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Determining Home Range and Preferred Habitat of Feral Horses On the Nevada National Security Site Using Geographic Information Systems

Ashley V. Burns
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Capstone Project

for

Masters of Science in Geographic Information Science

May 11, 2014

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Abstract

Feral horses (*Equus caballus*) are free-roaming descendants of domesticated horses and legally protected by the Wild and Free-Roaming Horses and Burros Act of 1971, which mandates how feral horses and burros should be managed and protected on federal lands. Using a geographic information system to determine the home range and preferred habitat of feral horses on the federally managed Nevada National Security Site can enable wildlife biologists in making best management practice recommendations. Site suitability was calculated for elevation, forage, slope, water presence and horse observations and were combined in successive iterations into one polygon. Suitability rankings established that 85 square kilometers are ideal habitat for feral horses on the NNSS, with 860 square kilometers of good habitat and 2,082 square kilometers of fair habitat and 484 square kilometers of poor habitat.

Introduction

Feral horses (*Equus caballus*) are free-roaming descendants of domesticated horses that can be found in many wilderness areas throughout western United States (Figure 1). This project will attempt to understand the ways vegetation, slope, elevation and water resources can be used to determine feral horse home range in an isolated geographic region using a geographic information system (GIS). Feral horses are legally protected by the Wild and Free-Roaming Horses and Burros Act of 1971 (Ninety-Second Congress of the United States 1971), which mandates how feral horses and burros should be managed and protected on federal lands. Using a GIS to determine the feral horse home range should improve horse management practices.

Figure 1. Two wild horses in southwest Wyoming (Anderson 2008)

Problem Statement or Thesis:

The Nevada National Security Site (NNSS) is a federally managed land located in a remote portion of the Great Basin and Mojave Deserts in south-central Nevada. Biologists conduct periodic horse census surveys on the

NNSS. The feral horse home range is then deduced to determine whether on-site activities are impacting the resident horses. Feral horse home range can be computed using GIS to determine the preferred habitat based on horse observations, vegetation type, slope, elevation and water accessibility. This research will assist wildlife biologists in making best management practice recommendations.

Comment [SRH1]: This is the problem right? State as a problem or questions.

Comment [SRH2]: How is this related to the problem or research question?

Literature Review

Feral horse monitoring has occurred on the NNSS since 1989 and has continued through the present (Hansen, et al. 2010). Biologists have acquired information on the resident horse population annually, including the geospatial location of individual horses and bands found on the NNSS. Road surveys are conducted to assess horse distribution by interpreting the observed sign found along roadways, including horse droppings and hoof prints. Water sources, both natural and man-made, were also assessed for horse usage by determining the condition of the area around the water source and through observation. The horse range is then manually estimated by melding the biologist's innate knowledge of the historic horse utilization with the observed sign during a particular calendar year.

Hooge et al. stated that GIS is the perfect environment to analyze movement patterns using multiple layers of habitat data. Further, Hooge et al. declares that there are "obvious advantages" of combining GIS with the spatial aspect of animal movement behavior. He then developed a software application with more than 50 functions because it was not available at the time with commercial off-the-shelf applications. These functions include, but are not limited to, home range analyses, random walk models, and habitat analyses (Hooge, Eichenlaub and Solomon 2001).

Selkirk and Bishop evaluated whether home range and habitat analysis can be extended and improved by using the tools integrated in geographic information software rather than using external home range software. They use the minimum convex polygon, fixed kernel techniques and Schoener index independence test for evaluating home range, which are integrated as functions in ArcView and various extensions (Selkirk and Bishop 2002).

Koehler and Pierce evaluated the size of home ranges to determine if the size was dependent upon sex, study site or objectives of forest management. Three study sites were evaluated in Washington, United States of America. Forest-cover was evaluated at each study site for individual bears and between study sites within composite home ranges to measure "use, interspersion and juxtaposition of cover types" (Koehler and Pierce 2003). Using fixed-kernel estimates of home range, Koehler and Pierce determined that males and females occupied different home-range sizes in different forest-cover types, which may be explained by differences in annual precipitation and behavioral differences between males and females (Koehler and Pierce 2003).

Comment [SRH3]: State of?
The USA context makes it sound confusing.

