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Spatial Distribution of Yellowstone Bison – Winter 2015

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Executive Summary: During July 2014, 4,865 bison were counted in Yellowstone National Park following calving, including 3,421 in northern Yellowstone and 1,444 in central Yellowstone. National Park Service biologists recommended removing 900 bison from the population during the forthcoming winter through hunter harvests (~300-400) in Montana and the capture and shipment of animals (~500-600) from northern Yellowstone to meat processing facilities.

To assist with planning for these removals, current information about bison movements was used to predict the timing and extent of migrations to management areas near the Park boundary. Under average snow conditions, numbers of bison in the Northern Management Area (Mammoth to Yankee Jim Canyon; see Figure 2) should increase substantially during January through March 2015, with approximately 2,000 bison present by the end of winter. Smaller migrations of fewer than 1,000 bison are expected if snow conditions are well-below normal. In the Western Management Area (Madison Junction to the Hebgen basin), approximately 100 bison should be present throughout autumn and winter, with numbers increasing during March to about 350 bison during April and May. Natural migrations by bison back into the interior of Yellowstone National Park should begin in April in the Northern Management Area and early June in the Western Management Area.

If weather conditions are approximately average, then sufficient numbers of bison should move to the Park boundary and into Montana to enable the recommended removal of 900 animals, primarily from the Northern Management Area. To limit impacts to hunting in the Northern Management Area, captures and shipments of bison should be implemented throughout the winter with small numbers (e.g., 25-100) of animals removed weekly through March. Captures and shipments of bison to meat processing facilities will likely need to be significantly biased towards adult females, calves, and juveniles to meet removal recommendations. It is important to begin these efforts early in winter to avoid sending females late in pregnancy to processing facilities.

Need and Purpose: Yellowstone bison are managed under an Interagency Bison Management Plan that is primarily designed to reduce the risk of brucellosis transmission from bison to livestock. Pursuant to this plan, bison are supposed to be managed towards an end-of-the-winter guideline of 3,000 animals. Managers at Yellowstone National Park also want to maintain breeding herds of bison in the central and northern regions of the park, similar proportions of male to females, and an age structure of about 70% adults and 30% juveniles. Managers want to maintain the processes of migration and dispersal by bison, while avoiding annual reductions in bison numbers of more than 1,000 due to disease, property, and safety concerns near wintering areas in Montana.

National Park Service biologists developed a model capable of forecasting the future abundance and demographic conditions of the Yellowstone bison population[1]. This model is used to identify a strategy for removing bison during winter and early spring to meet desired population conditions. However, hunting and culling only occur when bison migrate to the Park boundary with the State of Montana. Uncertainty in the timing and extent of annual migrations complicates our ability to implement the proposed removal strategy[2]. To assist with planning for removals, we predicted the timing and extent of annual migrations to out-of-Park wintering areas in Montana during winter 2015.

Bison Seasonal Distributions and Movements: During summer, bison in northern Yellowstone are concentrated in the Lamar Valley (Figure 1). A portion of these bison make prolonged forays to the high-elevation Mirror Plateau, with occasional trips to the Pelican and Hayden Valleys. Bison in central Yellowstone concentrate in the Hayden Valley during summer. By late summer, large numbers of these bison travel back and forth between the Hayden Valley, northern shore of Yellowstone Lake, and the Pelican Valley. In early autumn, bison throughout Yellowstone make brief trips from summer ranges to most winter ranges, with nearly all animals subsequently returning to summer ranges.

As winter progresses, bison in northern Yellowstone move downslope along the Yellowstone River to the Blacktail Deer Plateau and, in some years, the Gardiner basin where snow pack is lower and new vegetation growth begins earlier in spring. Some bison from central Yellowstone also migrate to these lower-elevation areas in the northern portion of the Park using the Norris Corridor. However, more bison in central Yellowstone migrate towards the western boundary following a historic migration route that connects the Hayden Valley and the Firehole Valley. From the Firehole Valley, bison move downslope to access several meadows along the Gibbon and Madison Rivers.

Movement patterns are reversed in spring as snow melts and bison follow new vegetation growth from lower to higher elevations. The onset of new vegetation growth typically begins earlier in northern Yellowstone with return migrations occurring during March and April. Emergence of new vegetation in the Western Management Area (Madison Junction to the Hebgen basin; Figure 2) occurs during the bison calving period in May while higher-elevation areas in central Yellowstone are still covered in snow. As a result, several hundred bison move to the Western Management Area at this time. These animals remain during calving, before rapidly returning to higher-elevation summer ranges inside Yellowstone National Park during June.

