Interim Performance Report:

Determining prescribed fire and fuel treatment compatibility with semidesert grassland habitat rehabilitation for the critically endangered masked bobwhite quail (*Colinus virginianus ridgwayi*)

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I. Project objectives

The principle objectives of this project are to 1) Improve field sampling methods to efficiently monitor long- and short-term fire treatment effects on semidesert grassland fine fuel loads, vegetation composition and structure important to masked bobwhite quail (*Colinus virginianus ridgwayi*) survival and reproduction, 2) Compare field plots, masked bobwhite habitat conditions and habitat suitability index (HSI) model outputs according to fire management histories summarized from the USFWS fire atlas, 3) assess how fire frequency and spatial and temporal pattern of burn can most likely achieve masked bobwhite habitat rehabilitation, and 4) Determine how other interacting site biophysical factors such as annual variation in rainfall, soil substrates, terrain variability and other edaphic factors may positively or adversely impact habitat conditions modified by fire. To the degree possible, grazing history and other land use factors will also be considered.

Previously derived expert-based HSI models will be used for this project because an established population of mask bobwhite quail does not currently exist on Buenos Aires National Wildlife Refuge (BANWR) study site or for any other location within the US (LaRoche and Conway 2012).

II. Changes to the project

We have completed the second year of this 3-year project. JFSP funding was awarded in July of 2013 and US Fish and Wildlife Service Southwest Region. Our Grants Contracts Office was only able to complete a cooperative agreement and sub-award to research partners at the Northern Arizona University (NAU) Lab of Landscape Ecology and Conservation Biology by February of 2014. This caused some delays to the project, and adjustments were made to the timing of field sampling. We had originally planned to complete all fieldwork in 2014, but have conducted a second full season of fieldwork in 2015 that will be completed this October. Nevertheless, we were able to collect destructively sampled herbaceous plant biomass together with ceptometer LAI measurements in 2013 as part of another USFWS funded project at BANWR. A dry weight biomass regression tree model was developed from oven dried and weighed biomass collected in 2013. The model performed well when tested with quadrat samples left out of model training (r^2 = 0.87). We applied this model to non-destructive samples collected on 2014 BANWR plots.

Despite adjustments to the project timeline, the LAI-based biomass model allowed us to dedicate a greater amount of time to measuring plots for in both 2014 and 2015 field seasons. We have also run preliminary analyses and comparisons with the first seasons plot data that are detailed below. Data summary and analysis scripts are anticipated to expedite final analyses using plot data collected in both 2014 and 2015.

III. Project progress

The following deliverables have been completed or are in progress during the first and second year of the project (**details on pages 3 - 6**):

Project Milestones	**Dates**
Fine fuel biomass data field collection protocol and processing	Aug. – Nov. 2013
Fine fuel biomass model completed	Dec. – Jan. 2014
MS graduate student recruited	Jan. 2014
Sub-award to project cooperator, Northern Arizona University, Lab of Conservation Biology and Landscape Ecology	Feb. 2014
Project kick-off meeting at with BANWR staff, fire managers, cooperators and stakeholders	Jun. 2014
Field stratification and protocol development using fire history and topoedaphic GIS data layers	Jul. 2014
1st field study of masked bobwhite habitat conditions, measuring vegetation composition and structure, soil and fine fuels	Aug. – Nov. 2014
Multivariate analysis of previous years (2012 – 2013) vegetation data	Sept. 2014
Soil sample processing	Jan. – Jun. 2015
Data processing and preliminary analyses of 2014 vegetation data	May – Jul. 2015
2nd field study of masked bobwhite habitat conditions, measuring vegetation composition and structure, soil and fine fuels	Aug. – Oct. 2015

a. Field study 2015

We began the second field sampling the first week of August 2015 that will continue until October or November of this year, depending on rainfall and the onset of annual plant senescence. As with 2014 plots, sampling methods followed the National Park Service (NPS) Sonoran Desert Network (SODN) Terrestrial and Soil Monitoring Protocol and Standard

Operating Procedures that incorporate fuels and other fire related measurements (Hubbard et al. 2012).

An overview of plot sampling methods used is as follows. Each rectangular plot was 20m x 60m with 6 line transects spaced at 10m intervals and 240 point intercepts spaced at 0.5m intervals a long a transect. All plant species were recorded in three height strata (0-0.5m, 0.5-2.0m, and >2.0m) as well as recording underlying soil substrate, biological crust or geologic material. A total of 18, 10cm depth soil samples were taken at three locations per transect in addition to one soil bulk density measurement per plot. Soil bulk density will be used to assess potential site impacts (e.g., compaction) such as those from prolonged grazing history prior to refuge establishment in 1985. Five ceptometer and leaf area index (LAI) measurements were taken at on each of 24 quadrats also recording canopy cover and height for grasses, forbs, cacti and woody material inside the quadrat. Other site features recorded are percent slope, land form attributes, slope type and position, a plot description and site diagram noting the position of dominant trees or other features for plot relocation. A digital photo was taken of the plot from each of four corners and two plot corners along the 50m baseline were permanently marked on the ground with a nail and metal tag.