Owen et al. examined home range size and habitat use of nine bats in West Virginia, United States of America. The mean home range was calculated using 95% adaptive kernel method and evaluated for preference between pristine areas verses disturbed areas (Owen, et al. 2003).

Litzgus and Mousseau evaluated habitat use, movement patterns and seasonal activity of spotted turtles using a combination of radio telemetry, global positional systems and GIS software. Habitat use during a three year period was different between male and female and varied seasonally. Annual fidelity was observed between individual animals with concentrated overlap during breeding. Because the study differentiated between the role of natural and anthropogenic disturbances, management recommendations for habitat preservation of this declining species were made (Litzgus and Mousseau 2004).

Wong et al. evaluate data from six radio-collared sun bears over a two-and-a-half year period in the rainforest of Borneo. Home range sizes were calculated using the 95% adaptive kernel method. Daily movement distances were calculated and were affected by food availability. Diurnal activity patterns were analyzed. Logging management practice recommendations were made based on the study (Wong, Servheen and Ambu 2004).

Katajisto and Moilanen declare that studies of habitat selection can be inherently biased because the radio-tracking data used to calculate the utilization density distribution is temporally irregular. Radio-tracking data consists of "frequent autocorrelated observations interspersed with temporally more independent observations" (Katajisto and Moilanen 2006). This results in some areas being heavily sampled, skewing the data. The common solution is to resample for a more appropriate time interval which may introduce data loss through over-reducing the sample size. Katajisto and Moilanen propose a time-kernel method to "account for temporal aggregation of observations" while reducing the potential data skew introduced by temporally autocorrelated observations.

Grueter et al. evaluates the choice of analytical methodology used to estimate home ranges, stating that the size can vary tremendously. Specifically addressing the grid cell and the minimum convex polygon methods, Grueter et al. proposes an adjusted polygon method where only those areas suitable for habitation are analyzed, stating that the adjusted minimum convex polygon method is much more reliable when group movement is limited. The minimum convex polygon was preferred for monthly and seasonal home range calculation while the grid cell method was more precise for annual home range estimates (Grueter, Li and Ren 2009).

Kie et al. evaluated how recent advances in animal telemetry technology have propagated large datasets where data-intensive techniques are used to determine animal home ranges. Kie et al. compares methodologies such as kriging and non-linear generalized regression models with more traditional methods such as kernel density estimators to determine if traditional methods are still relevant (Kie, et al. 2010).

Scull et al. declare that more meaningful home range modeling can be calculated from field data with GISs while evaluating mountain gorilla data from Uganda. Scull et al. compare the modeling methods of local convex hull and minimum convex polygon by looking at sensitivity to outliers, comparison between groups with different ranging behavior and proportion of home range found outside a predefined geographic area. The local convex hull ranges were found to be smaller than minimum convex polygon ranges and more sensitive to outliers (Scull, et al. 2012).

Girard et al. addresses how habitat selection can vary throughout the season in free-ranging feral horse herds in Alberta, Canada. By tracking global positioning system collared horses for two years, Girard et al. evaluated home ranges and vegetation preferences for four harems to establish critical horse habitats within a portion of the Rocky Mountain Forest Reserve. Home ranges were created using the Home Range Tool suite for ArcMap 9.3.1 (Girard, et al. 2013).

Design and Implementation:

The study area included all of the NNSS, which is located in Nye County in south-central Nevada (Figure 2). The southeast corner of the NNSS is about 90 kilometers northwest of the center of Las Vegas in Clark County. The NNSS encompasses about 1,360 square miles and is

Figure 2 Map of study area showing relative location of NNSS to Las Vegas, Nevada.

surrounded on all sides by federal lands (National Security Technologies, LLC. 2011). There is currently a Cooperative Agreement directing the Management and Operations Contractor that manages the NNSS to maintain favorable habitat for the existing feral horse population. Biologists conduct periodic horse census surveys on the NNSS by driving selected roads to observe both animals and animal signs and by using cameras to record individual animals. The direct population count for calendar year 2010 was 35 individuals, not including foals, occupying a home range of approximately 104 square kilometers (Hansen, et al. 2010). There were 137 records spanning from September 1, 2008, through December 4, 2011, used in this analysis.

