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**The Starkey Databases: Spatial-Environmental Relations
of North American Elk, Mule Deer and Cattle
at the Starkey Experimental Forest and Range
in Northeastern Oregon**

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Introduction

In the late 1980s, the Starkey Project was initiated to study interactions among North American elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*) and domestic cattle at Starkey Experimental Forest and Range (Starkey) in northeastern Oregon. As part of the Starkey Project, an automated radio telemetry system was developed to collect an unprecedented volume of location data on both wild and domestic ungulates (Rowland et al. 1997). That radio telemetry system was based on rebroadcast LONG RANGE aid to Navigation- (LORAN-) C signals. In this paper, we provide an overview of the databases resulting from this effort.

LORAN is a marine radio-navigation system that was well established before widespread use of the Navstar Global Positioning System (GPS). LORAN-A was the earliest version, developed during World War II, while today LORAN-C serves the civilian community and LORAN-D is used by the military (Logsdon 1992, West and Pittman 1993). LORAN systems operate by measuring the difference in arrival times of a radio signal broadcast at 100 kHz directly from a master station and after being relayed through several secondary stations. The time differences of arrival among the signals routed through the various secondary stations allow a LORAN receiver to determine its location on several hyperbolic lines of position. Where those lines cross is the estimate of the actual location of the receiver (Logsdon 1992, West and Pittman 1993).

The automated radio telemetry system at Starkey consists of a central computer base station, seven radio relay stations located throughout Starkey Forest and radio collars placed on individual elk, mule deer and cattle. Every 20 seconds, the base station pages one of the many radio collars deployed at any given time (Figure 1). As many as 150 animals have been included in the user-

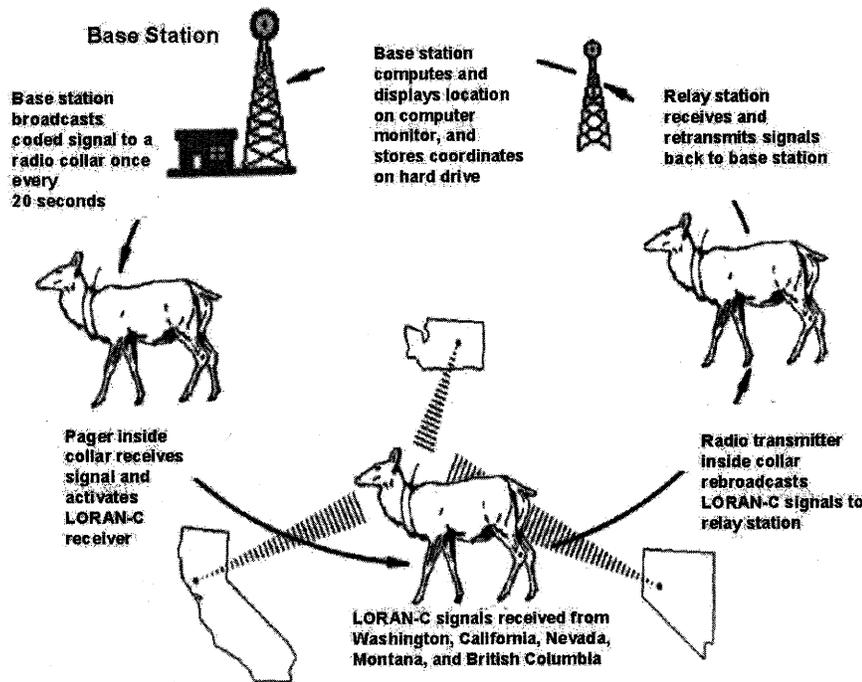


Figure 1. Automated, rebroadcast LORAN-C radio telemetry system used to collect location data on elk, mule deer and cattle at Starkey Experimental Forest and Range (from Rowland et al. 1997).

defined paging list. When a particular animal is paged, a LORAN-C receiver inside the collar responds by collecting raw data, which are then retransmitted via a very high frequency (VHF) radio link to one of the radio relay stations. The relay towers then transmit the data back to the central computer, where the raw data are decoded and information on the animal's location is stored electronically for future analysis (Figure 1). This LORAN-C system has a mean locational accuracy of about 55 yards (50 m); although, some errors can exceed 219 yards (200 m), particularly in the east-west direction (Findholt et al. 1996, 2002).