Plots were spatially referenced to the ground by recording UTM coordinates at each of four plot corners or transect ends using a Trimble GeoXT or Geo7 global positioning system and GPScorrect software to differentially correct positional error.

A total of 90 plots have been measured to date in 2015. All vegetation data is being entered into an NPS-SODN MS Access relational database as it is collected.

b. Preliminary analyses

We summarized field data collected in 2014 on *n* = 116 plots to estimate percent plant cover by species within each of the three height strata noted above (**Fig. 1**). We focused on 2014 plots which were specifically designed to address research questions for this project and included fine fuel biomass measurements. Field data were collected with the same protocol that is currently being used for the 2015 field study. We initially compared estimated herbaceous biomass on plots to herbaceous canopy cover (graminoids, forbs and other herbaceous plants) generated from point intercepts and plants measured in the principal fuel bed layer (0.0 to 0.5 m height) as a validation step. We also calculated overstory percent cover from the tallest plant species recorded at each point intercept on a plot.

We used plots located in three fire frequency strata (Low = 0 – 2, Medium = 2 – 4, and High = ≥5 fires since 1985) to compare species composition on plots with differing fire histories. We hypothesized that more frequent fire would favor plant groups such as a forbs and annual plants that typically develop during early successional stages with increased soil nutrients immediately after a fire. Perennial grasses also likely benefit from high fire frequency such as non-native *E. lehmanniana* where this species is abundant at BANWR on deep clay textured soils (Gieger and McPherson 2005). Conversely, shrubs, sub-shrubs, and other woody plant species may be less abundant on more frequently burned sites. Understanding these relationships is fundamental to determining how fire may influence semidesert grassland vegetation composition and structure important to masked bobwhite habitat rehabilitation.

We used multi-response permutation procedure (MRPP) to test for statistical differences between plant composition and fire frequency strata (global test) as well as compare plots in each frequency strata to each other. We used Bray-Curtis species dissimilarity matrices and 999 permutations to determine significant differences ($\alpha = 0.05$) for all MRPP tests. We removed rare species to emphasize common plants that contributed most to habitat composition and structure. Therefore, plant species with ≤4 occurrences on all plots ($n = 116$) were removed from analyses comparing composition within height strata 0.0 m – 0.5 m and species occurrences ≤1 were removed for the two upper height strata. Comparisons using percent overstory cover also removed species with ≤1 species occurrence.

We used permutational multivariate analysis of variance using distance matrices (PERMANOVA) to compare interactions between fire frequency class, herbaceous biomass (kg/ha), and plant species composition on plots. We also considered the effect of local hillslope terrain from the original plot sampling stratification. Terrain was classed as drainage bottoms and foot slopes, moderate mid-slopes, and steep-slopes or ridgetops using topographic wetness index (TWI; Moore et al. 1993) derived from a 10 m digital elevation model. We used terrain classes to estimate block effects and as a factor for fitting linear models to the species dissimilarity matrix. This analysis was restricted to the primary fuel bed layer and 0.0 to 0.5 m height stratum. We specified principal relationships in the data using non-metric multidimensional scaling (NMDS) and biplots. All statistical analyses were performed using the R statistics software v. 3.1.2 (R Development Core Team 2014) and vegan package (Oksanen et al. 2015).

Some preliminary computational methods were also devoted to estimating masked bobwhite habitat suitability index (HSI) values from plot data. We used 2012 and 2013 field plots from BANWR to initialize models that will be expanded using data collected from all years (2012 to 2015). This work was performed to establish methods needed to summarize plot data consistent with expert derived HSI models (**Fig. 2**). We developed two test HSI models using beta functions developed by LaRoche and Conway (2012) and applied them to plot data summarized by life form. Model functions for each input parameter were standardized and added together. A final standardized habitat suitability score (0.0 – 1.0) was assigned to plots to visually compare outputs using a histogram of plot frequencies within estimate suitability values. Model A was developed using beta functions for shrubs, forbs, and graminoid cover and mode B was developed using forbs and graminoids only as shrub cover is assumed to decrease under a frequent fire regime.

c. Preliminary results

Fine fuel parameters herbaceous biomass and canopy cover measured on plots compared well to one another (**Fig. 3**). These results indicated that field ceptometer measurements and regression tree models developed from destructive sampling in 2013 were applicable to 2014 plot conditions. These relationships will potentially allow use to develop fine fuel biomass models for many of the plots previously sampled in 2012 and 2013.

The total number of 2014 plots measured in each fire frequency strata were 38, 41 and 37 for low, medium, and high fire frequency classes respectively. There were a total of 323 plant species collected for the 0.0 to 0.5 m height strata that was reduced to 71 when plants with ≤4 occurrences on plot intercepts were removed. The 0.5 to 2.0 m height stratum had a total of 116 species that was reduced to 42 removing plant with ≤1 occurrence and the >2.0 m height stratum had a total of 157 species that was reduced to 43 removing plants with ≤1 occurrence. For our comparisons using percent overstory cover by species, we had a total of 316 plant species removing those with less ≤1 occurrence that retained 104 species for this analysis.

We initially compared the removal of ≤1 versus ≤4 occurrences that made no statistical difference in the outcome from results reported below.

