Using ArcMap and Logistic Regression to predict locations of gray wolf (*Canis lupus*) rendezvous sites

**Abstract:**
The reintroduction of gray wolves (*Canis lupus*) into Idaho has been successful. As wolves are reaching the threshold of a recovered population, new monitoring techniques are needed. Radio telemetry, the current monitoring method, is very effective, but logistically challenging and costly as the wolf population expands. Noninvasive genetic sampling is one of the most hopeful monitoring alternatives to radio telemetry. For field efficiency, resource selection maps are used to pinpoint areas of high probability rendezvous sites. Resource selection maps are developed using logistic regression models that are derived from landscape variables based on presence and absence wolf data. ArcMap is a very useful tool for deriving the variables to develop the regression model.

**Background:**
Currently gray wolf numbers across Idaho are stable, and wolves are approaching removal from the US Endangered Species List. After delisting, the management and funding for wolf monitoring will shift to the state’s jurisdiction (Nie 2003). Lacking the federal funding supplied under the Endangered Species Act, Idaho is actively piloting wolf management and monitoring methods to develop more cost effective approaches. Kunkel *et al.* (2005) proposed a suite of noninvasive methods that could work together to effectively monitor and manage Idaho’s wolf population, one of which is summer scat surveys coupled with genetic analysis.

The study area in Central Idaho is composed of two areas of high known wolf density (Game Management Unit 28 and GMUs 33, 34, and 35 combined) and two areas of known low wolf density (GMU 24 and GMU 42). An effective way to sample the large study area is to target rendezvous sites. After the pups are born, the pack moves to a rendezvous site where they stay for up to a month (Mack *et al.* 2006; Mech 1970). When these sites are located, there is indication of reproductive packs and a wealth of DNA samples. An 8 year study in Alaska found
den and rendezvous sites located on knolls or hillsides associated with south and/or east exposures and in aspen, willow and semi-open spruce stands (Ballard and Dau 1983). With knowledge of landscape parameters important to wolf rendezvous sites, resource selection maps can be constructed using logistic regression to identify places within the study areas with the highest probability of rendezvous sites.

Resource selection, a measure of use versus availability of resources, is a useful management tool for wildlife populations (Alldredge et al. 1998; Manly et al. 2002). Typical methods for resource selection include chi-square goodness of fit (White and Garrott 1986), multivariate analyses like logistic regression (Alldredge et al. 1998; Manly et al. 2002) and more modern techniques like Ecological Niche Factor Analysis (Hirzel et al. 2002). Together, logistic regression and GIS have been used to predict landslide hazards in northeastern Kansas (Ohlmacher and Davis 2003), build habitat suitability models for the endangered Mt. Graham red squirrel (Pereira and Itami 1991), and develop models of elk calving habitat in prairie environments (Bian and West 1997). ArcGIS is helpful in both extracting the variables to run logistic regression and to build resource selection maps based on the regression equation.

**Objectives:**

The main objective is to develop a logistic regression model, using landscape data, for the prediction of wolf rendezvous sites across Idaho. This model will be used to develop a resource selection map targeting high probability rendezvous sites for field crews to visit and collect wolf sign. The genetic analysis of the samples will provide wolf population information for managers.

**Methods:**

Game Management Unit 28 comprising the area of Salmon, ID was used for the fine-scale analysis. 126 wolf data points were collected the summer of 2007 within GMU 28. The 44
presence points were determined from wolf scat, hair, track, howls, and/or sightings. The 82 absence points were areas visited and after a thorough search no sign was found.

ArcMap 9.2 and accompanying tools were for the analysis. The GAP Idaho land cover map (Scott et al. 2002) was masked by GMU 28 (map from Bureau of Land Management, Idaho Office). The mid-scale Land Cover map has a cell size of 30 meters and has integer values ranging from 1000 to 9000 indicating different categories of land cover. The spatial analyst tool ‘reclass’ was used to combine the land cover values into common categories based on their thousands-place value (table 1). The data points were overlaid on the raster land cover and each point was buffered using the vector analysis tool ‘buffer.’ The buffer was a circle with a radius of 2.5 km (figure 2). The size of the buffer was decided based on literature indicating the daily movement distance of gray wolves in Italy and Poland between 17 – 38 km/day (Ciucci et al. 1997; Jedrzejewki et al. 2001). The buffer size chosen was on the small end because the studies were based on radio-telemetry and the movement calculated was net movement, not necessarily movement in a straight-line distance.

Hawth’s tools, an extension for ArcMap, were used to calculate the number of cells of each land cover value in each of the buffer zones (Beyer 2004). Hawth’s ‘thematic raster summary tool’ takes input of a categorical raster layer and a polygon layer and outputs a dbf table with cell counts of each category within each polygon (Beyer 2004). The area of each category within each polygon was calculated by multiplying the count by the cell size squared (30m x 30m). Since the area of each polygon was known (19,634,954 m²), the frequency, in percent, of each category within each polygon was calculated by dividing the area of that category by the total area and multiplying by 100 per category, per polygon (table 2; table 3).
The frequencies are continuous variables and can be used in logistic regression. SAS\textsuperscript{1} proc logistic was used to calculate the parameters for the model. Six different models were run and the AIC scores were viewed to pick the most parsimonious model (Burnham and Anderson 2002). All of the AIC scores were within 4 of each other. Based on the close AIC scores the models are viewed as equal and the most biologically significant model was chosen (table 4).

