A multifaceted approach to the management of the northern bison herd in Yellowstone National Park

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Abstract:

Bison bison (plains bison) plays a critical role as an herbivore in Yellowstone National Park's northern range. The current management strategies adopted by the Interagency Bison Management Plan (IBMP) lack a comprehensive understanding of the dynamics of the northern range ecosystem and the ecological role of bison. This study began with analyses of the northern bison herd population dynamics and annual vegetation consumption between bison and elk (*Cervus canadensis*), which led to a synthesis of the delicate ecological balance of the northern herd. Bison are now the dominant consumer of vegetation in the northern range and have likely been released from competition with the elk population post wolf reintroduction. Recruitment of woody vegetation is also likely still limited by cascading effects from elk and bison diet partitioning and new evidence of bison browse. In conclusion, the current strategies employed by the IBMP to reduce herd size and limit range expansion could result in counterproductive management strategies and the relationships outlined in this study need to be addressed by the IBMP to avoid creating negative long-term impacts on the northern range ecosystem.

1. Introduction

The plains bison (*Bison bison*) is an iconic North American species, whose conservation has become an imminent priority amongst wildlife managers. Dominating the American frontier for millions of years, bison used to exist in the millions prior to European settlement. Due to uncontrolled hunting and human expansion, by the late 1880s as few as a thousand individuals remained in the world (Halbert et al. 2006; Freese et al. 2007; Hedrick 2009). Today, there are approximately 500,000 bison in North America, but 96% of these individuals are used for commercial production, meaning fewer than 20,000 bison are protected with the intention of preserving the species (Freese et al. 2007; Hedrick 2009). The Yellowstone National Park (YNP)

herd was the only wild herd to narrowly escape extinction, which had as few as 25 individuals existing in the park in 1902 (Meagher 1973). During the time of these drastic declines, some remaining wild individuals were held captive and some were sent to Yellowstone to help rebuild the herd (Meagher 1973). Most of the existing bison today are descendants of this founder population of about 100 individuals (Hedrick 2009). This then leaves the bison of YNP to be the only continuously wild herd of the species (Halbert et al. 2006). Today, there are two herds that exist in the park: the central and the northern, and together they are composed of approximately 5,000 individuals (Geremia et al. 2016).

The Yellowstone bison continue to be unique. Due to the severity of the declines, desperate attempts to save the species, and ongoing commercial projects, crossbreeding with cattle was common and populations underwent frequent bottlenecks. It is estimated that only 1.5% of existing bison are free of cattle genes and research indicates that the Yellowstone bison herds are some of the most genetically diverse and genetically pure individuals left in the species (Halbert et al. 2006; Hedrick 2009). Furthermore, they are carriers of *Brucella abortus*, which is a bacteria that causes abortions in domesticated cattle when transferred, but does not demonstrate any negative effects on bison themselves (Meagher & Meyer 1994). This disease has since been eradicated in the United States except for the Greater Yellowstone Area (GYA) and remains a source of human-wildlife conflict between park bison and cattle ranchers who fear the transmission of Brucellosis (Rhyan et al. 2013). Thus, the Yellowstone bison have become the central focus of conservation efforts for this species based on their persistence as a wild herd, lack of interbreeding with cattle, and for their potential to transfer Brucellosis to domestic cattle.

The question that wildlife managers have been heavily debating is how to effectively manage this population? The central and northern herds are each other's source of genetic

diversity. They are effectively isolated from any other existing herds and unable to obtain new alleles (Halbert et al. 2006). Thus, a major concern is preserving the genetic fitness of the herd, which can be effectively done by maintaining a minimum herd size of 1,000-2,000 individuals (Hedrick 2009). Furthermore, Yellowstone National Park has maintained a natural regulation policy since 1968, meaning that unless a major component of the ecosystem is threatened, no direct management actions are taken to regulate populations such as hunting bison within park boundaries (National Research Council 2002). As a result, any direct management of the bison population must take place outside park boundaries.

Since 2000, the Interagency Bison Management Plan (IBMP) has been the main source of bison management in the GYA. Multiple agencies (The Animal and Plant Health Inspection Service; Forest Service; Montana Department of Livestock; Montana Fish , Wildlife, and Parks; National Park Service; Confederated Salish and Kootenai tribes; Nez Perce tribe; Inter-Tribal Buffalo Council) cooperate to achieve common goals for bison management (2016 Annual Report of the Interagency Bison Management Plan). The general goal of the agency is outlined as follows: "The purpose of the IBMP is to maintain a wild population of Yellowstone bison and address the risk of brucellosis transmission from bison to protect the economic interest and viability of the livestock industry in the state of Montana" (2016 Annual Report of the Interagency Bison Management Plan). The IBMP objectives are more specifically outlined in Table 1.

The IBMP has adopted an adaptive management approach, meaning that management decisions are based on current data and as new data becomes available, plans are adjusted. Data are collected annually in the form of aerial counts, age/sex surveys, collared individuals, removals, and testing brucellosis exposure at capture facilities (Geremia et al. 2014a). These

data is then used to make annual removal decisions but only takes into consideration the influence of removals on the population in the following year. There is no evidence to suggest that the IBMP takes a comprehensive approach to long-term implications of current management plans or considers how the dynamics of the Northern range ecosystem influences the bison population. Thus, there is concern that the clear goals of the IBMP in brucellosis management cause the cooperative agencies to only consider Yellowstone bison management through this specific lens, which may lead to inefficient management strategies or create repercussions within the ecosystem of Yellowstone's northern range.

Understanding a species role in overall ecosystem functioning is a key resource for designing effective management plans (Weisberg et al. 2002). However, this approach is relatively new as historic population models typically do not take into account impacts from vegetation herbivory or the influence of other species populations, such as the model used by the IBMP (Weisberg et al. 2002; Geremia et al. 2014a). Furthermore, the understanding of long term impacts of these dynamic relationships in forming major shifts in community and ecosystem structure and functioning is also less understood and there is a lack of comprehensive long term monitoring projects (Kiffner et al. *accepted*). Thus, it is critical that management plans take into consideration the immediate feedback loops within the ecosystem of the species of interest and considers how decisions may influence the creation of short and long term changes from the species to ecosystem level.