The Starkey Project has collected information on over 2 million animal locations since 1989. All animal data were collected following approval of protocols by an institutional animal use and care committee (Wisdom et al. 1993). This telemetry database represents one of the largest data sets of large-animal locations ever compiled. A variety of studies have been completed based on these data. Examples include research on ungulate interactions and resource selection (Johnson et al. 2000, Coe et al. 2001, Stewart et al. 2002), effects of roads

(Rowland et al. 2000) and traffic (Wisdom 1998) on elk, mule deer and cattle, spatial and temporal patterns of habitat use (Ager et al. 2003), effects of sample size on estimates of resource selection (Leban et al. 2001) and home range (Garton et al. 2001), and development of ungulate forage allocation models (Johnson et al. 1996).

To facilitate new analyses by other research wildlife biologists, we are providing access to a portion of the Starkey Project telemetry database over the World Wide Web at <http://www.fs.fed.us/pnw/starkey/data>. The telemetry database includes locations of animals in the main study area at Starkey Forest (Wisdom et al. 2004), recorded during spring and summer between 1993 to 1996, along with associated metadata. In addition, we are providing relevant geographic information systems (GIS) layers, such as habitat type, soil, a digital elevational model and the forest road network, in a second habitat database. The release of these data will allow other scientists to formulate and to test hypotheses that are best analyzed with comprehensive information about animal locations, such as that provided by the Starkey Project's data set.

Starkey Ungulate Telemetry Database

Records in the telemetry database consist of elk, mule deer and cattle locations ($n > 287,000$) collected in the 19,180-acre (7,762 ha) main study area at Starkey Forest (Wisdom et al. 2004) during spring and summer (April to mid-August) from 1993 to 1996 (Table 1). Animal locations are provided both as a point estimate in the Universal Transverse Mercator (UTM) coordinates (UTM Easting [E] and UTM Northing [N], all in UTM Zone 11) and also placed in the center point of each 33 by 33 yard (30 x 30 m) pixel that encompasses the point estimate (UTMGrid, UTMGridEast, UTMGridNorth). All UTM coordinates are given in North American Datum 1983 (NAD83). Animals are uniquely identified and were assigned a specific radio-collar number (RadNum) each year. The user should be aware that a given radio-collar number could be worn by different animals in different years. Time and date of each observation is provided in Greenwich Mean Time (GMTime) and in local time (LocTime, in Pacific Standard Time; no adjustments were made for daylight savings time). Time is also provided in a variable called Starkey Time, representing seconds from an arbitrary zero point at 0000 hours on 31 December 1987. Starkey Time is useful in determining elapsed time between any two observations. Sunrise and sunset

Table 1. Synthesized metadata description of variables included in the telemetry database of locations of elk, deer and cattle collected in Main Study Area, Starkey Experimental Forest and Range, spring and summer, 1993 through 1996.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
UTMGrid	Universal Transverse Mercator (UTM) Coordinates that identify the center point of each 33 by 33 yard (30 by 30 m) pixel within Starkey (Rowland et al. 1998); first six digits represent the UTM Zone 11 easting; second seven digits represent the UTM Zone 11 northing. Example: 373695 5014530 are the easting and northing coordinates, respectively, that identify the center point of a given pixel at Starkey.	Meters	Character			373695 5014470, 381885 5007540	Fixed (14)
UTMGrid East	Coordinates in UTM Zone 11 easting Example: 373695 are easting coordinates.	Meters	Numeric (long integer)			373695, 381855	Variable
UTMGrid North	Coordinates in UTM Zone 11 northing Example: 5014530 are the northing coordinates.	Meters	Numeric (long integer)			5005110, 5019120	Variable
ID	Unique alpha-numeric identification code assigned to each ungulate that was radio-collared. Example for deer: 890224EO4 Example for elk: 930318DO. Example for cattle: OSUX83041						Fixed (9)
Starkey time	Cumulative number of seconds that have elapsed since the Greenwich Mean Time of 00:00:00 on 31 December 1987, which represents a starting point of the Starkey ungulate research. Example: Starkey time equals 1 at Greenwich Mean Time of 00:00:01 on 31 December 1987.	Seconds	Numeric			168825628, Variable 272245926	

Table 1 (continued). Synthesized metadata description of variables included in the telemetry database of locations of elk, deer and cattle collected in Main Study Area, Starkey Experimental Forest and Range, spring and summer, 1993 through 1996.

