Spatiotemporal Dimensions of Grizzly Bear Recovery

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PS- data acquisition, geospatial analysis, methods and results of movement pathways and creation of all new maps.

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Michael Bäder[1] Paul Sieracki[2]

Abstract

Essential elements of conservation and recovery planning for the threatened Grizzly bear (*Ursus arctos*) include estimates of viable population size and persistence time, mean densities, current and projected distribution and analysis of grizzly bear habitat areas between the designated core Recovery Areas. Grizzly bears are often secretive and elusive animals, making it challenging to study them with absolute precision. Benchmarks based on data from rigorous scientific investigations provide realistic goals for the numbers, time, space and configuration required to achieve natural grizzly bear recovery. We estimate the spatiotemporal dimensions of grizzly bear recovery in the U.S. northern Rockies are ≈ 3,000 grizzly bears on ≈ 250,000 km^2 of landscape over several hundred years in a single connected population or metapopulation. Larger estimates will require protected landscape connectivity with southern British Columbia and Alberta. We conclude the 1993 Grizzly Bear Recovery Plan and Conservation Strategies will not achieve a genetically diverse and demographically viable grizzly bear population. We recommend a Northern Rockies Grizzly Bear Recovery Plan that incorporates realistic population estimates and human population growth and distribution and their resource demands as well as climate change.

Introduction

The grizzly bears in the U.S. Northern Rockies, southern British Columbia and Alberta are from a unique genetic lineage called Clade 4 which remains only in the Rockies and on Hokkaido Island and thus have high global conservation value (Mattson 2019). After 150 years of indiscriminate killing and extirpations (Mattson and Merrill 2002) the grizzly bear (*Ursus arctos*) was listed as a threatened species under the Endangered Species Act (ESA) in 1975 in the 48 states south of Canada. At that time only a few hundred bears remained, mostly in Glacier and Yellowstone National Parks where hunting was and remains prohibited. A subsequent Recovery Plan was not finalized until 1993 and has not been updated.

Under the 1978 amendments to the ESA, critical habitat designation was not required for the grizzly bear but neither was it prohibited. Rather than designate critical habitat, the U.S. Fish & Wildlife Service (1993, 1996, 2000) designated five Recovery Areas in the northern Rockies in Washington, Idaho, Montana and Wyoming.

Grizzly bears have perhaps the lowest reproductive rate of North American mammals (Yellowstone Grizzly Project 2024) which limits their capacity to rebound from threats and population declines. Moreover, about half of all cubs die within the first year (Costello et al. 2024). Most grizzly bear mortality (≈ 85%) is human-related (US Geological Survey 2024) and very few grizzly bears live their natural life span in the wild (Schwartz et al. 2003) which means fewer breeding opportunities. Interior grizzly bears typically exist at low densities and use a large habitat area dictated by habitat and food availability, social factors and human influences that ultimately restrict population sizes (Mowat et al. 2013). Documented individual life ranges may be up to ≈ 900 km^2 or more (Blanchard and Knight 1991).

Population Viability Analyses

Population Viability Analysis (PVA) provides information on the expected longevity of wildlife populations (Ralls et al. 2002). Luikart et al. (2010) wrote: "Population census size (N_c) and effective population size (N_e) are among the most important parameters in wildlife management and conservation because they can inform management and help predict the extinction risk of populations."

Effective population size (N_e) is the size of a genetically ideal population that would experience the same amount of genetic drift as the observed population. These are the adults breeding in a given season. The "50/500 rule" (Franklin 1980, Gilpin and Soule' 1986) states that $N_e = 50$ is needed to avoid inbreeding depression for short term viability. $N_e = 500$ is the minimum necessary for survival and adaptation over several centuries. Larger numbers overcome the accumulation of harmful alleles. N_e and N_c aren't the only factors in grizzly bear persistence. Individual fitness, mortality risk, fragmentation and loss of habitat are also important.