Yellowstone's northern range is one of the most studied protected areas in the United States (National Research Council 2002; Greater Yellowstone Ecosystem 2016). Much of this research presents concerns about over-grazing and over-browsing by park ungulates including bison and elk. (National Research Council 2002; Greater Yellowstone Ecosystem 2016;

Coughenour 2005). Other research suggests complicated trophic cascades that involve elk, bison, and woody vegetation recruitment following the reintroduction of wolves (Ripple et al. 2010) Thus, it was the goal of this study to compile this research and create a comprehensive summary of the components of the northern range ecosystem relevant to the northern bison herd and synthesize these relationships in the form of feedback loops that take into consideration the IBMP's current management practices (Ripple et al. 2010). To fully understand the magnitude of some of these relationships more specific analyses on the overall population trends of the herd using the IBMP data and estimates/trends of overall herbivore vegetation consumption between elk and bison in the northern range supplemented the study. The goal was to use this comprehensive analysis to be able to make reasonable predictions about both short- and long-term impacts on Yellowstone's northern bison herd and how this may have cascading effects in the northern range ecosystem. In an effort to avoid any immediate or long-term negative repercussions in the management of this critical population, it is recommended that the IBMP incorporate this approach into their management strategy.

3. Methods

3.1 Removals from the northern bison herd

Removal data were compiled by the IBMP from 1985-2016 and include the total number of bison removed from the northern herd north of the park boundary during the winter season (*in* Geremia et al. 2016). Removal methods included management culls to slaughterhouses, hunter harvest, and individuals sent to quarantine for Brucellosis infection. Descriptive statistics were calculated for the raw data including median, variance, standard deviation and range. Standard functions in Microsoft Excel 2011 were used to generate these calculations, including the VAR.P and STDEV.P functions for variance and standard deviation respectively.

The percent of the population that was removed annually was calculated by dividing the number of removals by the number of individuals counted in the previous summer under the assumption that those individuals were included in the summer count. Descriptive statistics were calculated using the same methods aforementioned. Two separate medians and associated statistics were calculated to determine the average removal across the entire study period and the average removal among years where removals were greater than zero.

3.2 Population analyses of elk and bison

Bison population data were also used from Table 3 of Geremia et al. (2016). These numbers were derived from aerial counts conducted in the summer of each year from 1985-2016 counting both the central and northern herds separately. Percent growth was calculated using the following equation: Percent growth = $((N_{t+1}-N_t)/N_t)*100$, where N_t and N_{t+1} are the populations of the preceding and following year respectively. Descriptive statistics were calculated on the raw count data as well as the percent growth calculations.

Population data for elk were obtained from aerial counts conducted by the Northern Yellowstone Cooperative Wildlife Working Group in each winter from 1960-2017 (data provided via correspondence with Thi Pruitt). A spearman-rank test was used to identify a potential negative correlation between the annual count data of elk and bison to determine if one herbivore population is limiting the other in the northern range (SPSS version 24). The count data were not manipulated to take into account removals due to an incomplete data set for elk removals.

3.3 Herbivore vegetation consumption

To measure the annual vegetative consumption of both the elk and northern bison herds, body weights and daily food intake were obtained from previous literature. Coughenour (2005) described a maximum daily forage intake for both elk and bison to occur at 3.5% of the individual's body mass. However, the maximum intake level is only reached during summer periods, with consumption decreasing in winter months according to decreased forage quality and increased snow cover. Due to the maximum intake rate being only during summer months a lesser daily consumption rate of 3% of body weight was used to calculate annual consumption, noting that in more severe winters with increased snow cover, consumption will likely be much lower for both species.

Coughenour (2005) also described mean body weights of elk and bison to be the following: elk calves=114 kg, kg, elk cows=240 kg, elk bulls=330 kg, bison calves=160 kg, bison cows=450 kg, bison bulls=650 kg. Due to the elk and bison population counts having incomplete sex/age data, calculations for daily consumption were based on an average of the cow and bull body weight for each species (elk= 285 kg, bison=550 kg). The decision to not adjust consumption for the portions of each herd that are calves is based on the rationale that the majority of each herd are in the adult stage and because the goal is to understand maximum vegetative consumption, which adults consume more due to their larger body size.

Bison are predominantly grazing species. Alternatively, elk are a mixed feeding herbivore, consuming both graze and browse annually. There is recent evidence documenting bison browse in the northern range but no quantitative measure of how much of the diet is due to browse (Painter & Ripple 2011). Due to the fact that bison are a historically grazing species it was assumed that bison diet is still 100%, however, this analysis may be limited until research

can quantify bison browse. For elk, proportions of graze and browse were borrowed from Christianson & Creel (2008). Elk browsing increases during winter months and continues to increase with severity of winter. During warmer months elk diet is approximately 90% graze/10% browse and 65% graze/35% browse in winter months (Christianson & Creel 2008). An average for graze and browse of 78% graze and 22% browse was used to calculate consumption for elk. Recent evidence for increased browse in all seasons by elk as a result of wolf reintroduction was not incorporated in the calculation, but is considered in the discussion (Christianson & Creel 2008).

The amount of annual graze and browse consumed by the northern elk and bison herds were calculated using the aforementioned parameters. Daily consumption was calculated using 3% of species body weight 285 kg (elk) and 550 kg (bison). Then the corresponding proportions of graze and browse were applied to the daily consumption then multiplied for annual consumption. A Spearman-rank correlation test was utilized to identify a potential relationship between bison and elk graze (SPSS version 24). Total combined annual vegetation consumption and the percent of total annual vegetation consumption by elk and bison individually were also calculated.