Ecological data used in these analyses were provided by National Security Technologies, LLC. Ecological Service wildlife biologists (National Security Technologies, LLC., Ecological Services 2014). Horse observations, roads surveyed for horses, water resources, and vegetation data are provided in an ESRI file geodatabase. Horse observations from conducted surveys and opportunistic sightings are available from 2000-present;

Comment [SRH4]: Where did the company get the data?

however, only data collected from September 1, 2008 through December 4, 2011 will be analyzed. These data include the number of animals observed in each band or the type of sign observed, their geospatial location and general condition comments for observations occurring on a specific date, including number of horses observed. Horse survey roads indicate the routes driven by biologists while conducting horse surveys on the NNSS during 2010. Water resources provide the spatial locations of 30 naturally occurring and man-made watering holes on the NNSS that include seeps, springs, ponds and tanks. Data include the geospatial coordinates, names and type of resource. The m~~M~~ethodology used while conducting these surveys ~~are~~ is available in the Annual Environmental Monitoring and Compliance Report (Hansen, et al. 2010).

Additional ecological data include vegetation polygons for the whole NNSS. These geospatial polygons combine similar vegetative groups together into ecological landform units or ELUs. Transects sampled within the ELU provide information on species of plants and their frequency within the ELU. The attribute data also contains previously calculated information on slope, elevation and average vegetation cover (Ostler, et al. 2000). Biologists also noted during transect surveys if signs of animal use, including horse sign were detected. All data were provided in an ESRI file geodatabase.

Additional local geographic data used were provided by the National Security Technologies, LLC. Geographic Information Systems Group. Data provided include the NNSS Operational Boundary, Road Centerlines, and shaded-relief (National Security Technologies, LLC., Geographic Information Systems Group 2014). The NNSS Operational Boundary is the administrative extent of the NNSS as defined by various Public Land Orders and Memoranda of Understandings with the United States Air Force. Road Centerlines were digitized from orthophotography collected in 1997-1998 at a scale of 1:2000 feet. The shaded-relief was created from the DEM generated in 1997-1998. These data will be used to provide geographic context to the biologic data used in the analyses and were provided in an ESRI file geodatabase.

Background images provided in maps for context are accessed via ESRI's ArcGIS Online and include the National Geographic World Map Service (National Geographic, Esri, DeLorme, NAVTEQ, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, iPC 2011) and USA Counties Map Service (Esri, TomTom, Department of Commerce, Census Bureau, U.S. Department of Agriculture (USDA), National Agricultrual Statistics Sercice (NASS), United States Central Intelligence Agency 2012). Maps and spatial geostatistical analyses used throughout this document were created using ArcGIS® version 10.1 software by Esri (Esri 2012). Jake Wall's Movement Ecology Tools for ArcGIS® (ArcMET) were used to calculate an Adaptive Local

Convex Hull (a-LoCoH) range (Wall 2014). All maps were designed with a Universal Transverse Mercator, North American Datum 1983, meters, projection.

Geostatistical analyses were used to ascertain whether there is a correlation between horse observations and vegetation, slope and elevation. Vegetation data was spatially joined using to the horse observation data to determine which vegetation association horses can be most frequently seen or scat observed. The Chi-square Test, Correlation Coefficient and Frequency and Percentage Distributions were calculated in Microsoft Excel® (Microsoft 2007). To test whether there is a link between horse observations, slope and elevation, vegetation data will be spatially joined to the horse observation data to determine their associated vegetation association and extract their slope and elevations. Records with missing slope and elevation data will be excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase® (Wadsworth/Thomson Learning 2001). To test whether there is a link between horse observations, average vegetation cover and elevation, vegetation data were spatially joined to the horse observation data to determine their related vegetation association and extract their average vegetation cover and elevations. Records with missing vegetation cover and elevation data were excluded. The Multiple Regression and Correlation data will be calculated in Student MicroCase®. To test whether there is a link between horse observations and average vegetation cover, slope and elevation, vegetation data will be spatially joined to the horse observation data to determine their related vegetation association and extract their average vegetation cover, slope and elevations. Records with missing vegetation cover, slope and/or elevation data were excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase®. Results for all analyses are reported in tables and maps.