Data Collection: Ninety-three aerial surveys were completed during 2000 through 2014 to count bison in the Yellowstone population and determine seasonal distributions. Surveys were completed using one or two Piper Super Cub airplanes to survey 10 established count units in the central and northern portions of Yellowstone National Park. The observer in each plane searched for and counted the numbers of bison in groups and the pilot recorded the location of groups using an onboard Global Positioning System (GPS).

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[1] Geremia, C., R. Wallen, and P.J. White. 2014. Population dynamics and adaptive management of Yellowstone bison. National Park Service, Yellowstone National Park, Mammoth, Wyoming. Available at http://ibmp.info/.

[2] Geremia, C., P. White, J. Hoeting, R. Wallen, F. Watson, D. Blanton, and T. Hobbs. 2014. Integrating individual- and population-level information in a movement model of Yellowstone bison. Ecological Applications 24:346-362.

Habitat selection by bison is related to gradients of snow and forage conditions. Therefore, we used a validated snow pack model[3] to estimate snow-free areas within each wintering area for each day of the winter. This model was also used to predict daily snow water equivalents (SWE) as the average of daily values within each wintering area. Forage conditions were estimated using the normalized differential vegetation index (NDVI) recorded by the Terra and Aqua Moderate Resolution Imaging Spectrometer (MODIS). Weekly NDVI values were averaged across non-forested areas within each bison range and wintering area.

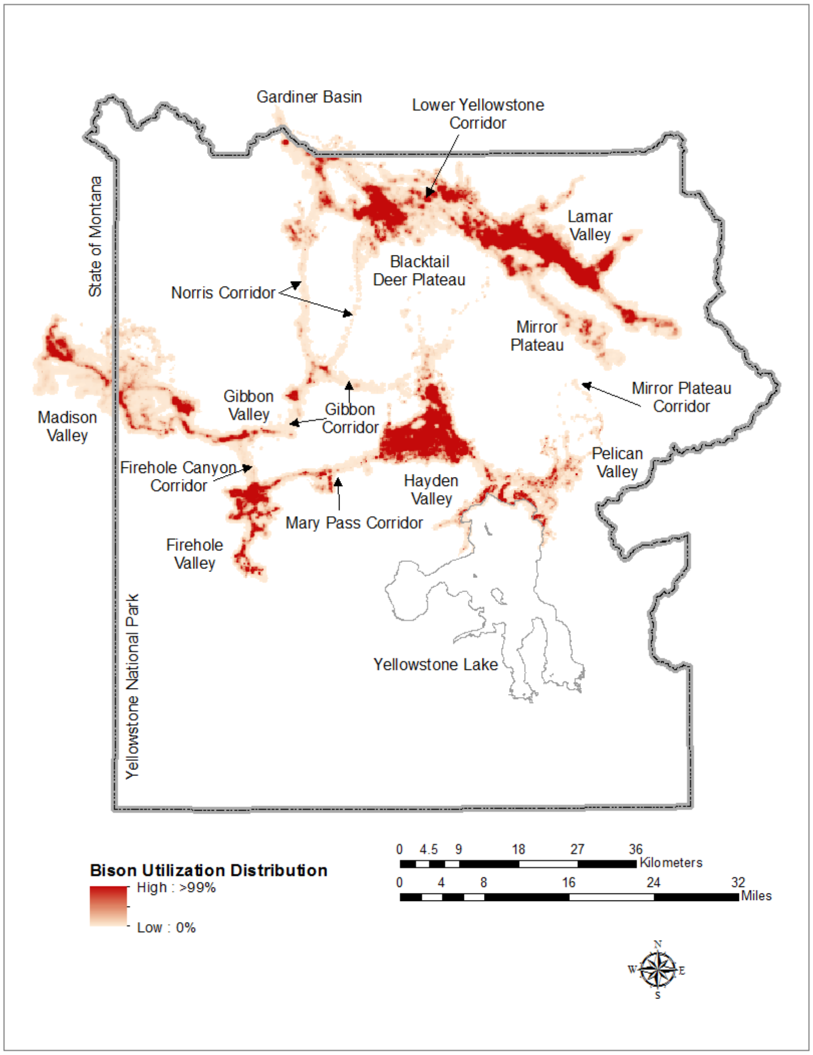

Figure 1. Names of various places and areas used by bison in and near Yellowstone National Park. Darker shading indicates areas used more frequently by about 66 adult female bison fit with GPS radio collars during 2004 through 2012.