4. Results

4.1 Northern bison herd removals

The median removal over the study period was 33.5, but inconsistent, ranging from 0 – 1459 (s=119,751, s^2=346). The percent of the population that was removed annually was also inconsistent, ranging from no removals to as high as 92.36% in 1997. There were nine years with no removals. Over the study period the median annual removal was 2.63% (s=528.95, s^2=23.00).

However, the median removals considering only years where actual removals took place was 9.10% (s=633.725, s^2=25.17; Figure 1).

4.2 Population analyses of elk and bison

The northern bison herd population remained fairly consistent until the early 2000s with a relatively small population rarely exceeding 1,000 individuals. The herd has since more than tripled in size with a most recent population size of 3,627 individuals (2016). The median population size of the herd was approximately 896 individuals (s=83,0441, s^2=911.29; Figure 1). The annual percent growth of the herd fluctuated heavily across the study period ranging from -42.04% - 69.41% with a median growth of 6.76% (s=656.32, s^2=25.62; Figure 2). Furthermore, the elk and bison herds demonstrated a significant moderate negative association (Spearman rank=-0.684, $p<0.0001$).

4.3 Herbivore vegetation consumption

In general the estimates of vegetation consumption closely reflect the populations of the elk and bison herds respectively in each year. The declining trend in the elk population is overall reflected in the consumption estimates. The amount of elk grazing in the northern range is at a historic low (within the study period) with a most recent estimate of 13 million annual kilograms in comparison to a high of 46.36 million annual kilograms in 1993 (Figure 3).

The total annual consumption has continued to decline across the last 31 years, indicating that each year approximately less vegetation is removed from the northern range (Figure 4). Elk have historically been the dominant consumer. It was not until recently in 2009 where the bison population has grown enough to consume more than 50% of the total annual vegetation

consumption in the northern range (Figure 5). Overall, the annual amount of graze consumed by bison has increased across the study period, which is reflective of the population's growth (Figure 3). There is also a significant negative association between elk and bison graze consumption (Spearman rank=-0.591, $p<0.0001$).

5. Discussion

5.1 Influence of the IBMP on the northern bison herd population

The northern bison herd's current status above the minimum suggested herd size (1,000-2,000 individuals) suggests the successful preservation of the herd's genetic diversity and the strongest genetic fitness in over thirty years (Hedrick 2009). This reflects the successful completion of the IBMP goal to maintain a viable, wild population in the context of the northern herd.

The analysis on the herd's percent growth is limited due to inconsistent management practices across the study period, limited removals prior to 2003, and severe winters in 1989 and 1997 that led to massive slaughters outside park boundaries (Memorandum 2016; National Research Council 2002). Due to these inconsistencies, limited conclusions can be made about how the population was influenced by the naturally occurring dynamics of the northern range ecosystem. Also, the role of removals in annual percent growth cannot be effectively isolated; however, it does explain the large decline from 1995-1997 where 725 individuals were slaughtered (Geremia et al. 2016). This demonstrates the need for consistent management as this hindered the use of this available data for explaining the recent persistence in annual herd growth.

The IBMP utilizes two strategies that each directly impacts the northern herd population, including hazing and removals in the form of hunting seasons, management culls, and

slaughterhouse removals. The IBMP has limited tolerance for bison outside park boundaries, where only numbers that are sufficient to fulfill slaughter and hunter harvest are tolerated. Bison that approach "non-tolerance boundaries", which involve proximity to private property, highways, and domestic cattle are hazed back into the park (Memo for IBMP 2016). However, an oversight of the IBMP is their lack of consideration for how bison density-dependent responses impact their management strategies.

Typical elk density-dependent responses are declines in pregnancy rates and increase in juvenile mortality as they approach carrying capacity (Houston 1982). However, bison typically respond by increasing their range (Taper et al. 2000). Their historic range in America and large population numbers are evidence of this adaptive strategy in order to accommodate increased pressure on food resources (Coughenour 2005). The IBMP has acknowledged how winter conditions influence this bison movement, where bison migrate outside park boundaries earlier in years of deeper snow pack and in increased numbers, but they also retreat inside park boundaries earlier in years of lighter snow pack (Geremia et al. 2014b). However, hazing efforts create a counter force when management pushes bison back to the boundaries that the species is naturally trying to break out of, contributing to the creation of the northern range as a static ecosystem that limits movement. This theoretically results in the increase of the magnitude of impacts of implemented management strategies on the northern range ecosystem.

The main use of removals by the IBMP is to reduce the total bison population size in the park to around 3,000 individuals (2016 Annual Report). However, the northern bison population appears to still be increasing despite management attempts as the total population is approximately 5,000 individuals, and the northern herd accounts for an estimated 3,600 (Geremia et al. 2016). Removal recommendations have been increasing in recent years to

address the high population status. Removals are only based on the previous year and estimated growth, but it is clear that this strategy is not yielding desirable results, suggesting that there is further research required to understand the underlying causes of this growth. A plausible explanation is that by successfully removing more individuals, this decreases the pressures of vegetative competition between bison, allowing for successful herd growth. Thus, it is suggested that the IBMP explores this idea further to determine if the current management strategy is counterproductively encouraging the growth of the northern herd.

A secondary strategy for removals is to limit range expansion. Bison movement could theoretically be limited if the population size of the herd is small enough that competition for winter feeding grounds is reduced to the point that range expansion is not necessary. However, research is lacking in what the necessary herd size is to keep bison below this movement threshold. This threshold is also contingent on normal winter conditions, as deeper snowpack may require movement regardless of the threshold. Due to nontraditional density dependence responses, no carrying capacity has been confidently agreed upon, which ultimately limits the effectiveness of this strategy (Taper et al. 2000; Coughenour 2005).

5.2 Competition between elk and bison on the northern range

The northern herd's inability to consistently rise above 1,000 individuals until 2006 remains unexplained. The inverse associations of the elk and bison populations and elk and bison graze are potential evidence for interspecific competition. Multiple studies support that interspecific competition has played a role in limiting bison abundance in the northern range (Coughenour 2005; Ripple et al. 2010). Ripple et al. (2010) concludes that elk declines as a result of wolf reintroduction to the park in 1995 initiated a delayed response in bison to be

relieved of this competition. Therefore, the most reasonable explanation for the herd's recent growth is due to this competition release. Furthermore, this delay in release demonstrates the need for careful consideration of potential long-term impacts on current management practices, as this growth response by bison was not initially predicted upon wolf reintroduction.