These benchmarks are not precise for every population or species. They are "rule of thumb" minimums based on scientific investigation. They are generally accepted for grizzly bears (Harris et al. 2022, Allendorf et al. 2019, Horejsi 2016) and they provide a useful comparison for evaluating recovery strategies. They are part of the precautionary principle approach to risk management for rare, threatened and endangered species.

For grizzly bears, estimates for long term viability range from 3,000-5,000 individuals in a single population or solidly connected meta-population (Allendorf and Ryman 2002; Allendorf et al. 2019). Current population estimates suggest there are about 2,000 grizzly bears south of Canada (U.S. Fish & Wildlife Service 2023).

Methods

Analysis Area

The analysis area is the U.S. northern Rockies, the five grizzly bear recovery areas and potentially suitable habitats as shown in Figure 1.

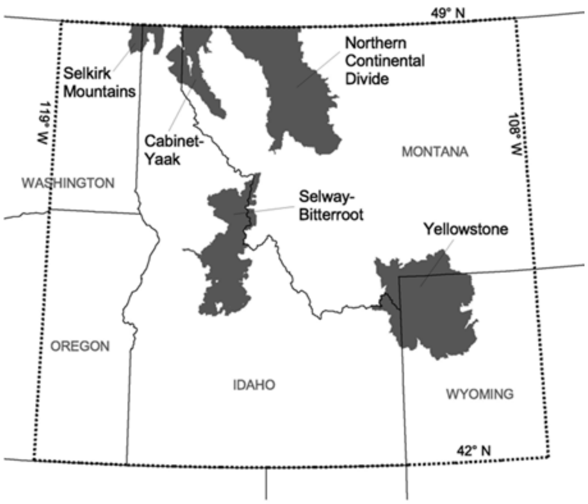


Figure 1. The Northern Rockies Analysis Area.

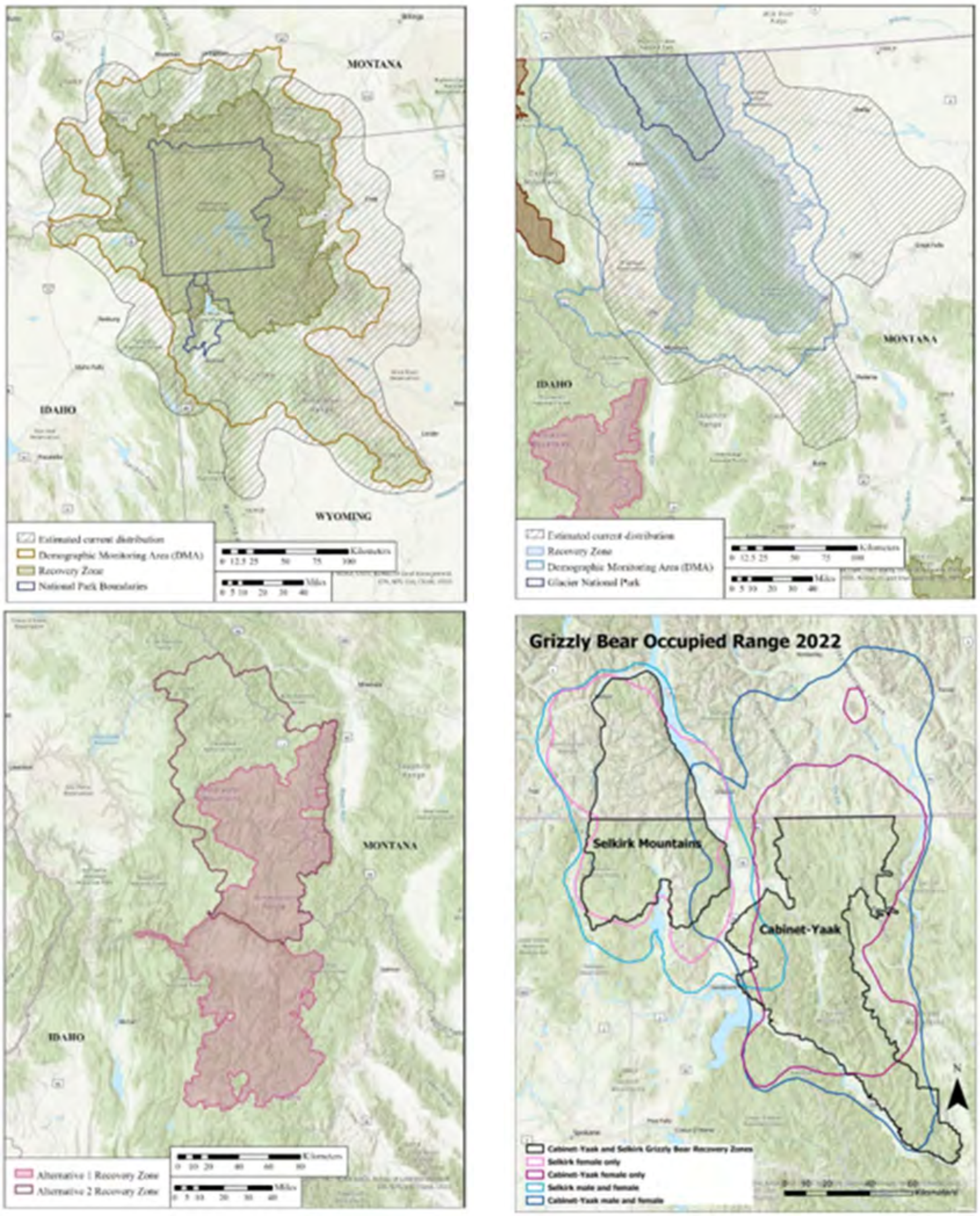
Population Estimates, Occupied Habitat Areas and Bear Density