All comparisons among plant height classes showed that plant species composition was significantly different in the three fire frequency classes (**Table 1**). Plots summarized by overstory plant species cover were also significantly different among fire frequency classes.

Results from PERMANOVA suggest that fire frequency, biomass, and terrain conditions are significantly related to one another (**Table 2**). As fires are mainly prescribed burns on BANWR, a focus on fuels reduction on productive and grass dominated sites is likely a driving factor for this outcome. Moreover, principal drainage areas are often protected or excluded from prescribed burns on BANWR. Significant terrain effects are, in part, likely related to prescribed fire management activities being focused on upland terrain. Analysis of soils and soil compaction data is expected to reveal further relationships between fire history, site biophysical factors and vegetation composition and structure (Geiger and McPherson 2005).

NMDS ordinations resulted in a three-dimensional solution using random starts with convergence after only 7 iterations. NMDS plots showed that the non-native perennial bunch grass *E. lehmanniana* was increasingly dominant on plots with greater fire frequency (**Fig. 4A, B**). These relationships were stronger when cover estimates were limited to the 0.0 to 0.5m height strata (**Fig. 4C, D**), which is the principal fuel bed layer with fine fuels needed to carry a fire in semidesert grasslands. NMDS ordination and biplots of primary plant life forms showed that grass dominated areas with higher biomass conditions were the principal areas burned with prescribed fires (**Fig. 5A, B**). Plots dominated by annual forbs and herbaceous plants showed lower fire frequency, which were likely a result of more recent fire activity on sites (Yurcich, personal communication). Time since last burn estimates from the BANWR fire atlas will be incorporated into future analyses.

In addition, while our plot database contained a shrub category for plant life forms, all leguminous woody plants were placed in the tree category, and secondarily classed them as shrubs, as they can be shorter in stature on more xeric sites. From NMDS plots, areas with greater tree cover appeared to be infrequently burned although fire has been used on the refuge at times to reduce *Prosopis velutina* canopy cover, a dominant tree in the study area. Conversely, principal drainages where *P. velutina* is typically more abundant are often protected from fire during prescribed burns as noted above.

We considered these initial comparisons preliminary that will be updated once 2015 field data are collected and summarized. Further data manipulation and analyses are needed to understand how fire treatment have influenced leguminous shrub species cover that are likely to be important to the masked bobwhite such as *Senegalia gregii*, *Acacia angustissima*, *Mimosa grahmii* and others (Tomlinson 1972).

Preliminary masked bobwhite HSI used to characterize plots showed that outcomes can differ depending on the variables and model functions used. HSI Models outputs can differ substantially according to habitat variables included and how they are characterized in the plants database (**Fig. 6A, B**). A great deal of refinement is needed to more fully develop these methods. For example, life form categories should be refined to reflect growth form conditions for plants in the study area. Foundational work to prepare databases, data summaries and HSI model scripts completed to date will help further develop this aspect of the study.

d. Next steps

Newly collected vegetation data will be processed (e.g., check for quality and summarized) and analyzed during the winter and spring of 2015. Soil chemical and physical properties developed from lab analyses will be conducted at NAU during the same time period. Our goal is to have all data prepared for final analyses prior to April 2016. Future analyses will include comparisons using soil factors and 2014 and 2015 plot data in addition to other site biophysical data. Other fire variable from spatial data layers such as time since last burn and burn severity indices will also be included in future comparisons.

Methods to estimate masked bobwhite HSI values for all plots (2012 – 2015) will be refined to incorporate a broader range of masked bobwhite habitat covariates identified by experts. Development of HSI will facilitate disturbance and biophysical modeling techniques to help determine how fire management approaches may impact masked bobwhite habitat and recovery efforts on BANWR.

e. Presentations

Sesnie, S.E., L.J. Zachmann, B.G. Dickson, E. Yurcich, J.M. Rundall, and L. Johnson. 2015. Multiscaled approaches to southwestern arid lands vegetation monitoring, modeling, and management. Biennial Conference of Science and Management on the Colorado Plateau & Southwest Region. October 5 – 8, Flagstaff, AZ

Sesnie, S.E., M. M. Altemus, and L. Johnson. 2014. Field ceptometer LAI measurements for monitoring semidesert grassland biomass, fuel loads, and wildlife habitat conditions with remotely sensed data. ASPRS Rio Grande Chapter Annual Spring Meeting, April 5th, 2014. University of New Mexico, Albuquerque, NM.

Sesnie, S.E. 2015. Presentation to the masked bobwhite quail recovery team: Mapping habitat suitability for masked bobwhite quail (*Colinus virginianus ridgwayi*) using MODIS phenology products. February 18th, Tucson, AZ.

f. Related publications and reports

Sesnie, S.E. *Submitted*. DOI Remote Sensing Activities 2015. Estimating prescribed fire effects on semidesert vegetation composition and structure using 30-year Landsat derived fire history data. DOI Remote Sensing Working Group. On-line report.

Sankey, T., B. Dickson, S. Sesnie. O. Wang, A. Olsson, and L. Zachmann. 2014. WorldView-2 high spatial resolution improves desert invasive plant detection. Photogrammetric Engineering and Remote Sensing, 80: 885-893.