As outlined by Weisberg et al. (2002), considering herbivore interactions in the context of species-specific population dynamics is essential for being able to make effective and informed management plans. However, the IBMP does not account for the competition between elk and bison in the northern range, despite this competition directly influencing the northern herd size and seasonal range expansion. It is well documented that large populations of elk and bison occupy the northern range and are responsible for the majority of vegetation consumption, where bison occupy this territory year round and elk use the area as their annual winter grounds (National Research Council 2002; Greater Yellowstone Ecosystem 2016; Painter et al. 2015) During the winter, less available forage initiates bison movement outside park boundaries, resulting in hazing. If the IBMP achieves their goal of a smaller herd size, it may initiate a reverse effect resulting in the release of elk from competition with bison. The elk population would likely increase, resulting in less available forage for bison, initiating range expansion despite using removals to limit this. Thus, the IBMP must consider competition between elk and bison and how management strategies may be influenced by this relationship. This is a major oversight of the IBMP that should be immediately addressed.

5.3 Patterns of vegetative consumption on the northern range

Concerns have been raised about the vegetative condition of the northern range, proposing the idea of overconsumption and lower recruitment of essential woody vegetation that

may lead to devastating impacts on multiple species including both elk and bison (National Research Council 2002; Greater Yellowstone Ecosystem 2016; Coughenour 2005). However, the declining trend in the total vegetation consumption analysis suggests that the northern range has historically sustained much higher rates. This is best explained by the large decrease in elk biomass across the study period, which further reinforces the aforementioned release of bison from competition. However, this analysis suggests that since 2014 bison have become the dominant consumers of the vegetation in the northern range. Therefore, it is important for the IBMP to consider this in the context of their management strategies as it may result in greater impacts on the northern range vegetation than previously considered.

Although consumption may be reduced from previous years, recent evidence suggests that the dynamics of herbivore consumption in the northern range may be more complicated than originally documented. Recruitment of Yellowstone aspen, willow, and cottonwood has been significantly reduced due to large sums of consumption by elk. This woody vegetation is important for erosion prevention, supporting the populations of beaver and browsing ungulates, as well as providing habitat for many bird species (Northern Research Council 2002). Until recently, increased recruitment has been documented due to declines in the elk population as a result of wolf introduction to Yellowstone National Park in 1995 (Painter et al. 2015; Ripple et al. 2015). However, the recent evidence of bison browsing suggests that bison may now be a limiting factor in woody vegetation recruitment (Ripple et al. 2010; Painter et al. 2011). The magnitude of bison browsing is not well understood, but it is important for accurately measuring annual consumption and recruitment of woody vegetation in the northern range (Ripple et al. 2010; Painter et al. 2011).

Bison browse could generate long-term impacts because if the recent release from competition with elk continues to promote the growth of the bison herd, bison browse will increase and result in a new declining trend of woody vegetation recruitment if this is not addressed by the IBMP.

It is presumed that elk are forced to be more flexible in their diet than ever previously recorded. Elk are able to adjust their diet depending on available forage, often varying seasonally the amount of graze and browse in their diet, but tend to favor herbaceous vegetation (Coughenour 2005). However, with the reintroduction of wolves, there is some evidence that elk may be increasing the amount of browse in their diet as the woody vegetation habitat provides more coverage and may reduce predation risk (Christianson & Creel 2008). Furthermore, the transition to bison as the dominant source of vegetation consumption likely contributes to a decrease in available herbaceous forage and the need to increase browse in their diet. These conditions presumably serve as a limiting factor for woody vegetation recruitment in the northern range in addition to bison browse.

Herbaceous vegetation is also important in the northern range for sustaining grazing ungulates, such as the elk and bison. Although elk graze has declined due to the decrease in the population, this is slowly being replaced by bison graze, evidenced by the recent increasing trend seen in Figure 3 and the inverse association between elk and bison graze. Therefore, grass recruitment must remain at levels high enough to sustain the growing bison population and persisting elk population, and because the bison are now the dominant consumers how the IBMP influences the bison herd will be a major contributing factor influencing recruitment. Removals may be helpful in reducing pressure on herbaceous vegetation, however, due to the competition between elk and bison, it is likely that elk will eventually balance the reduced consumption and continually limit recruitment.

Essentially, as soon as one species is released from competition, it is likely that the other replaces it, creating a perpetual cycle of limited recruitment in the vegetation of the northern range. More research on elk and bison diet partitioning is required due to the major structural changes in the ecosystem of the northern range since prior research has been published. Thus, the major oversight of the IMBP to consider herbivore vegetation dynamics needs to be immediately addressed.

Conclusions

The northern bison herd in Yellowstone National Park is a critical population for the conservation of its species, as well as maintains an essential role in the dynamics of Yellowstone's northern range. The IBMP has successfully addressed some of their goals such as limiting brucellosis exposure and maintaining the recommended minimum herd size in the north. However, the IBMP needs to address a few significant oversights. First, how hazing and removal strategies are currently implemented to reduce range expansion need to be reevaluated in the context of the northern range ecosystem and reconsidered to address potentially counterproductive effects. Secondly, more research on bison browsing is needed and new research that reevaluates diet partitioning between elk and bison in the northern range. The IBMP also need to immediately address the complex role that bison assume in influencing park vegetation including competition with elk and their current status as the dominant source of vegetation consumption. These recommendations are made with the intention of limiting potentially negative long-term impacts on the management of the bison population and the northern range ecosystem. All of the aforementioned relationships described in this study are summarized in Figure 6. This multivariate approach is essential for producing effective

management plans. It was the goal of this study to highlight how management plans for critical populations, such as the northern bison herd in Yellowstone's northern range, lack this methodology and how major oversights lend to unproductive effects.