Variable name	Variable definition	Units	Storage type ^a	Code Codes	Code definitions	Range (min, max)	Data format ^b
GMTTime	Greenwich Mean Time expressed as hour:minutes:seconds; 8 hours ahead of Pacific Standard Time. Example: 18:31:47 is 31 minutes, 47 seconds after hour 18 in the 24-hour cycle, as set on GMTtime.	Hour:Minutes:Seconds		Character		00:00:00, 23:59:59	Fixed (8)
GMDate	Date associated with the Greenwich Mean Time, expressed as Year/Month/Day Example: 19930526 is 26 May 1993	Year/Month/Day		Character		19930507, 19960815	Fixed (8)
LocDate	Date synchronized in relation to Pacific Standard Time, which is 8 hours behind Greenwich Mean Time. LocDate is expressed as year/mondi/day and is set for the Pacific Time Zone. Example: The Pacific Standard Time of 19:59:27 has an associated date for the Pacific Time Zone of 19930512, or 12 May 12 1993. However, the commensurate Greenwich Mean Time of 03:59:27 has an associated date of 13 May 1993.	Year/Month/Day		Character		19930506, 19960815	Fixed (8)
LocTime	Pacific Standard Time, which is 8 hours later than Greenwich Mean Time. No adjustment is made for Pacific Daylight Savings Time. Example: 19:59:27 is 59 minutes, 27 seconds after hour 19 of a 24-hour cycle, as set on Pacific Standard Time, which is commensurate with 03:59:27 of Greenwich Mean Time.	Hour:Minutes:Seconds		Character		00:00:00, 23:59:59	Fixed (8)

Table 1 (continued). Synthesized metadata description of variables included in the telemetry database of locations of elk, deer and cattle collected in Main Study Area, Starkey Experimental Forest and Range, spring and summer, 1993 through 1996.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
RadNum	Unique identification code assigned to a given radio-collar. Note that a given radio-collar could be worn by one or more animals within or across years and, thus, should not be confused with the unique identification code for each radio-collared animal, or ID.	Numeric				8,450	Variable
Species	Species of ungulate associated with the animal location, where C = cattle, D = deer, and E = elk.		Character	C, D, E	C = cattle, D = deer, E = elk.		Fixed(1)
UTME	Coordinates in the easting direction. Constitutes the x-coordinate of the point estimate of the animal location.	Meters	Numeric			373705, 381853	Fixed(6)
UTMN	Coordinates in the northing direction. Constitutes the y-coordinate of the point estimate of the animal location.	Meters	Numeric			5005110, 5019118	Fixed(7)
Year	Year in which the animal location was collected.	Year	Numeric			93,96	Fixed(2)
Grensunr	Time of sunrise at Starkey for a given date, expressed in Greenwich Mean Time. See GMT variable.	Hour: Minutes: Seconds	Numeric			12:05:00, 13:35:00	Fixed(8)
Grensuns	Time of sunset at Starkey for a given date, expressed in Greenwich Mean Time. See GMT variable.	Hour: Minutes: Seconds	Numeric			02:23:00, 03:49:00	Fixed(8)
Obswt	Correction to the bias in observation rate of an animal location, where observation rate is defined as the probability of obtaining an animal location from a radio-		Numeric			1.14,3.5	Variable

Table 1 (continued). Synthesized metadata description of variables included in the telemetry database of locations of elk, deer and cattle collected in Main Study Area, Starkey Experimental Forest and Range, spring and summer, 1993 through 1996.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
Obswt (cont.)	collared animal, when an animal location is requested by the Loran-C telemetry system. Application of Obswt (1 divided by the observation rate) increases the number of locations for a given area, according to the degree of bias in observation rate associated with that area (Johnson et al. 1998). Example: An Obswt of 2 would place twice the weight on a given animal location, whereas an Obswt of 1.5 would place 1.5 times the weight on a given animal location. These weights correct for animal locations in a given UTMGrid that were not observed, given the bias in observation rate among pixels (Johnson et al. 1998).						