The most recent estimates for population and occupied habitat area for the Northern Continental Divide Ecosystem (NCDE), Greater Yellowstone Ecosystem (GYE), Selkirk Ecosystem (SE) and Cabinet-Yaak Ecosystem (CYE) grizzly bear populations (Costello et al. 2023, 2024, U.S. Fish & Wildlife Service 2023, Kasworm et al. 2024) were used to estimate population density expressed as bears/1000km^2.

The density calculations were combined with the N_e = 500 benchmark at varying N_e to estimate a range of the spatial dimensions necessary to support 2,500, 3,000 and 5,000 grizzly bears.

Until more specific density studies are initiated this is the best available information for calculating coarse estimates sufficient for measuring benchmarks for population size and protected area and analysis of current recovery strategy. The density figures used for this analysis were 12.0, 13.5, 15.0, 16.5 and 18.0 bears per 1000km^2.

Figure 2. Estimated Occupied Grizzly Bear Habitat in the Northern Rockies (U.S. Fish & Wildlife Service). Upper left: Greater Yellowstone. Upper right: NCDE. Lower left: Bitterroot (no known breeding population). Lower right: Selkirk and Cabinet-Yaak.



Estimates for N_e

A range for N_e/N_c of approximately 0.10-0.25 applies to populations of grizzly bears (Harris and Allendorf 1989, Miller and Waits 2003, Luikart et al. 2010). Much higher N_e 0.42-0.66 for grizzly bear in GYE were estimated by Kamath et al. (2015) which is inconsistent with other estimates (Shafer 2022). Luikart et al. (2010) found that when adjusted for population fluctuations, four previous estimates of N_e for grizzly bears were significantly reduced. The N_e used for this analysis were 0.10, 0.17, 0.20, and 0.25.

Analysis of Designated Recovery Areas and Protected Lands

Grizzly Bear Recovery Areas (U.S. Fish & Wildlife Service 2023) and conservation strategies (U.S. Fish & Wildlife Service et al. 2018, U.S. Forest Service et al. 2024) were evaluated against the estimates for spatial and temporal dimensions as well as scientifically-derived management standards.

Analysis of Potential Habitat Beyond Recovery Areas

Due to the high interest in population connectivity and its implications for population viability, results from grizzly bear movement pathway analyses (also known as corridors or habitat linkages) modeled by Walker and Craighead (1997), Proctor et al. (2015), Peck et al. (2017) and Sells et al. (2023b) were used to produce maps showing overlap of modeled results and a spatially adjusted total for illustrative purposes to show what has been done.