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Appendix

Table 1. List of specific objectives outlined by the Interagency Bison Management Plan and current goals set for each objective (2016 Annual Report of the Interagency Bison Management Plan).

Figure 1. Annual population counts for bison with indicated removals in that year from 1985-2016. Each bar reflects the total bison population counted in the summer of each year. Removals were subtracted from the total estimate and are reflected in orange since the removed individuals were during the following winter and were assumed to have been counted in the summer counts. There were no count data for 1989 so only the removal data is included that year.

Figure 2. Percent growth of the northern bison herd for each year from 1985-2016 based on the count data provided from Geremia et al. (2016). No count data was collected in 1989 so there were no calculations from 1989-1990.

Figure 3. Estimates for annual graze and browse consumption by elk and bison in the northern range from 1985-2016. Estimates are reflected in millions of kilograms. For bison there was no population data for 1989 and no data for elk in 1994, 1995, 2005, and 2013.

Figure 4. Estimated total annual vegetation consumption combined between elk and bison in the northern range from 1985-2016. Data is represented in millions of kilograms. Data was not combined for 1989, 1994, 1995, 2005, or 2013 since there was no population data available for at least one of the species in those years.

Figure 5. The percent of total vegetation consumption (in kg) that was removed by elk and bison each year from 1985-2016. Data was not included for 1989, 1994, 1995, 2005, or 2013 since there was no population data available for at least one of the species in those years.

Figure 6. Concept map summarizing the relationships between bison, elk, wolves, and both herbaceous and woody vegetation in Yellowstone's northern range. The influence of IBMP strategies via removals and hazing on the naturally occurring relationships are also summarized in the map.

Table 1. List of specific objectives outlined by the Interagency Bison Management Plan and current goals set for each objective (2016 Annual Report of the Interagency Bison Management Plan).

	General Objectives of the IBMP
1	Address bison population size and distribution; have specific commitments relating to the size of the herd
2	Clearly define a boundary line beyond which bison will not be tolerated
3	Address the risk to public safety and private property damage by bison
4	Commit to the eventual elimination of brucellosis in bison and other wildlife
5	Protect livestock from the risk of brucellosis transmission from bison
6	Protect the state of Montana from risk of reduction in its brucellosis status
7	Maintain a viable population of wild bison in YNP based on biology, genetics, and ecology
8	Be based on factual information, with the recognition that the scientific database is changing
9	Recognize the need for coordination in the management of natural and cultural resource values that are the responsibility of the signatory agencies

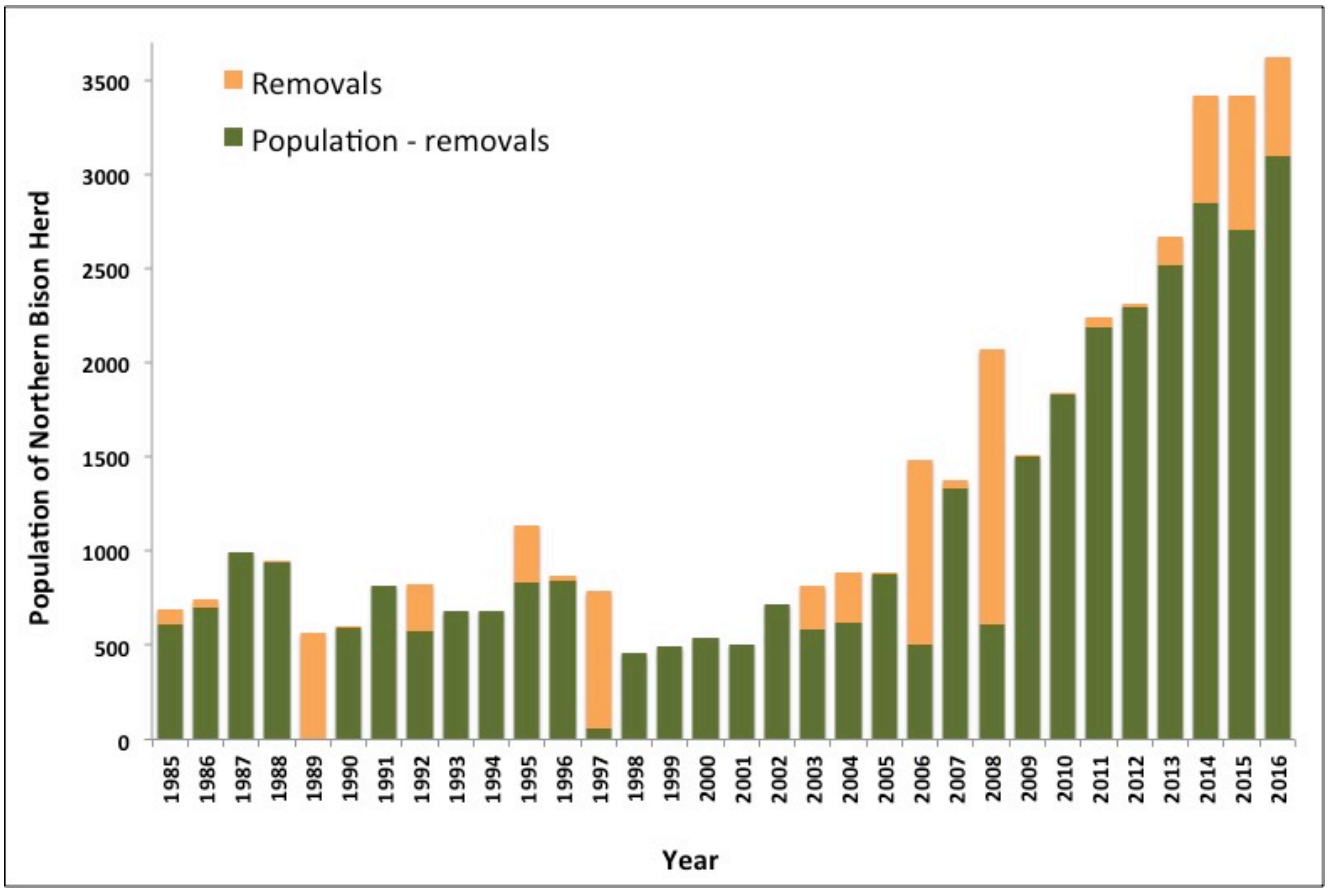


Figure 1. Annual population counts for bison with indicated removals in that year from 1985-2016. Each bar reflects the total bison population counted in the summer of each year. Removals were subtracted from the total estimate and are reflected in orange since the removed individuals were during the following winter and were assumed to have been counted in the summer counts. There were no count data for 1989 so only the removal data is included that year.