Sesnie, S.E., 2013. Field leaf area index (LAI) measurements for estimating fuel loads. U.S. Department of Interior. DOI Remote Sensing Activities 2013. DOI Remote Sensing Working Group. On-line report.

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Geiger, E.L. and G.R. McPherson. 2005. Response of semi-desert grasslands invaded by non-native grasses to altered disturbance regimes. Journal of Biogeography 32: 895-902.

Hubbard, J. A., C. L. McIntyre, S. E. Studd, T. Nauman, D. Angell, K. Beaupre, B. Vance, and M. K. Connor. 2012. Terrestrial vegetation and soils monitoring protocol and standard operating procedures: Sonoran Desert and Chihuahuan Desert networks, version 1.1. Natural Resource Report NPS/SODN/NRR—2012/509. National Park Service, Fort Collins, Colorado.

LaRoche, D. D. and C.J. Conway. 2012. Developing a Habitat Suitability Index Model for Masked Bobwhite: Progress report to the masked bobwhite recovery team. USGS Idaho Cooperative Fish and Wildlife Research Unit. 9p.

Moore, I.D., P.E Gessler, G.A.Nielsen, and G.A Petersen. 1993. Terrain attributes: estimation methods and scale effects. In Jakeman, A.J.; Beck, M.B.; McAleer, M. Modelling Change in Environmental Systems. London: Wiley. p. 189 - 214.

Oksanen, J., F.G. Blanchet, R. Knidt, P. Legendre, P.R. Minchin, R.B. O’Hare, G.L. Simpson, P. Solymos, M. Henry, H. Stevens, and H. Wangner. 2015. Vegan: Community Ecology Package. R package version 2.3-0. http://CRAN. R-project.org/package=vegan.

R Development Core Team 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Tomlinson, R.E.1972. Review of the literature on the endangered masked bobwhite quail. United States Department of the Interior Fish and Wildlife Service. Resource Publications 108. 28p.

Tables

Table 1. Comparison of 2014 plant species composition on 2014 plots (*n* = 116) from three height and fire frequency sampling strata using MRPP. Comparisons were run using 999 permutations. Fire frequency strata sampled were 1 = 0 – 2 fires, 2 = 3 – 4 fires, and 3 = ≥ 5 fires recorded between 1985 and 2014. Comparisons made using overstory composition were developed by selecting the tallest plant species recorded at each point intercept on a plot to estimate canopy cover by species.

Height stratum (m)	No. species	Comparison	Observed δ	Expected	*T*	*p-value*	*A*
0.0 – 0.5	71	All (global)	0.69	0.72	-7.56	0.001	0.040
		1 vs 2	0.74	0.75	-7.84	0.002	0.018
		1 vs 3	0.68	0.72	-7.54	0.001	0.045
		2 vs 3	0.65	0.68	-7.06	0.001	0.031
0.50 – 2.0	42	All (global)	0.76	0.70	-7.48	0.001	0.040
		1 vs 2	0.72	0.73	-7.74	0.007	0.017
		1 vs 3	0.63	0.67	-7.09	0.001	0.054
		2 vs 3	0.67	0.69	-7.29	0.004	0.023
>2.0	43	All (global)	0.21	0.22	-42.8	0.002	0.040
		1 vs 2	0.20	0.21	-41.7	0.030	0.014
		1 vs 3	0.21	0.22	-42.5	0.002	0.046
		2 vs 3	0.21	0.22	-43.0	0.004	0.032
Overstory	104	All (global)	0.67	0.79	-9.51	0.001	0.041
		1 vs 2	0.70	0.72	-9.77	0.002	0.018
		1 vs 3	0.66	0.69	-9.48	0.001	0.050
		2 vs 3	0.64	0.66	-9.98	0.001	0.027

Table 2. PERMANOVA results comparing plant species composition on 2014 plots (*n* = 116) in the primary fuel bed layer (0.0 to 0.5 m height) to fire frequency and terrain classes, and herbaceous biomass. We used Bray-Curtis dissimilarity and 999 permutations for all comparisons. Terrain classes were drainage bottoms and foot slopes, moderate mid-slopes, and steep-slopes or ridgetops using TWI derived from a 10 m digital elevation model. Terrain was used to account for block effects in the first two models.

Model compare	Source	df	SS	MS	F-Model	P(>F)
Sps[1] ~ Freq[2]	Freq	2	2.6	1.31	5.06	0.001
	Residuals	113	29.3	0.26		
	Total	115	31.9			
Sps ~ Freq*BIOM[3]	Freq	2	2.6	1.31	5.51	0.001
	BIOM	1	1.9	1.91	8.02	0.001
	Freq*BIOM	2	1.4	0.57	2.40	0.004
	Residuals	110	26.2	0.23		
	Total	115	31.9			
Sps ~ Freq + Terrain[4]	Freq	2	2.6	1.31	5.30	0.001
	Terrain	2	1.8	0.89	3.60	0.001
	Residuals	111	27.5	0.25		
	Total	115	31.9			

[1]Species composition on plots, [2]Fire frequency class, [3]Herbaceous biomass, [4]Terrain class

Figures

Figure 1. BANWR study area (left figure) and masked bobwhite management zone (pink area). Fire frequency and terrain strata sampled on plots (black dots) during the 2014 field season are shown in the middle and right figures.