These studies are not apples to apples because they had different purposes, methods, data sets and study areas. For example, Sells et al. (2023b) used a step selection function that did not include road density or distance to roads as variables. Sells and Costello (In Press) state: "As noted above, a further caveat is that our simulations do not account for mortality risk, which we would expect to be higher in areas of higher road density and human development, a factor especially important when considering the natural recolonization simulations." Sells et al. (2023b) and Sells and Costello (*In Press*) used movement data from the core interior of the NCDE with relatively high bear density. Bader and Sieracki (2024a) wrote that such data may be inconsistent with longer dispersals into unoccupied or sporadically occupied habitat areas.

Thus, direct comparisons between the results are not robust and the cumulative results are a “data mashup.” However, these study results are informative as to possibilities for grizzly bear movement and population connectivity. Data mashups using GIS allow analysis and visualization of spatial data from multiple sources, assisting in management planning (Fleming et al. 2014).

Movement pathway datasets (“pathways”) were reconstructed using PDF images from Walker and Craighead (1997) (see figure 3) in conjunction with Geographic Information System (GIS) datasets from Proctor et al. (2015), Peck et al. (2017), and Sells et al. (2023). This integration aimed to create a comprehensive representation of existing modeled movement pathways between Grizzly Bear recovery areas.

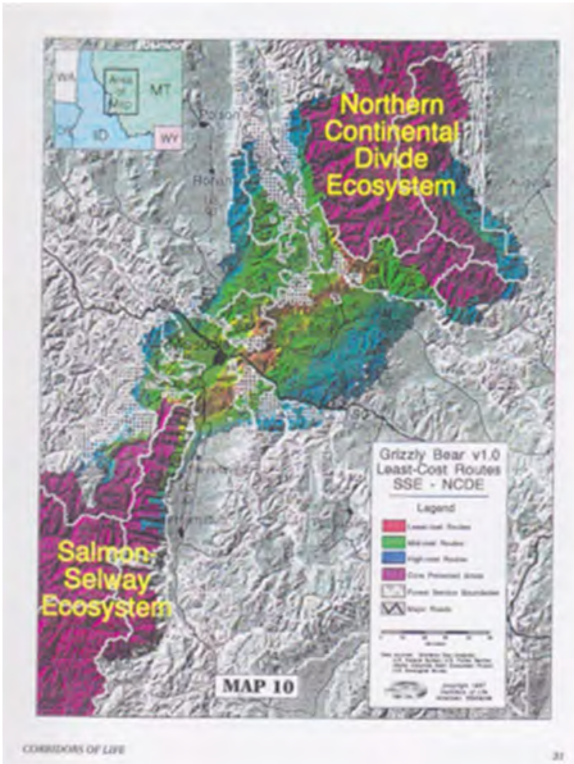


Figure 3. Example of Walker and Craighead maps.

The movement pathways derived from PDF sources were rasterized and georeferenced, with surrounding areas that were not in the pathways converted to no data values, thereby facilitating the classification of the pathways.

The resulting images were classified utilizing the ISODATA method (ESRI 2024). Gaps in corridor data were identified due to the presence of roads, state lines, and administrative boundaries. Classifications of pathways were extracted from the ISODATA sets and ranked for their ecological value. To reconstruct a continuous movement pathway approximation for the mashup, high-value polygons were used to create a resistance surface for a least-cost analysis. This process effectively smoothed over data gaps, providing an illustrative approximation of high and medium-value areas within the pathway.

The analysis focused on the number of pathway overlaps to gain insights into the perceived functionality of pathways by researchers. Two methods were employed: first, pathways were normalized and summed to produce a composite showing relative values, where areas with high pathway connectivity received the highest sums. The pathway mashup was then divided by six, representing the number of pathways, to estimate the selection of pathways for modeling by researchers.