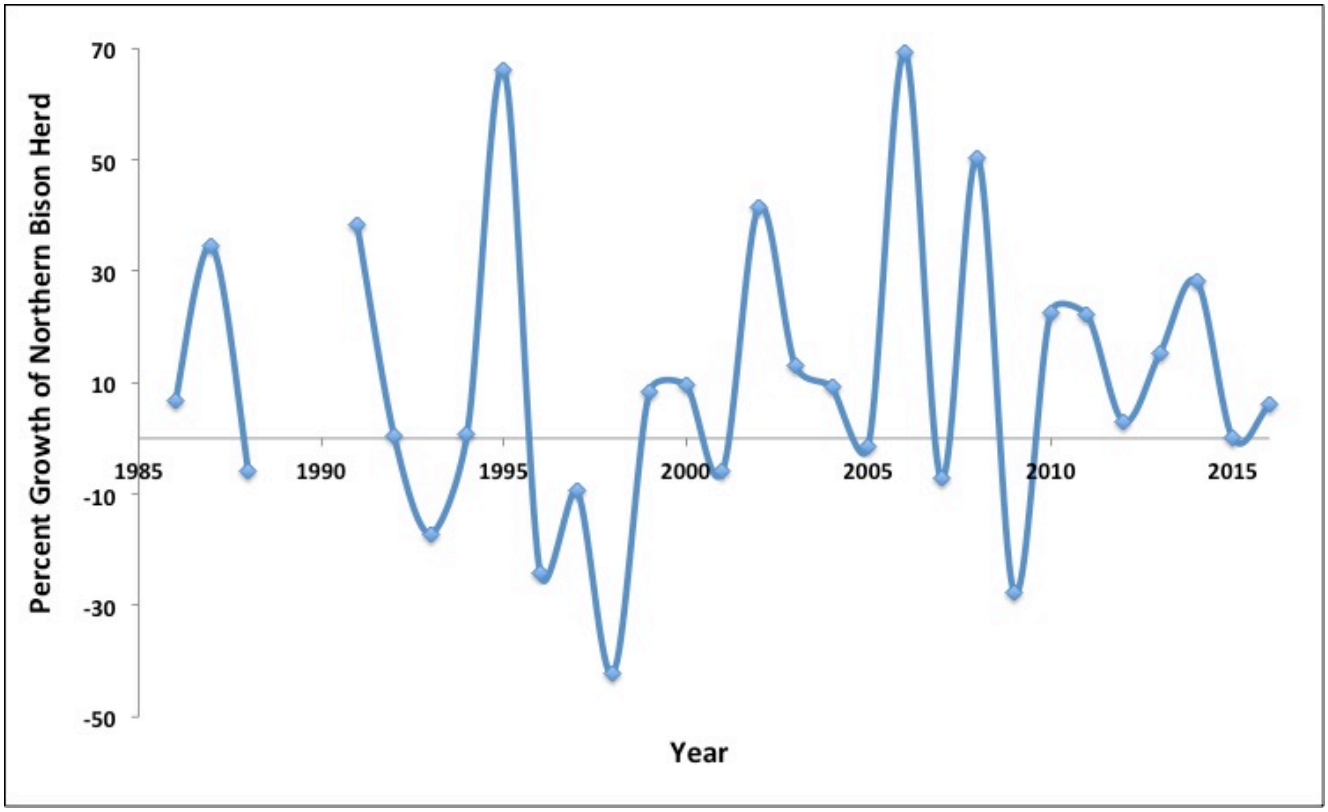


Figure 2. Percent growth of the northern bison herd for each year from 1985-2016 based on the count data provided from Geremia et al. (2016). No count data was collected in 1989 so there were no calculations from 1989-1990.