[3] Watson, F., W. Newman, J. Coughlan, and R. Garrott. 2006. Testing a distributed snowpack simulation model against diverse observations. Journal of Hydrology 328:453-466.

Predicting Seasonal Distributions: Habitat selection is based on decisions made by bison at several spatial scales. Selection decisions are nested such that choices made at finer spatial resolution are conditioned on choices made at coarser spatial resolution. We identified two spatial scales of habitat selection by bison. At the coarsest resolution, animals chose to use northern or central ranges of the Park (Figure 2). Based on choosing one of these two ranges, animals made finer resolution choices of using an individual wintering area (Figure 2).

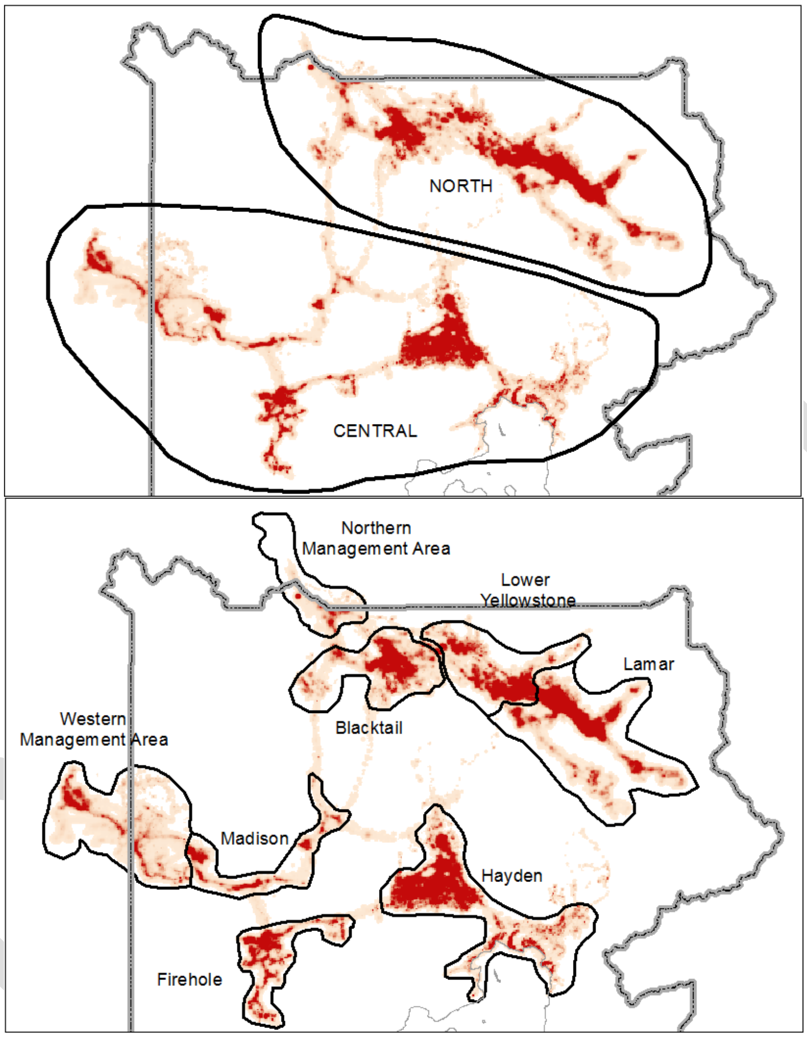

Figure 2. Habitat selection was estimated by separating the areas commonly used by bison into ranges (top) and wintering areas (bottom). Habitat selection was nested such that use of wintering areas was conditioned on choosing a range.

We represented habitat selection as $P(S_1,S_2) = P(S_2|S_1) \times P(S_1)$ where $P(S_1)$ was the probability of choosing a range (northern or central) and $P(S_2|S_1)$ was the probability of choosing a particular wintering area conditional on the range. We used a Bayesian generalized linear model to estimate $P(S_1,S_2)$. To estimate habitat selection for a range, $P(S_1)$, we defined the matrix $\mathbf{Y}_{range}$ as our response variable where each row included a cell for the number of bison counted in central Yellowstone and the total number of bison counted in the entire Park. $\mathbf{Y}_{range}$

was related to predictor variables using the beta-binomial model. We considered various combinations of, and interactions among, predictor variables, including central and northern herd sizes, the proportion of animals in central Yellowstone, snow conditions from different wintering areas and ranges, and time since the beginning of the breeding season in July. The top supported model was selected using the deviance information criteria (Table 1).