^a Refers to way in which data is entered, such as character (text), long integer, or floating point.

^b Refers to whether data is of fixed or variable length; for fixed variables, maximum number of characters is displayed

times are given based on GMTIME (Grensunr, Grensuns). Finally, a correction factor is provided to account for spatially dependent observation rates, as discussed by Johnson et al. (1998). The observation rate is defined as the probability of obtaining an animal location as a function of its location at Starkey. The correction factor (Obswt), defined as the inverse of the observation rate (1/observation rate), can be used to weight locations for assessing patterns of spatial use.

Starkey Habitat Database

Spatial layers for various features are provided in the habitat database (Table 2). Each record in the database is identified by UTM coordinates, and represents a unique 33 by 33 yard (30 x 30 m) pixel in main study area, Starkey. All UTM coordinates are given in North American datum 1983 (NAD83). Values for variables, such as ecoclass, soil depth and canopy closure, are provided. Details of the habitat database are available in Rowland et al. (1998).

In addition to providing habitat information in database form, habitat layers are included using ArcInfo (Environmental Systems Research Institute, Redlands, California) interchange format (Table 3). Raster files include ecoclass, soil, a digital elevational model, a canopy closure of overstory trees and black hole corrections for differences in telemetry observation rates as per Johnson et al. (1998). A polygon file is provided showing forest stand boundaries. Line files include roads, streams and fences (game-proof fences and barbed-wire cattle fences). Water sources are given as a point coverage. In addition, metadata is included for the Starkey map coverages. This metadata follows the general format of the Federal Geometric Data Committee's Content Standard for Digital Geospatial Metadata (Federal Geographic Committee 1998). It can be accessed, using a Web browser, as a hyperlinked list of "frequently asked questions" (FAQs), one list per map coverage.

Publications

Additional information about the Starkey Project is available on the World Wide Web at <http://www.fs.fed.us/pnw/starkey>. Two publications from the Starkey Project, to interpret the telemetry and habitat databases, are available there in PDF format; there is also a general history of the Starkey Project, which

Table 2. Synthesized metadata description of variables included in the habitat database for Main Study Area, Starkey Experimental Forest and Range.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
UTMGrid	Universal Transverse Mercator (UTM) coordinates that identify the center point of each 33 by 33 yard (30 by 30 m) pixel within Starkey (Rowland et al. 1998); first six digits represent UTM Zone 11 easting; second seven digits represent the UTM Zone 11 northing. All coordinates are given in NAD83. Example: 373695 5014530 are the easting and northing coordinates, respectively, that identify the center point of a given pixel at Starkey.	Meters	Character			373695, 5014470, 381885, 5007540	Fixed (14)
UTMGridEast	Easting coordinate in UTM Zone 11.	Meters	Numeric (long integer)			373695, 381855	Fixed (6)
UTMGridNorth	Northing coordinate in UTM Zone 11.	Meters	Numeric (long integer)			5005110, 5019120	Fixed (7)
SoilDepth	Soil depth to the restrictive layer (obtained from the Wallowa-Whitman National Forest soils resource inventory [SRI])	Centimeters	Numeric			9,60	Variable
PerSlope	Percent slope (Rowland et al. 1998)		Numeric			0,84	Variable
SINAspct	Sine of aspect (Rowland et al. 1998)		Numeric			-1,1	Variable

Table 2 (continued). Synthesized metadata description of variables included in the habitat database for Main Study Area, Starkey Experimental Forest and Range.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
COSAspct	Cosine of aspect (Rowland et al. 1998)		Numeric			-1, 1	Variable
Convex3	Convexity (Rowland et al. 1998)		Numeric			465.86, 524.64	Variable
DistCWat	Distance to the nearest water source from within a cattle pasture, including class I through III streams and water point sources such as stock ponds and springs	Meters	Numeric	-99	-99 denotes 33 by 33 (30 by 30 m) pixels in the pasture that are not available to cattle. These pixels should be excluded from any analyses of cattle distance to water.	-99,2714	Variable
Canopy	Total canopy closure (%) of all trees > 1 inch (2.5 cm) diameter at breast height)		Numeric			0.85	Variable
Elev	Elevation (Rowland et al. 1998)	Meters	Numeric			1121,1500	Fixed (4)
DistEWat	Distance to the nearest water source from within an ungulate-proof pasture (e. g., Main Study Area), including class	Meters	Numeric			0,1188	Variable