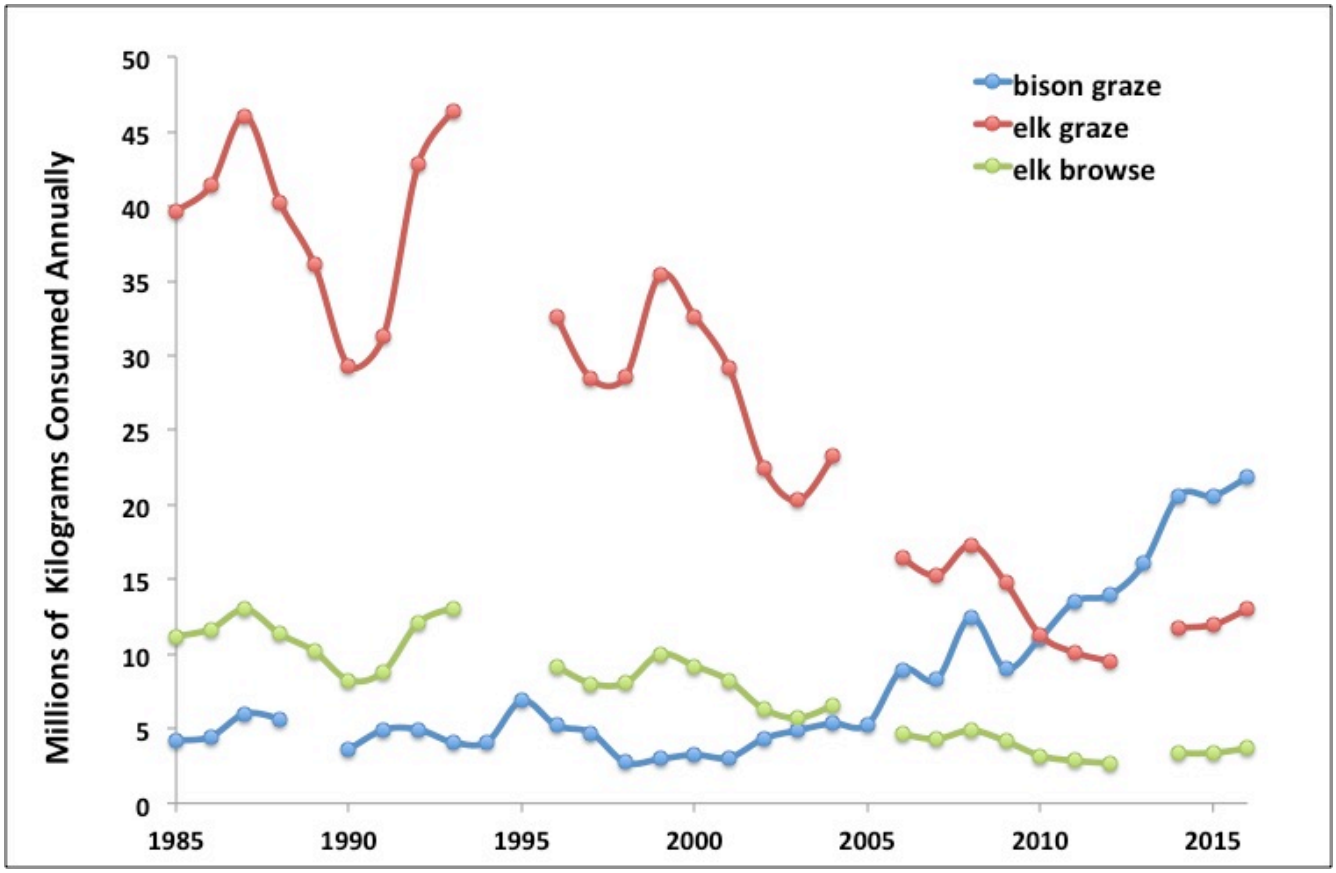


Figure 3. Estimates for annual graze and browse consumption by elk and bison in the northern range from 1985-2016. Estimates are reflected in millions of kilograms. For bison there was no population data for 1989 and no data for elk in 1994, 1995, 2005, and 2013.

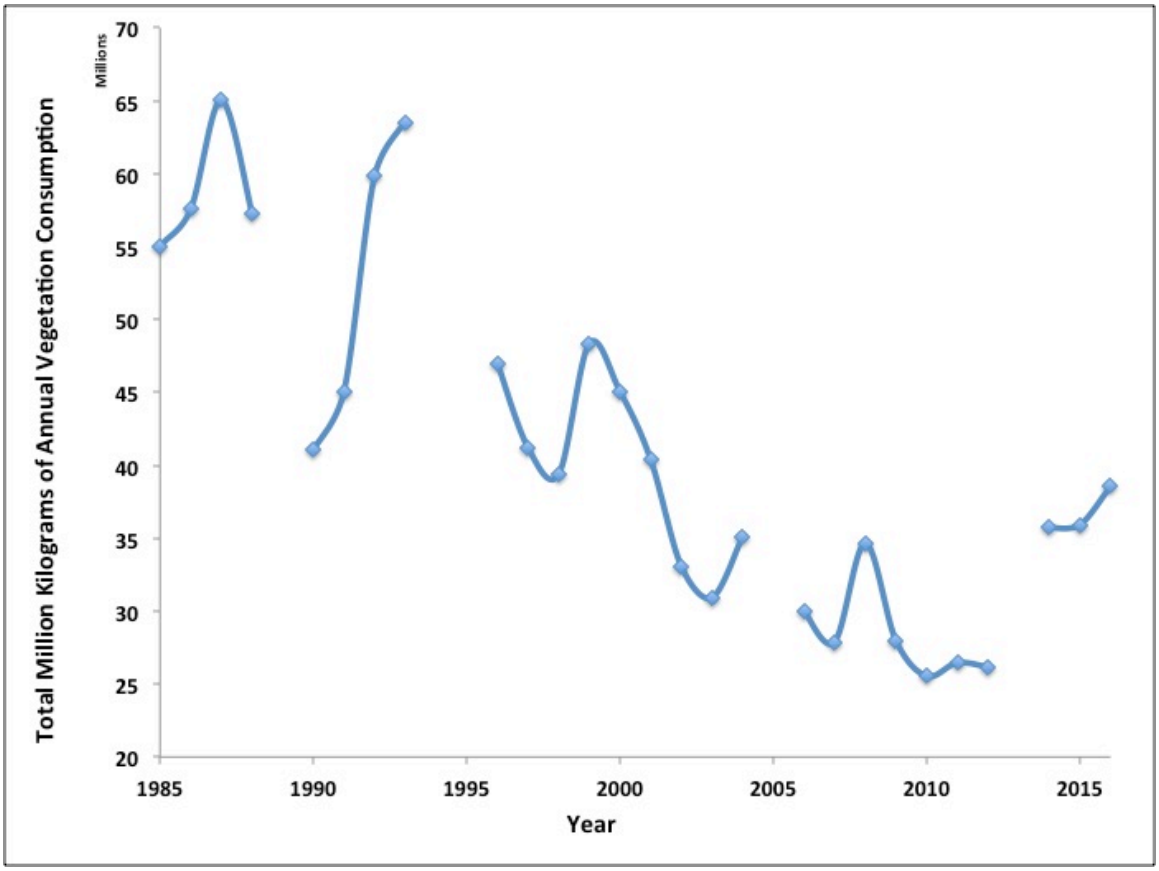


Figure 4. Estimated total annual vegetation consumption combined between elk and bison in the northern range from 1985-2016. Data is represented in millions of kilograms. Data was not combined for 1989, 1994, 1995, 2005, or 2013 since there was no population data available for at least one of the species in those years.