Habitat selection for each wintering area, $P(S_2|S_1)$, was evaluated separately. For the i^{th} wintering area within the northern range, each row of our response matrix $\mathbf{Y}_{area,i}$ included a cell for the number of bison counted in i^{th} wintering area and the total number of bison counted on the northern range. Similarly, for the j^{th} wintering area within the central range, each row of our response matrix $\mathbf{Y}_{area,j}$ included a cell for the number of bison counted in the j^{th} wintering area and the total number of bison counted on the central range. In each case, $\mathbf{Y}_{area}$ was related to predictor variables including the effects of herd sizes, snow conditions, and forage conditions using the beta-binomial model. We identified a top supported model for each wintering area.

Seasonal distributions of bison during winter 2015 were predicted using a population of 4,865 bison, including 3,421 bison in northern Yellowstone and 1,444 in central Yellowstone[4]. We assumed snow and forage conditions that were averages of observed values since 2000. First, numbers of bison were predicted on northern and central ranges for the first day of each month during July 2014 to June 2015. Then, numbers of bison were predicted on wintering areas conditional on the numbers of bison that were predicted on ranges.

Model Implementation: Model parameters and latent quantities were estimated using Markov chain Monte Carlo techniques. Samples were drawn from the posterior distribution using a hybrid Gibbs sampler. We used a random walk Metropolis-Hastings algorithm for estimating each parameter. Each of three MCMC chains was run for 25,000 iterations and the first 10,000 iterations were discarded to allow for burn-in. The algorithm included a 5,000-step iteration phase. Model convergence was confirmed by using the Gelman and Rubin test statistic. All analyses were completed using program R.

Predicted Migrations to Management Areas during Winter 2015: Numbers of bison on the northern range are predicted to increase during winter 2015 and peak near 3,800 (95% credible interval = 3,250-4,200) animals during April. Numbers of bison occupying the Northern Management Area (Mammoth to Yankee Jim Canyon; Figure 2) depend on total snow accumulation in the Lamar Valley and the extent of the snow-free area on the Blacktail Deer Plateau. Under average conditions, numbers of bison in the Northern Management Area will increase substantially during January through March with approximately 2,000 (95% credible interval = 700-3,000) bison present by the end of winter (Figure 3). Bison are predicted to begin return migrations during April, with few bison present in the Northern Management Area by early May. Lower snow conditions will reduce the number of bison moving to the Northern Management Area, delay the time when animals arrive, and reduce the amount of time bison spend in the area. Large migrations are also predicted under more mild conditions (e.g., 80% of average), with an average of 1,200 bison moving to the Northern Management Area. Smaller migrations of fewer than 900 animals are predicted if snow conditions are well-below normal (e.g., 60%; Figure 3).

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[4] Geremia, C., R. Wallen, and P.J. White. 2014. Population dynamics and adaptive management of Yellowstone bison. National Park Service, Yellowstone National Park, Mammoth, Wyoming. Available at http://ibmp.info/.

Table 1. Predictor variables affecting the number of bison found within ranges and wintering areas of Yellowstone National Park.

Habitat Selection	Predictor Variables of Top Model
$P(S_1)$: Central Range	Proportion of the population in central Yellowstone areas during breeding, time since the breeding period, and the interaction between central herd size and snow (SWE) conditions in the Hayden Valley.
$P(S_2\|S_1)$: Northern Wintering Areas	
Lamar Valley	Forage conditions (NDVI), snow-covered area (SCA), and snow (SWE) conditions in the Lamar Valley, and northern herd size.
Lower Yellowstone Valley	Snow conditions (SWE), snow-covered area (SCA, 2nd order), and forage conditions (NDVI, 2nd order) in the lower Yellowstone Valley.
Blacktail Deer Plateau	Snow-covered area (SCA, 2nd order) on the Blacktail Deer Plateau and northern herd size.
Northern Management Area	Snow conditions (SWE) in the Lamar Valley and the interaction between snow-covered area (SCA) on the Blacktail Deer Plateau and total population size.
$P(S_2\|S_1)$: Central Wintering Areas	
Hayden Valley	Forage conditions (NDVI) and snow-covered area (SCA) in the Hayden Valley, and snow conditions (SWE, 2nd order) in the Firehole Valley.
Firehole Valley	Snow conditions (SWE,2nd order) and forage conditions (NDVI,2nd order) in the Firehole Valley.
Madison/Gibbon valleys	Forage conditions (NDVI, 2nd order) in the Madison Valley.
Western Management Area	Snow conditions (SWE) and forage conditions (NDVI) in the Hayden Valley, snow conditions (SWE) and forage conditions (NDVI, 2nd order) in the Western Management Area, and Before/After adaptive changes were implemented in 2006 to reduce bison hazing efforts and allow hunting.