Results

To test the null hypothesis that vegetation associations cannot be used to predict horse observations, vegetation data were spatially joined to the horse observation data to determine in which vegetation association horses were most frequently seen or scat were observed. The Chi-square Test, Correlation Coefficient and Frequency and Percentage Distributions were calculated in Excel (Table 1). Vegetation associations and horse observations are not related strictly by chance, which can be seen in Figure 3; the null hypothesis is rejected.

Vegetation Association	Horse Observation
Artemisia nova-Artemisia tridentata	3.51%
Artemisia nova-Chrysothamnus viscidiflorus	16.14%
Artemisia tridentata-Chrysothamnus viscidiflorus	12.98%
Chrysothamnus viscidiflorus-Ephedra nevadensis	6.67%
Chrysothamnus ramosissima-Ephedra nevadensis	4.56%
Ephedra nevadensis-Grayia spinosa	5.96%
Ephedra nauseosa-Ephedra nevadensis	11.93%
Hymenoclea salsola-Ephedra nevadensis	2.11%
Pinus monophylla-Artemisia nova	17.19%
Pinus monophylla-Artemisia tridentata	8.77%
Disturbed	10.18%
Total	100.00%
(N)	285

$\chi^2 = 20.976$; df = 10; $p < 0.02$; $r = 0.710$

Table 1 Chi-square Test, Correlation Coefficient and Frequency and Percentage Distribution: Vegetation Association by Horse Observations

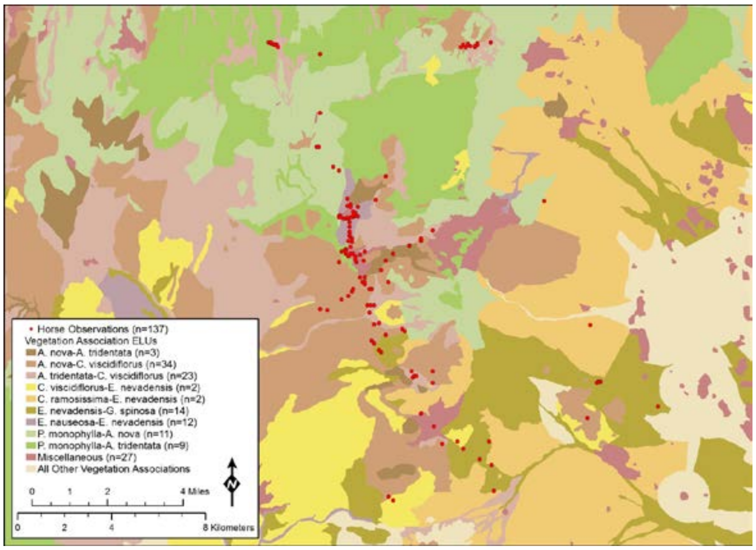

Figure 3 All Horse Observations within Vegetation Associations

To test the null hypothesis that slope and elevation cannot be used to predict horse observations, vegetation data were spatially joined to the horse observation data to determine their related vegetation association and extract their slope and elevations. Records with missing slope and elevation data were excluded. The Multiple Regression and Correlation data were calculated

Analysis of Variance
Dependent Variable: horse
N: 97 Missing: 3
Multiple R-Square = 0.061 Y-Intercept = 8.270
Standard error of the estimate = 1.976
LISTWISE deletion (1-tailed test) Significance Levels: **=.01, *=.05

Source	Sum of Squares	DF	Mean Square	F	Prob.
REGRESSION	23.864	2	11.932	3.056	0.052
RESIDUAL	367.023	94	3.904		
TOTAL	390.887	96			

	Unstand.b	Stand.Beta	Std.Err.b	t
slope	-0.009	-0.043	0.023	-0.406
elevation	-0.003	-0.229	0.001	-2.163 *

Figure 4 ANOVA Statistic from Student MicroCase® for Horse Observations by Slope and Elevation

in Student MicroCase® (Figure 4). Slope, elevation and horse observations are not related strictly by chance, which can be seen in Figure 5; the null hypothesis is rejected.