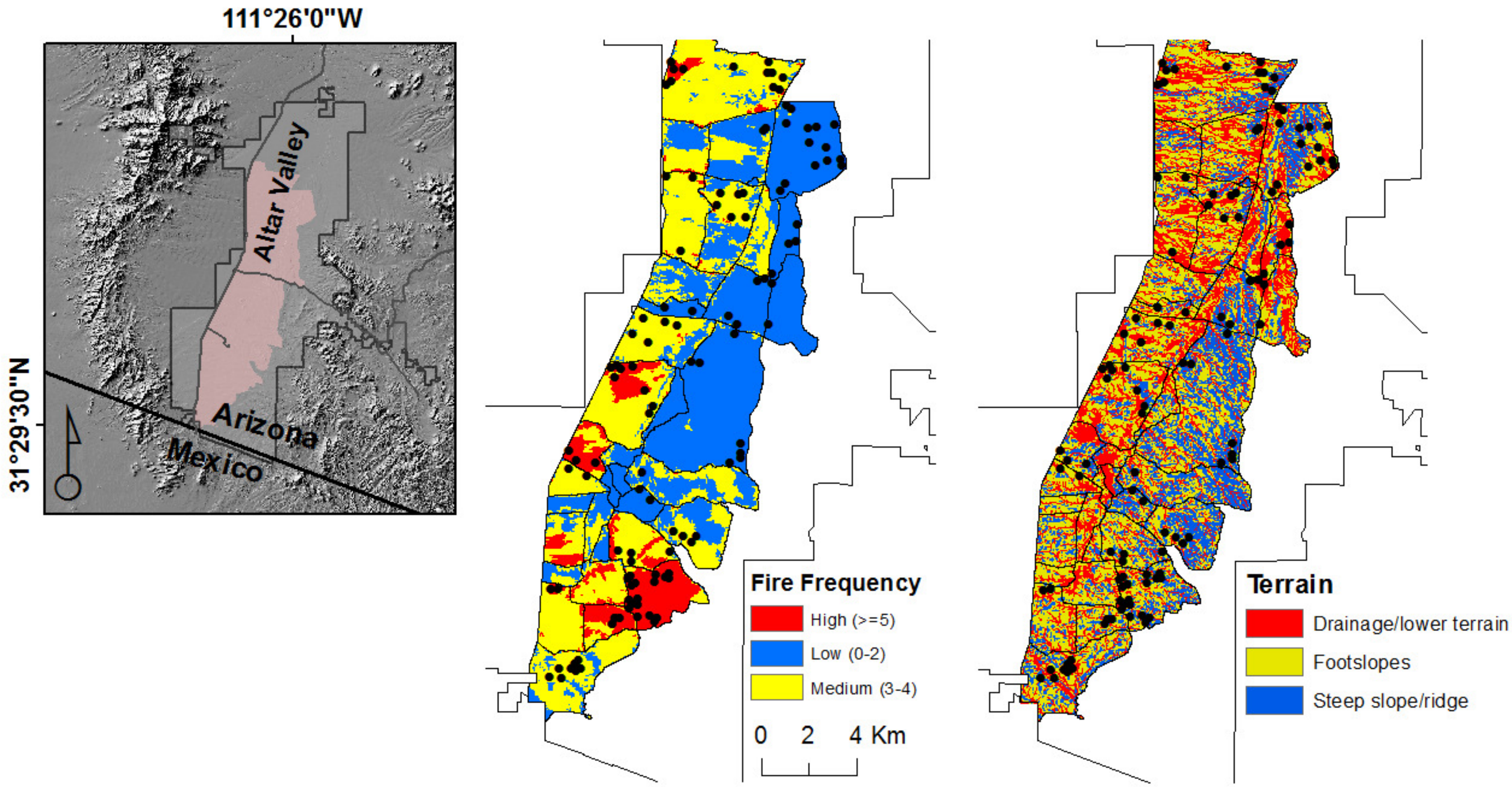
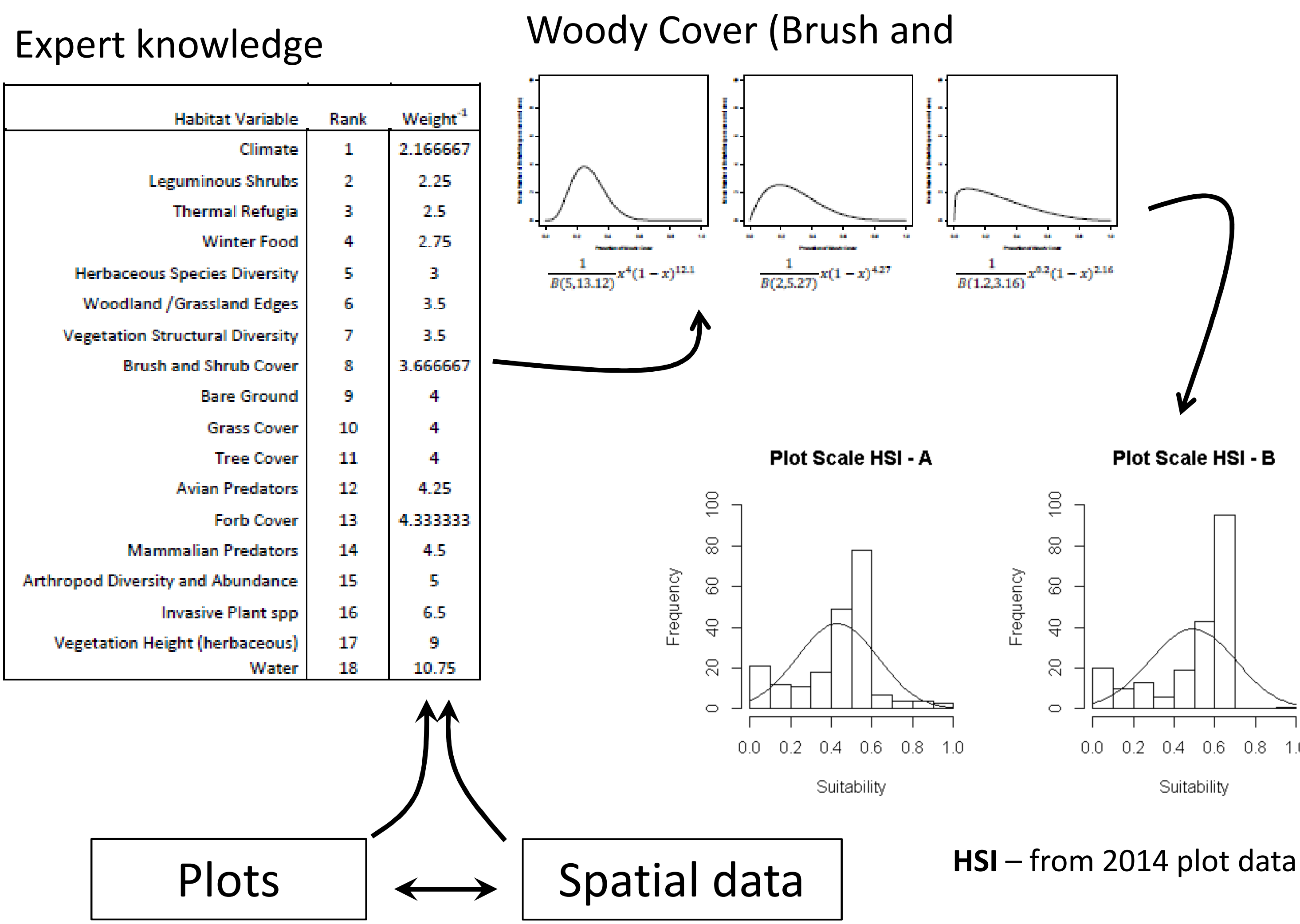