The second method involved dividing the pathway mashup by a raster that displayed the spatially adjusted overlapping pathway count, thereby visualizing areas identified by multiple researchers as higher-value pathways. This visualization process was intended to highlight potential pathways and was not designed for direct comparison of pathway values or quantitative analysis.

Layers for suitable three-season habitats and suitable denning habitats were also considered (Carroll et al. 2001, 2003, Hogg et al. 2001, Merrill et al. 2002, Podruzny et al. 2002, Boyce and Waller 2003, Proctor et al. 2015, Bader and Sieracki 2022, 2024, Sells et al. 2022, 2023a, 2023b). Verified observations of grizzly bears outside the estimated occupied areas from 2013-2024 (n = 265) U.S. Fish & Wildlife Service et al. (2024) were overlaid on these results.

Protected areas outside of Recovery Areas were measured by size (thousand km^2) and as a percent of the estimated spatial dimensions. Categories for these protected areas come from the International Union for the Conservation of Nature (IUCN, Dudley 2013).

The cumulative result of the assessment was mapped.

Results

The five grizzly bear population areas have a gross mean population density of 11.6/1000 km^2. (see Table 1). The spatial requirements for 3000 grizzly bears at 12/1000km^2 in the U.S. northern Rockies are ≈ 250,000 km^2 (see Figure 2). For 5,000 bears this rises to > 400,000 km^2. The most optimistic scenario of N_e = 0.25 and density = 18/1000km^2 uniformly across the region exceeds the 80,662 km^2 of the five isolated Recovery Areas by ≈ 30,000 km^2 (see Table 2).

Table 1. Mean Density of Grizzly Bears in the Northern Rockies.

Population Area	N	Area (km^2)	Density (Bears/1000km^2)
Yellowstone	965	70,468[1]	13.7
NCDE	1100	55,562[2]	19.8
Selkirk	75	10,928[3]	6.9
Cabinet-Yaak	60-65	18,814[4]	3.2-3.5
Bitterroot•	321	22,244	14.4
			Average = 11.6/1000km^2

1 Occupied Habitat Area (U.S. Fish & Wildlife Service 2023).
2 Occupied Habitat Area (Costello, et al. 2023).
3 Occupied Area males & females (Kasworm et al. 2024).
4 Occupied Area males & females (Kasworm et al. 2024).
• Estimate (Boyce and Waller 2003) K = 321 = 14.4

Population estimates for GYE, SE, CYE (U.S. Fish & Wildlife Service 2023); NCDE (Costello 2024).

Figure 4. Spatial Dimensions for Northern Rockies Grizzly Bears.