Numbers of bison occupying the Western Management Area are affected by total snow accumulation and forage conditions in both the Western Management Area and the Hayden Valley. As a result, we predict approximately 100 bison in the Western Management Area throughout autumn and winter under average snow and forage conditions (Figure 4). Numbers should increase rapidly during March, with approximately 350 bison occupying the area during April and May. Natural migrations by bison back into the interior of Yellowstone National Park should begin during early June as snow and forage conditions become more favorable in the Hayden Valley, and vegetation conditions in the western areas of the Park become less optimal.

Implications for Management: Near-average weather conditions suggest sufficient numbers of bison will move to the Northern and Western Management Areas to enable the recommended removal of 900 animals through harvests and culling during the winter of 2015. In the Western Management Area, approximately 100 bison are predicted to occupy hunting districts throughout state and tribal hunting seasons, which could allow for the harvest of at least 50 animals. In the Northern Management Area, bison movements to hunting districts are expected to begin during January, with large numbers of animals present through April.

To limit impacts to hunting in the Northern Management Area, captures and shipments of bison should be implemented throughout the winter with small numbers (e.g., 25-100) of animals removed weekly through March. This stepwise approach would (1) limit animals held within capture facilities, (2) minimize effects on hunting opportunities, (3) reduce logistical constraints of transporting large numbers of bison to meat processing facilities over brief periods, (4) limit transporting females late in pregnancy to processing facilities (which could occur if captures and shipments began after the close of hunting seasons), and (5) lower the chances of out-of-Park abundance surpassing levels which exacerbates conflict. Under this approach, biologists could track the age and sex composition of harvests to appropriately adjust culling efforts as winter progresses.

Shipments of bison to meat processing facilities will likely need to be significantly biased towards adult females, calves, and juveniles to meet removal recommendations. It is important to begin these efforts early in winter to avoid sending females late in pregnancy to processing facilities. If bison migrations are delayed due to lower snow conditions, then managers may need to send females late in pregnancy to meat processing facilities. Alternatively, managers could establish a terminal pasture where animals could be contained for harvest after the calving period.

Managers have successfully prevented the spillover of brucellosis from bison to livestock and mitigated private property complaints with more than 500 bison outside of the western and northern boundaries of the Park. Removal of nearly 900 animals from the Northern Management Area will reduce the number of bison using out-of-Park areas towards this threshold. Targeted hazing due to private property concerns and animals attempting to move beyond the limits of the conservation area will likely be needed throughout winter. Larger hazing efforts to move bison back into Yellowstone National Park will likely be most successful if timed with natural return movements that are predicted to occur in April in the Northern Management Area and June in the Western Management Area.