Figure 2. Generalized work flow for developing HSI models for the masked bobwhite quail from plots and geospatial data (LaRoche and Conway 2012). Empirical model functions were used to interpret expert information for quantifying habitat suitability on individual field plots.



Habitat Variable	Rank	Weight^{-1}
Climate	1	2.166667
Leguminous Shrubs	2	2.25
Thermal Refugia	3	2.5
Winter Food	4	2.75
Herbaceous Species Diversity	5	3
Woodland /Grassland Edges	6	3.5
Vegetation Structural Diversity	7	3.5
Brush and Shrub Cover	8	3.666667
Bare Ground	9	4
Grass Cover	10	4
Tree Cover	11	4
Avian Predators	12	4.25
Forb Cover	13	4.333333
Mammalian Predators	14	4.5
Arthropod Diversity and Abundance	15	5
Invasive Plant spp	16	6.5
Vegetation Height (herbaceous)	17	9
Water	18	10.75

Figure 3. 2014 plot biomass (*n* = 116) predicted from field ceptometer LAI measurements compared to herbaceous plant cover in the primary fuel bed layer (0.0 to 0.5 m height). Least squares regression (black) and Lowess (blue) lines indicate a strong relationship between the two fine fuels measurements.

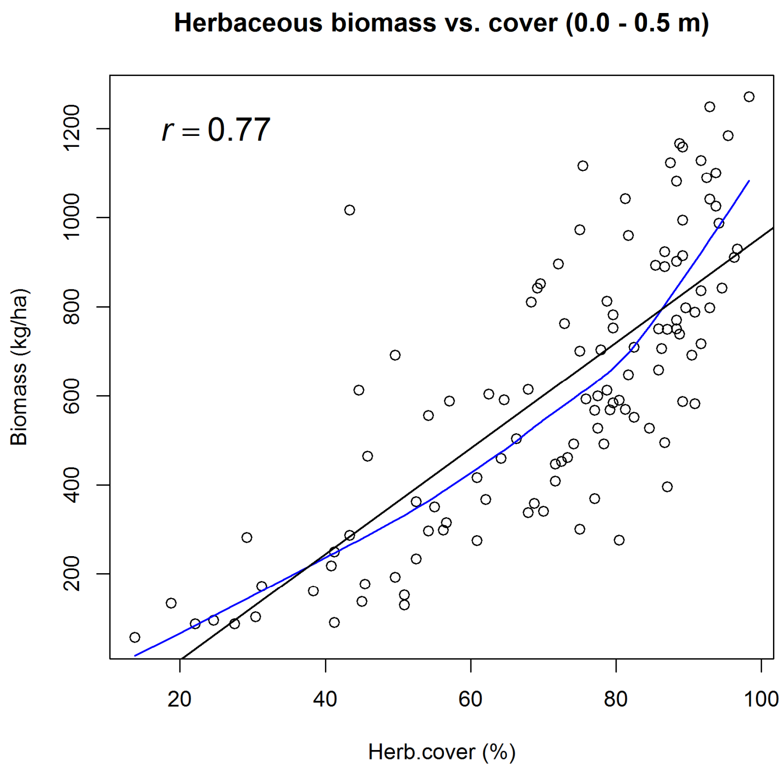


Figure 4. Plot and plant species ordination with a rotation on *E. lehmanniana* comparing A) overstory plant composition (black dots), dominant species (blue arrows), and *E. lehmanniana* cover contours (red lines), B) overstory plant composition (black dots), herbaceous plant biomass (BIOM) and fire frequency (Freq; blue arrows), and herbaceous biomass contours (kg/ha; red lines), C) herbaceous plant composition 0.0 – 0.5 m height (black dots), dominant species (blue arrows), and *E. lehmanniana* cover contours (red), and D) herbaceous plant composition (black dots), herbaceous plant biomass and fire frequency (blue arrows), and herbaceous biomass contours (kg/ha; red lines). Blue arrows in A) and C) are ERLE = *E. lehmanniana*, AMPA = *Amaranthus palmeri*, and PRVE = *P.velutina*.

