g., patch shape and juxtaposition) probably also affect classification rates. This may explain some of the variation observed among variables where the proportion of correctly classified categories differed with the same patch sizes. It also may explain why differences between point and error neighborhood estimates were not obtained at sites within riparian areas where mean patch sizes were smaller than the radiotelemetry area estimate.

We assumed that measurement error did not exist in our GIS database for the seven environmental variables examined. We estimated that error associated with continuous environmental variables was less than 5 percent (Rowland et al. 1998). Currently, we do not have estimates of measurement error for the discrete variables except for canopy cover, which has a classification accuracy of 82 percent (Rowland et al. 1998). Considering measurement error of continuous variables would not have changed our conclusions because error was small. However, if we added the classification error associated with canopy cover to the error from our analysis, the proportion of correctly classified patches would have been 63 percent with the 80 percent error neighborhood.

We are uncertain whether error neighborhood estimates or point estimates are more useful when environmental variables are incorporated with radiotelemetry locations. Error neighborhoods, however, may provide more accurate environmental data in highly heterogeneous landscapes with small patch sizes. Additional research is needed, especially computer simulations, to determine the relation between radiotelemetry error, habitat heterogeneity (patch size), and sample size. For individuals using radiotelemetry and a GIS, we recommend that our procedure or a similar technique be used to determine whether more accurate values of environmental variables are obtained from radiotelemetry point or error neighborhood estimates.

Samuel and Kenow (1992) describe another method that potentially provides improved estimates of habitat use when misclassification is probable. Their analytical technique involves obtaining random subsamples from the theoretical error distribution of an estimated animal location. Results of Monte Carlo simulations designed to simulate triangulation errors and evaluate habitat misclassification suggest that the subsampling method may improve estimates of habitat use. These adjustment techniques for misclassification should be compared to our error neighborhood approach.

Our model has utility beyond evaluating whether point or error neighborhood estimates more accurately describe an animal's habitat. It may be used to assess how accurately environmental variables can be determined with radiotelemetry points and error neighborhood estimates across extremes of habitat and topographic variability within a study area. It also may be used to determine how many categories of a discrete variable are required to obtain a desired accuracy level. Our method provides insight into whether a telemetry system is sufficiently accurate for habitat analyses or to determine the spatial scale at which analysis is acceptable.

Methods described in this paper could be used with radiotelemetry systems other than those based on LORAN-C, if sufficient locations are obtained to estimate probability weights for pixels surrounding estimated locations. The procedure we describe could be accomplished with automated radiotelemetry systems such as those that use satellites, or those that have fixed-tower receiving stations. Satellite telemetry systems that seem well-suited for our approach include the Argos method (Keating 1994, Keating et al. 1991) and those based on GPS technology (Moen et al. 1996, 1997; Rempel and Rodgers 1997; Rempel et al. 1995). A variety of radiotelemetry systems with fixed-tower receiving stations have been used to locate birds and mammals (Flores and Eddleman 1995, Inglis et al. 1968, Lee et al. 1985). We believe that our approach may be impractical with various types of conventional telemetry such as aerial tracking, homing in on the animal when the animal is not actually seen, and triangulation location techniques such as vehicle-mounted receiving systems or hand-held antenna and receivers. In these instances, directional bearings could be obtained from an unlimited number of locations. This would make it difficult to obtain enough locations to estimate probability weights for pixels around estimated locations.

Acknowledgments

Our study was funded under provisions of the Federal Aid in Wildlife Restoration Act (Pittman-Robertson Act), administered by the Oregon Department of Fish and Wildlife. Funding also was provided by the USDA Forest Service Pacific Northwest Research Station and Pacific Northwest Region. We thank J.H. Noyes, M.M. Rowland, and M.J. Wisdom for reviewing this paper. Research on elk and deer at Starkey is in accordance with approved animal welfare protocol (Wisdom et al. 1993).

English Equivalents

When you know:	Multiply by:	To find:
Meters (m)	3.28	Feet
Hectares (ha)	2.47	Acres
Kilometers (km)	0.62	Miles

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