\textit{Results and Discussion:}

The parameters of non-forest, forest, and riparian were kept in the model (table 4):

\begin{equation}
\text{Logit } Y = -1.0403 + 0.0244 \text{ [Nonforest]} + 0.00515 \text{ [Forest]} - 0.1538 \text{ [Riparian]}
\end{equation}

The model chosen as the best model is only the best model among the six models ran in SAS. Therefore, it is necessary to look at the biological meaning of the model and use logic to conclude if the model is a good predictor of rendezvous sites. The average frequency of land cover for presence and absence points reveals very little difference in the percent frequency of used versus avoided (figure 1). The ‘best’ model may not be a biologically meaningful model. A much more thorough search will follow using the same methods of deriving variables using ArcMap and GIS layers. Other variables that might help predict rendezvous sites include: slope, elevation, aspect, distance to water, distance to roads, distance to areas of high human density, elk habitat, and land ownership. More logistic regression models will be run and the variables that significantly contribute to the prediction will be kept. The final model can be input into ArcGrid Workstation or Raster Calculator to develop a resource selection map to predict wolf rendezvous sites.

\textsuperscript{1} The regression model for this paper was generated using SAS software, Version 9.1 of the SAS System for Windows. Copyright \textcopyright 2002-2003. SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.
Works Cited


Table 1: Reclassification of ID GAP Land Cover map based on nine broad categories (Scott et al. 2002).

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<th>Map value (Reclassified)</th>
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<td>9000s*</td>
<td>Other (e.g. ice, snow, cloud cover)*</td>
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*No buffer zones contained any of this type of land cover; variable was not included in model.

Table 2: Derivation of frequency (%) of land cover value from cell counts. Land cover value used is ‘Non-Forested.’

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<th>Area of Buffer (m²)</th>
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<th>Non-forest area (m²)</th>
<th>Non-forest frequency (%)</th>
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Table 3: Summary of frequency (%) of each land cover value within each polygon derived from the output of Hawth’s ‘thematic raster summary tool.’

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</table>

2 Table 3 only includes 55 of the 126 presence and absence data points used in the analysis.
Table 4: Models developed to determine the best model for predicting the occurrence of wolf rendezvous sites across central Idaho, based on land cover.

<table>
<thead>
<tr>
<th>Model</th>
<th>AIC³</th>
<th>Parameter</th>
<th>Ward’s chi-square⁴</th>
<th>p-value⁵</th>
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</thead>
<tbody>
<tr>
<td>Global</td>
<td>170.788</td>
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<td>0.1891</td>
<td>0.6637</td>
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<tr>
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<td></td>
<td>Agriculture</td>
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<td>0.5166</td>
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<td>0.7110</td>
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<td>0.0590</td>
<td>0.8081</td>
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<tr>
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<td>Water</td>
<td>0.0006</td>
<td>0.9800</td>
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<tr>
<td></td>
<td></td>
<td>Riparian</td>
<td>1.6608</td>
<td>0.1975</td>
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<td>Alpine Meadow</td>
<td>0.0004</td>
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<tr>
<td>Without ‘Water’</td>
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<tr>
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<td></td>
<td>Agriculture</td>
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<tr>
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<td></td>
<td>Nonforest</td>
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<td>0.8443</td>
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<td>Forest</td>
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<td>0.8806</td>
</tr>
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<td></td>
<td>Riparian</td>
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<td>0.3111</td>
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<td></td>
<td>Alpine Meadow</td>
<td>0.0001</td>
<td>0.9914</td>
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<tr>
<td>Without ‘Water’ and ‘Alpine Meadow’</td>
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<td>Developed land</td>
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</tr>
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<td>Riparian</td>
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<tr>
<td>Developed Land, Agriculture, Nonforest, and Riparian</td>
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<td>Riparian</td>
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<td>0.3384</td>
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<td>Developed Land, Nonforest, Forest, and Riparian</td>
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<td>Developed land</td>
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<td>Riparian</td>
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<tr>
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<td>Nonforest</td>
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<td>Riparian</td>
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<td>0.3141</td>
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</tbody>
</table>

³ Lowest AIC score indicates most parsimonious model (Burnham and Anderson 2002).

⁴ Wald statistic uses a chi-square distribution and tests for the statistical significance of the individual parameters.

⁵ Significance is determined at the α=0.05 level. Significance indicated by “*”.
Figure 1: Frequency (%) of land cover for presence and absence data

- Developed
- Agriculture
- Non-forested
- Forested
- Water
- Riparian
- Alpine Meadow

Frequency (%)

- Absence
- Presence
Figure 2: Land coverage map for buffered presence and absence points in Salmon district, ID

Land Coverage for Wolf Data in Salmon District, ID

Legend

<table>
<thead>
<tr>
<th>Wolf Data Point</th>
<th>Land Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Present</td>
<td>Agriculture</td>
</tr>
<tr>
<td>○ Absent</td>
<td>Non-forested</td>
</tr>
<tr>
<td></td>
<td>Forested</td>
</tr>
<tr>
<td></td>
<td>Water</td>
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<tr>
<td></td>
<td>Riparian</td>
</tr>
<tr>
<td></td>
<td>Alpine Meadows</td>
</tr>
<tr>
<td></td>
<td>Developed</td>
</tr>
</tbody>
</table>

Land Cover data from GAP (INSIDE Idaho)
Salmon District Boundary from Idaho BLM

Buffer (r=2.5 km)