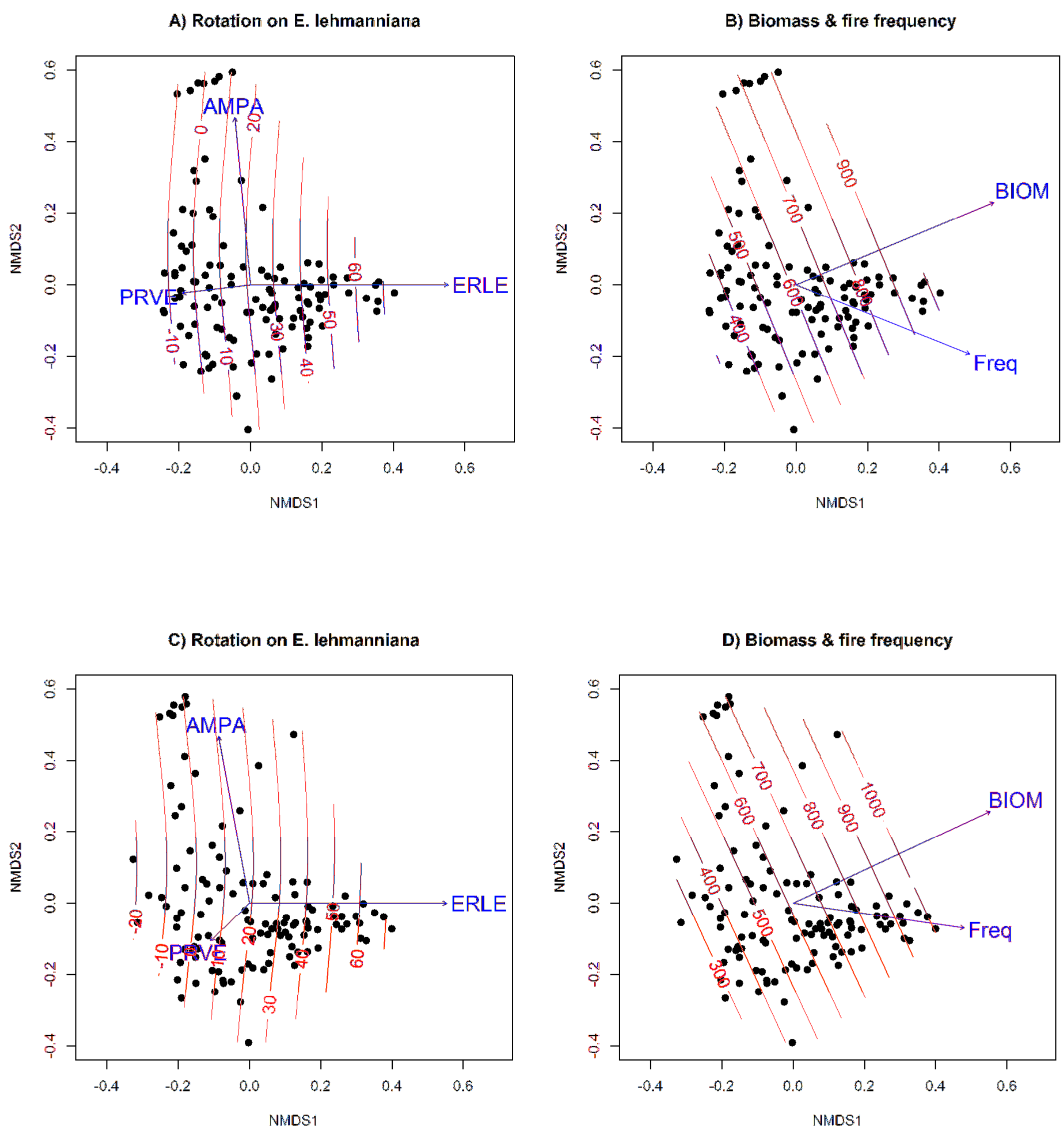


Figure 5. NMDS and biplot of A) species composition on plots (black dots) and principal plant life forms (blue arrows) along axes 1 and 2 and B) species composition on plots (black dots) and principal plant life forms along axes 1 and 3. Red arrows in A and B are fire frequency (Freq) and herbaceous plant biomass (BIOM). Note that a few species with unknown life form information need to be corrected in the plants database.