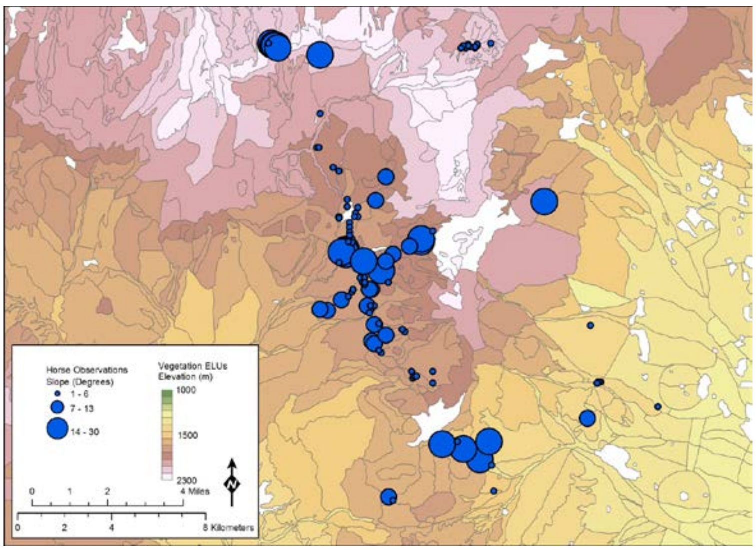

Figure 5 Horse Observations Symbolized by Slope with Vegetation Associations Symbolized by Elevation

To test the null hypothesis that average vegetation cover and elevation cannot be used to predict horse observations, vegetation data were spatially joined to the horse observation data to determine their associated vegetation association and extract their average vegetation cover and elevations. Records with missing vegetation cover and elevation data were excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase® (Figure 6). Average vegetation cover, elevation and horse observations are not related strictly by chance, which can be seen in Figure 7; the null hypothesis is rejected.

Analysis of Variance
Dependent Variable: horse
N: 97 Missing: 5
Multiple R-Square = 0.059 Y-Intercept = 8.446
Standard error of the estimate = 1.978
LISTWISE deletion (1-tailed test) Significance Levels: **=.01, *=.05

Source	Sum of Squares	DF	Mean Square	F	Prob.
REGRESSION	23.226	2	11.613	2.969	0.056
RESIDUAL	367.661	94	3.911		
TOTAL	390.887	96			

	Unstand.b	Stand.Beta	Std.Err.b	t
elevation	-0.003	-0.243	0.001	-2.398 *
avgvegcove	0.001	0.004	0.020	0.038

Figure 6 ANOVA Statistic from Student MicroCase® for Horse Observations by Average Vegetation Cover and Elevation

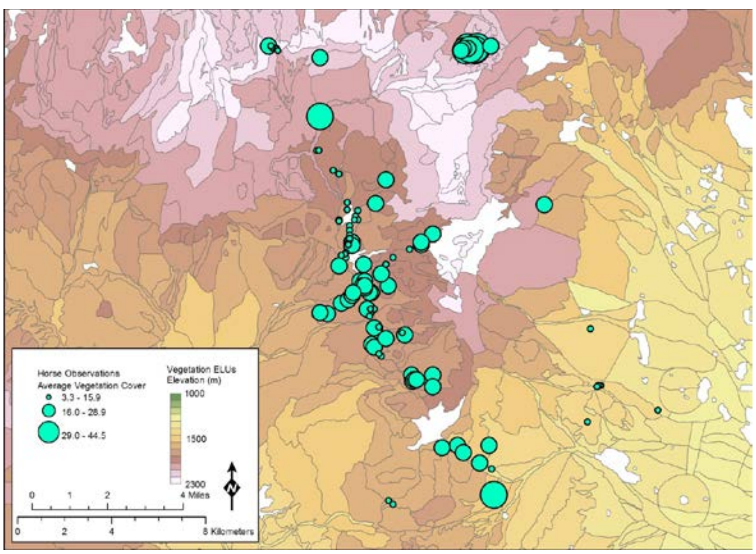

Figure 7 Horse Observations Symbolized by Average Vegetation Cover with Vegetation Associations Symbolized by Elevation

To test the null hypothesis that average vegetation cover, slope and elevation cannot be used to predict horse observations, vegetation data were spatially joined to the horse observation data to determine their associated vegetation association and extract their average vegetation cover, slope and elevations. Records with missing vegetation cover, slope and/or elevation data were excluded. The Multiple Regression and Correlation data were calculated in Student MicroCase®, which can be seen in (Figure 8) the null hypothesis is rejected.