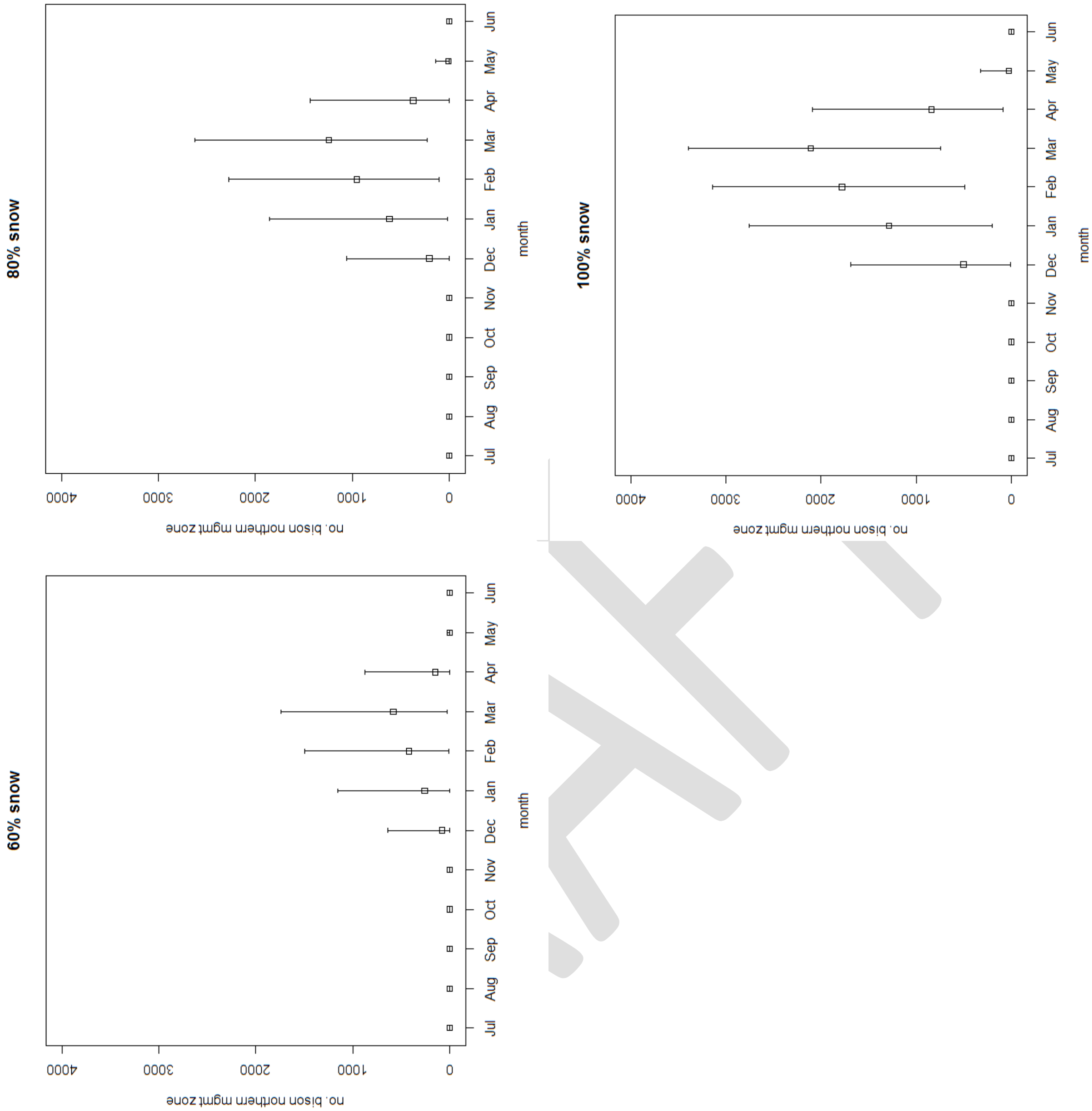

Figure 3. Predicted migrations of bison into the Northern Management Area during winter 2015 under 60%, 80%, and 100% of snow conditions averaged during 2000-2014.

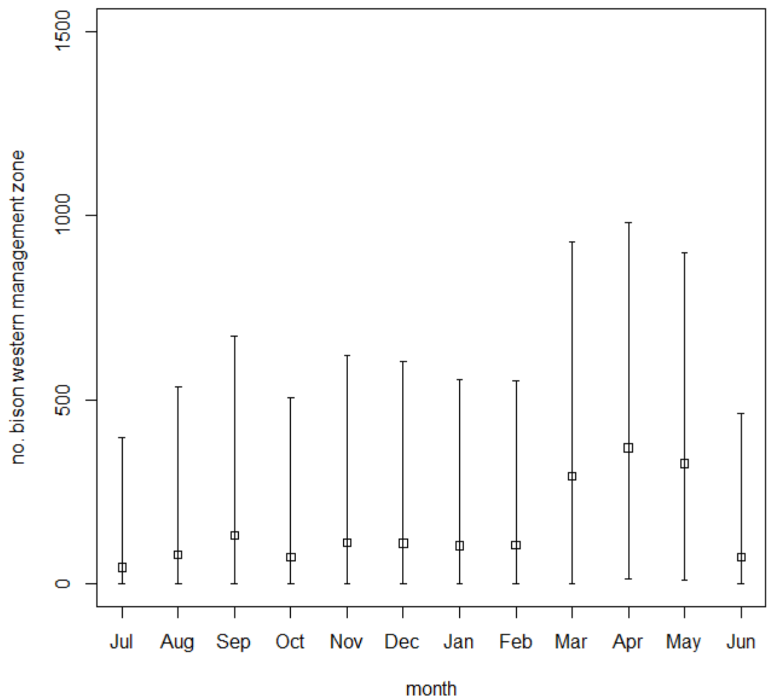

Figure 4. Predicted migrations of bison into the Western Management Area during winter 2015 under near-average snow and forage conditions.