Table 2 (continued). Synthesized metadata description of variables included in the habitat database for Main Study Area, Starkey Experimental Forest and Range.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
DistEWat (cont.)	I through III streams and water point sources such as stock ponds and springs.						
EcoGener	General ecoclass description; modified from the original ecoclass variable (Rowland et al. 1998) to include only the dominant forest canopy species		Character	AB CD CJ CL CP CW GB MD MM MW NR SD WR	Buildings, structures, roads Douglas-fir, Juniper, Lodgepole pine, Ponderosa pine White fir, grand fir, Bunchgrass vegetation, Dry meadow ^c , Moist meadow ^d , Wet meadow ^e , Rocky land, Dry shrubland ^f , Running water (stream, river, creek, ditch)		Fixed (10)
DistOPEN	Distance to the nearest open road (Rowland et al. 1998)	Meters	Numeric			0,2419	Variable
DistRSTR	Distance to the nearest restricted access road (Rowland et al. 1998)	Meters	Numeric			0,2315	Variable

Table 2 (continued). Synthesized metadata description of variables included in the habitat database for Main Study Area, Starkey Experimental Forest and Range.

Variable name	Variable definition	Units	Storage type ^a	Codes	Code definitions	Range (min, max)	Data format ^b
DistCLSD	Distance to the nearest closed road (Rowland et al. 1998)	Meters	Numeric			0,2208	Variable
DistEFnc	Distance to the nearest ungulate-proof fence (Rowland et al. 1998)	Meters	Numeric			0,4243	Variable
CowPast	Cattle pasture (Rowland et al. 1998)		Character	BEAR HORSE SMITH- BALLY HALF- MOON MDW- CRK NE STRIP			Fixed
ForgProd	Forage production (biomass of under-story species considered forage for ungulates; Hall 1973)	Kilograms/ Hectare	Numeric		0,2200		Variable
DistEdge	Distance to nearest edge, based on the EcoGener polygons used for ecoclasses	Meters	Numeric		0,426		Variable

^a Refers to way in which data are entered, such as character (text), long integer, or floating point.

^b Refers to whether data is of fixed or variable length; for fixed variables, maximum number of characters is displayed.

^c Water table available part of the season.

^d Water table available all growing season.

^e Surface moist or wet all of growing season.

^f Includes sagebrush and non-forest zone shrubland; not desert.

Table 3. Habitat layers in Arc Info export format for Main Study Area, Starkey Experimental Forest and Range.

Habitat layer name	Layertype	Description
vegetation-ecoclass	grid	Map of vegetation ecoclasses; 33 by 33 yard (30 by 30 m) cells
soils	grid	Map of soil types; classified by soil series and depth; 33 by 33 yard (30 by 30 m) cells
DEM	grid	Digital elevation model for Starkey; 33 by 33 yard (30 by 30 m) cells
Black-hole corrections	grid	Black-hole corrections for spatial differences in telemetry observation rates (Johnson et al. 1998); 33 by 33 yard (30 by 30 m) cells
canopy closure	grid	Canopy closure of overstory trees
vegetation forest-stands	polygon	Map of forest stands; classified by ecoclass
roads	line	Map of all roads on and immediately adjacent to Starkey; classified by road type
streams	line	Map of all stream drainages; classified by stream class, presence or absence of running water
game-proof fences	line	Map of game-proof fences only
all-fences	line	Map of all fences, including barbed-wire cattle fences and enclosures
water points	point	Location of water point sources such as stock troughs

contains information about telemetry data (Rowland et al. 1997) and details of the Starkey Habitat Database (Rowland et al. 1998). A complete list of Starkey Project publications, many available as full-text PDF files can be found at <http://www.fs.fed.us/pnw/starkey/publications>.

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