Analysis of Variance
Dependent Variable: horse
N: 97 Missing: 5
Multiple R-Square = 0.061 Y-Intercept = 8.249
Standard error of the estimate = 1.987
LISTWISE deletion (1-tailed test) Significance Levels: **=.01, *=.05

Source	Sum of Squares	DF	Mean Square	F	Prob.
REGRESSION	23.867	3	7.956	2.016	0.117
RESIDUAL	367.019	93	3.946		
TOTAL	390.887	96			

	Unstand.b	Stand.Beta	Std.Err.b	t
elevation	-0.003	-0.229	0.001	-2.124 *
avgvegcove	0.001	0.003	0.020	0.029
slope	-0.009	-0.043	0.023	-0.403

Figure 8 ANOVA Statistic from Student MicroCase® for Horse Observations by Average Vegetation Cover, Slope and Elevation

Horse observation data were manipulated to format the time and date of the observations in the correct format for the ArcMET a-LoCoH Range Tool to calculate an estimated home range (Wall 2014). Records without a time stamp were given a default value of 12:00:00, since the tool assumes all geospatial locations have been provided through Global Positioning System tracking systems. Polygons were generated at the 50%, 90%, 95% and 100% level, where the percentage indicates how many points are closest to the average center of all the points located within the polygon. A total area of 103.3 square kilometers were derived at the 100% level (Figure 9); 68.0 square kilometers for the 95% level; 55.2 square kilometers for the 90% level and 8.7 square kilometers for the 50% level.

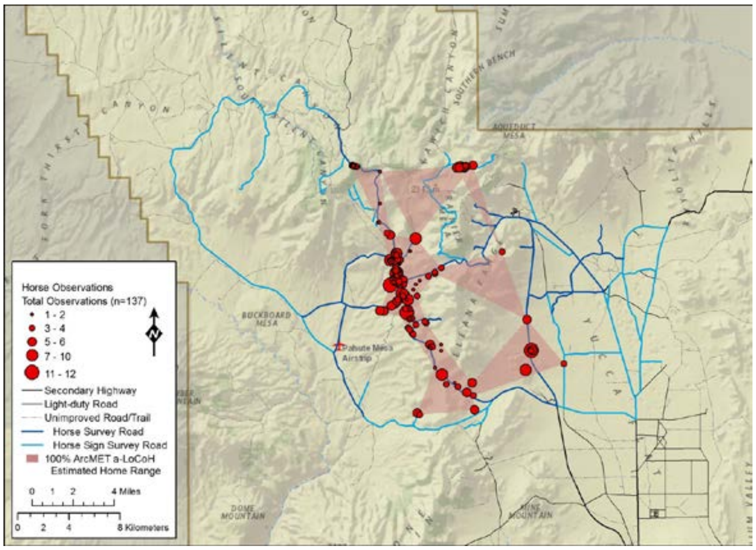

Figure 9 ArcMET Adaptive Local Convex Hull Estimated Home Range with All Horse Observations

Site Suitability was calculated in ArcGIS® using the Identify Tool (Andris 2008). The Identify Tool requires that all features must have the same geometry type, so point values were spatially joined to polygons for analysis. Since the Identify Tool copies attribute values from the input feature classes into the output feature class, part of the preparation involved deleting fields unnecessary to the final analysis.

Point data were prepared for analysis by performing spatial joins on the vegetation association polygons to determine presence or absence within the polygon extent. Water resources, both man-made and naturally occurring were calculated with a value of 10. All other polygons without documented water resources were assigned a value of 0. Horse observations documented by biologists during annual surveys were calculated with a value of 20; horse sign documented during vegetation surveys were calculated with a value of 5. All other polgyons polygons without horse observations were assigned a value of 0.

Slope and elevation data were spatially joined to horse observation data to determine horse preference. Polygons containing NULL values for Slope or Elevation were not evaluated. The slope spatial join indicated that any value less than 20 was desirable; these were calculated with a value of 10. Slope values between 21 and 30 were calculated with a value of 5 and all other polygons were calculated with a 0. The elevation spatial join indicated that any elevation between 1300 and 2000 were used most frequently by horses observed on the NNSS; these were calculated with a value of 10. Elevations between 2001 and 3000 and elevations between 1000 and 1299 were used less frequently, but horses were still observed to utilize locations; these were calculated with a value of 5. All remaining polygons were calculated with a 0.