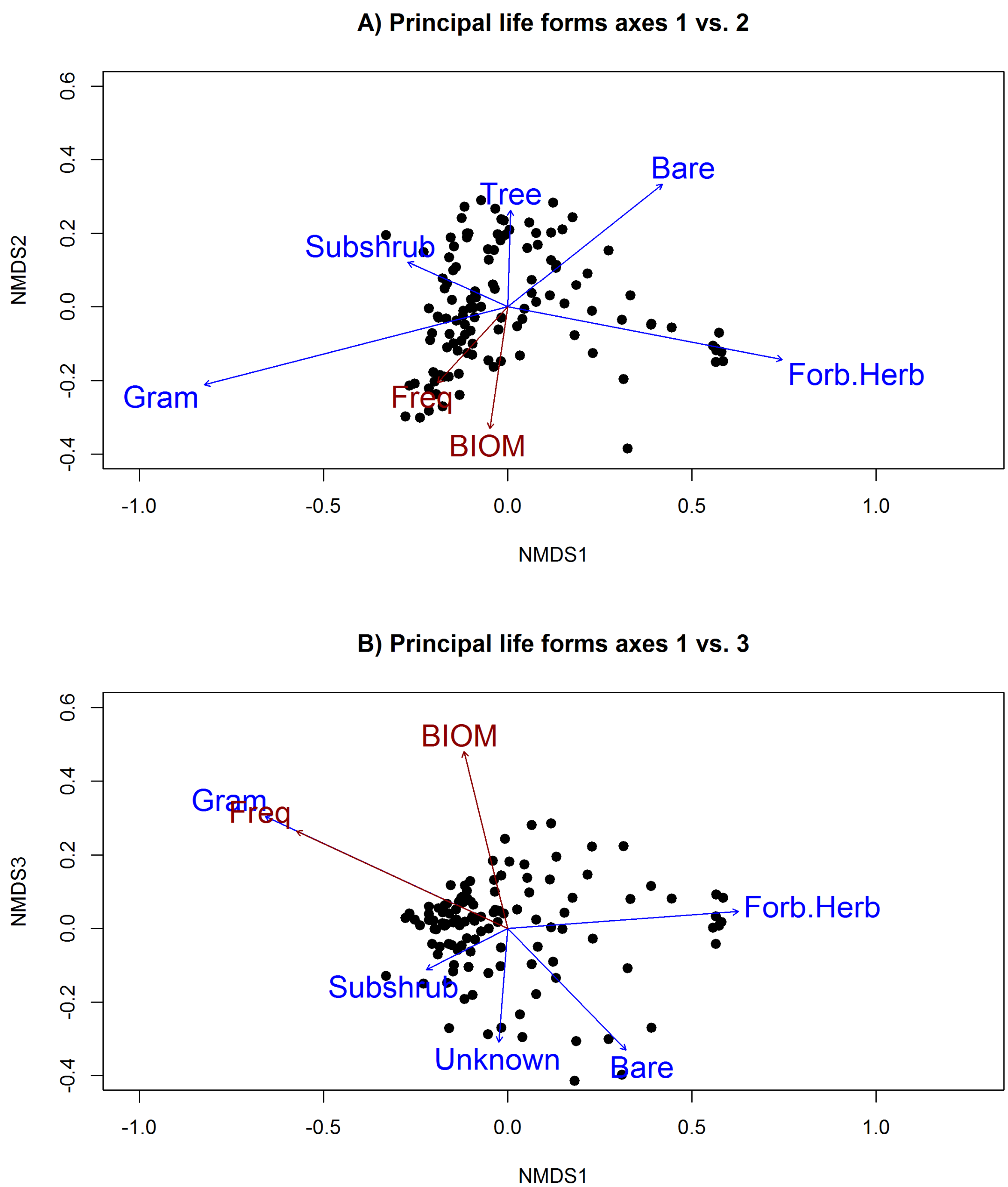


Figure 6. Frequency distribution for two separate masked bobwhite quail HSI models applied to for 2012 and 2013 field plots on BANWR comparing A) shrub, graminoid and forb cover model functions and B) graminoid and forb cover model functions only. HSI models based on expert opinion and empirical curve fitting methods were initially developed to help establish computer code, database, and information needs that will be expanded with field data collected in 2015.