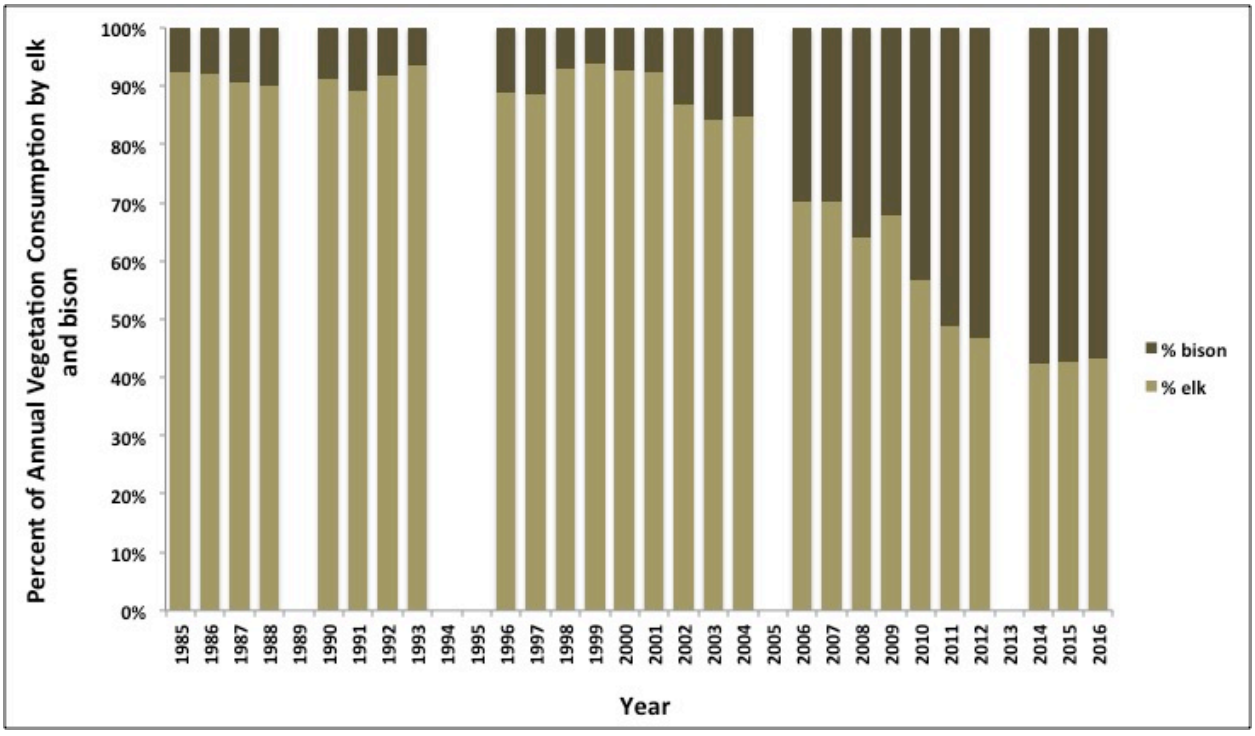


Figure 5. The percent of total vegetation consumption (in kg) that was removed by elk and bison each year from 1985-2016. Data was not included for 1989, 1994, 1995, 2005, or 2013 since there was no population data available for at least one of the species in those years.

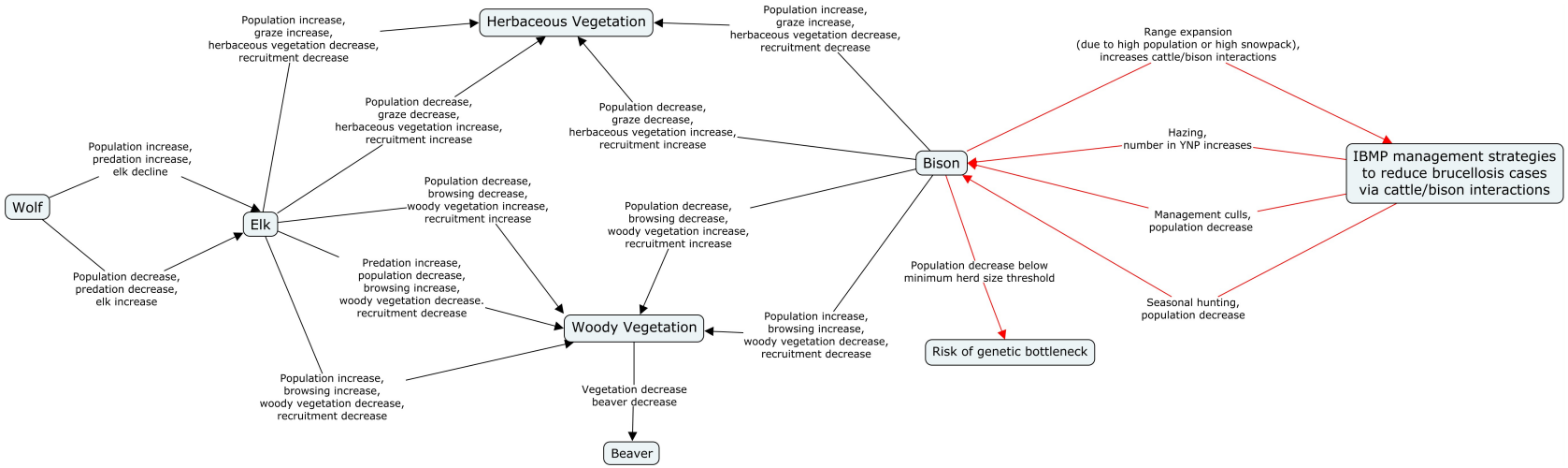


Figure 6. Concept map summarizing the relationships between bison, elk, wolves, and both herbaceous and woody vegetation in Yellowstone's northern range. The influence of IBMP strategies via removals and hazing on the naturally occurring relationships are also summarized in the map.