The values for forage were derived from the vegetation association data by determining if specific species of plants were more desirable as forage. The Bureau of Land Management states that forage species important to feral horses include sagebrush, spiny hopsage, winterfat and various grasses and forbs (U.S. Department of the Interior, Bureau of Land Management 2013). The U.S. Forest Service maintains an online database of plants and their importance for management considerations (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory 2014). One management consideration is whether or not the plant is valuable as forage. Crosschecking the vegetation association dominant plants against the U.S. Forest Service database yielded that *Krascheninnikovia lanata* (winterfat), *grayia spinosa* (spiny hopsage) and various species of *Artemisia* (sagebrush) and *Ephedra* (jointfir) are documented as good forage sources (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory 2014). These species were assigned a value of 10. Additionally, if biologists indicated during the vegetation transects that there were forbs and grasses present, the polygons were assigned a value of 5. All remaining polygons were calculated with a 0.

Values from the prepared polygons for elevation, forage, slope, water presence and horse observations were combined in successive iterations into one polygon. A new field was created named Suitability to house the final calculation. Then, the values for each variable were added together using the Field Calculator in ArcMap® in the field Suitability. Derived data values ranged from 0 through 55 and are displayed in Figure 10 using Natural Breaks (Jenks) with 5 classes. The ArcMET a-LoCoH estimated home range is provided for reference. Suitability rankings established that 85 square kilometers are ideal habitat for feral horses on the NNSS, with 860 square kilometers of good habitat and 2,082 square kilometers of fair habitat and 484 square kilometers of poor habitat.

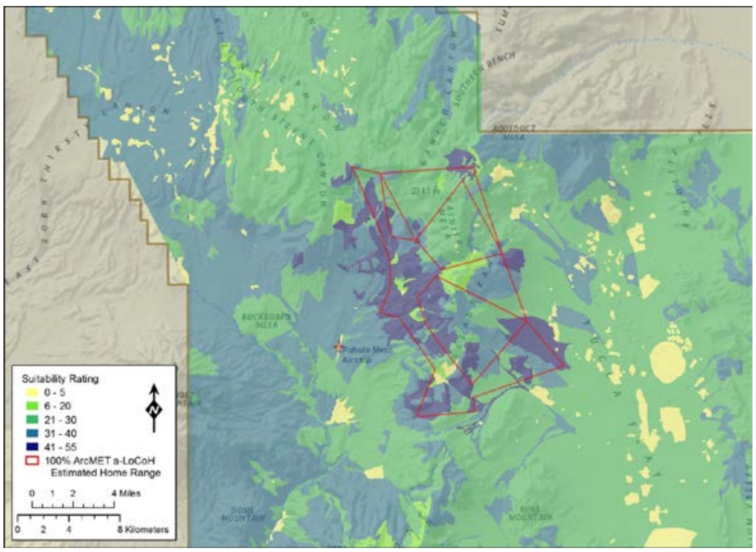

Figure 10 Site Suitability Index Rating

Discussion

Water resources are available as both seasonally and perennially available springs, seeps, ponds, and tanks. Water availability had a strong correlation to where feral horses are geospatially located. The community of feral horses living on the NNSS are similar to other communities living in desert ecosystems in that they are exposed to temperature extremes and are limited by access to sufficient water resources. Rain fall in the desert is generally no more than a few inches in a typical year, mostly occurring during the winter months as snowfall. This necessitates the need for wildlife to locate a persisting water resource during the summer months as an essential for survival.

Vegetation type, which is an indicator of preferred food resources, also had a strong correlation to the geospatial location of horses. Elevation and slope are related to vegetation type, since both are tied to presence or absence of specific plant species. Food and water together comprise the basic elements for survival of any animal species. It is no surprise that these variables can contribute to a meaningful geospatial model predicting preferred feral horse habitat.

Areas for further research?

Nice work and good job integrating tools learned in classes taken.

I'd like to find out more about ArcMET.

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