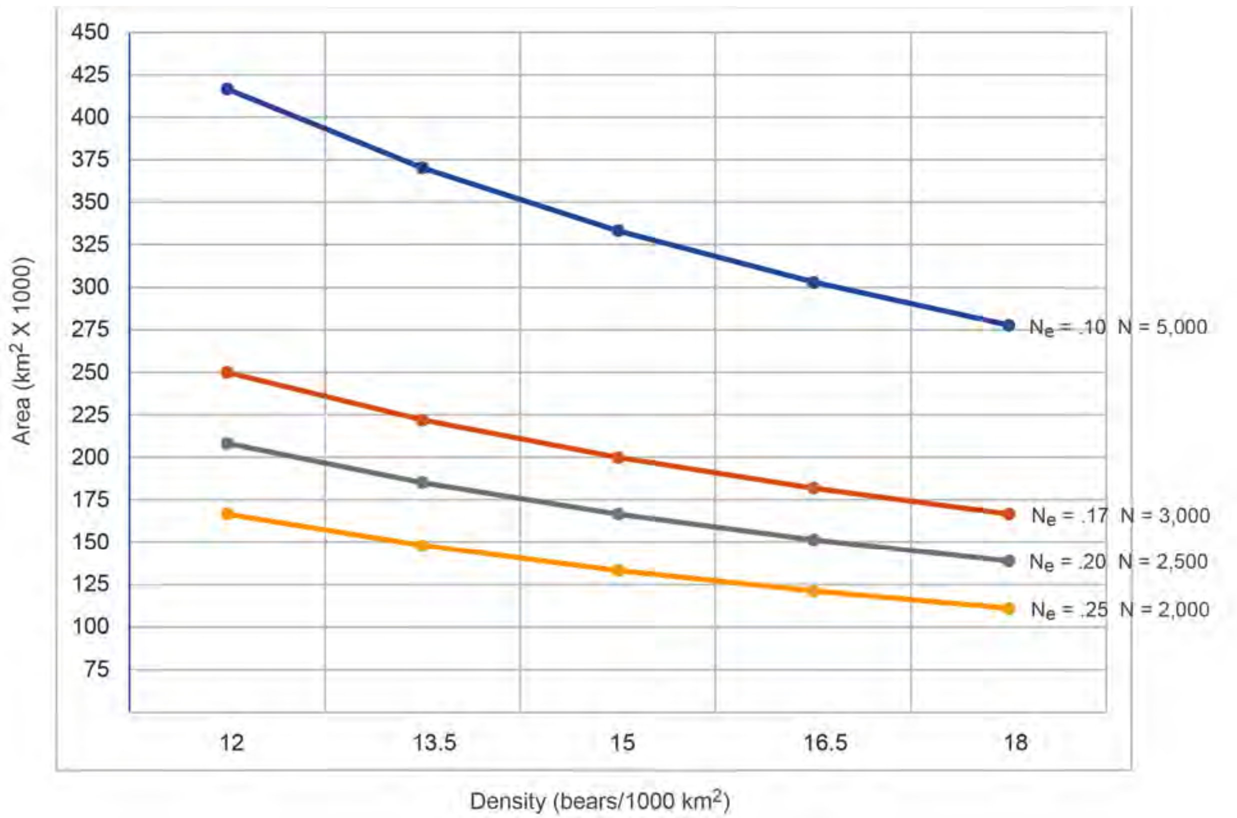


Table 2. Isolated Recovery Areas (km²) Compared to the Estimated Range of Spatial Needs

Population	Recovery Area	Percent of Range	DMA*	Percent of Range
GYE	23,853	9.5-14.3	49,928	20.0-30.0
NCDE	23,135	9.3-13.9	42,602	17.0-25.6
CYE	6,705	2.7-4.0	-	-
SE	6,575	2.6-3.9	-	-
BE	15,100	6.0-9.1	-	-

*The NCDE and GYE areas have larger Demographic Monitoring Areas (DMAs) from which population statistics are gathered.

The Conservation Strategies for the NCDE and GYE areas fall well below viability benchmarks and persistence time. The NCDE Conservation Strategy is based on maintaining a 90% chance of not falling below 800 total bears which Montana Fish, Wildlife & Parks (2024) acknowledges has never been peer-reviewed and published. The GYE Conservation Strategy manages for 800-975 bears. These plans consider persistence for just 100 years.

There are no explicit references to climate change in either the Recovery Plan or the Conservation Strategies which further reduces the efficacy of the undersized and isolated landscape reserves.

The spatial analysis shows ≈ 250,000 km^2 of grizzly bear habitat area is available on primarily public lands in the U.S. northern Rockies south of Canada (see Tables 3 and 4). The International Union for the Conservation of Nature (IUCN 2013) states that 75% of a reserve area should consist of protected lands. Applying the "75% Rule" to Northern Rockies grizzly bears, 185,000km^2 of the reserve area should be in protected categories. There are approximately 195,000km^2 of Recovery Areas, Protected Areas outside of Recovery Areas, NCDE Zone 1 and private land conservation easements. Habitat shown to have value for grizzly bears in the Northern Rockies and modeled in one or more analyses is shown in Figure 5. There are differences across this area in terms of habitat productivity, habitat security, mortality risk, density or local carrying capacity. There are also good quality grizzly bear habitats on private lands and key movement pathways are partially located on private lands as shown in Figure 5.

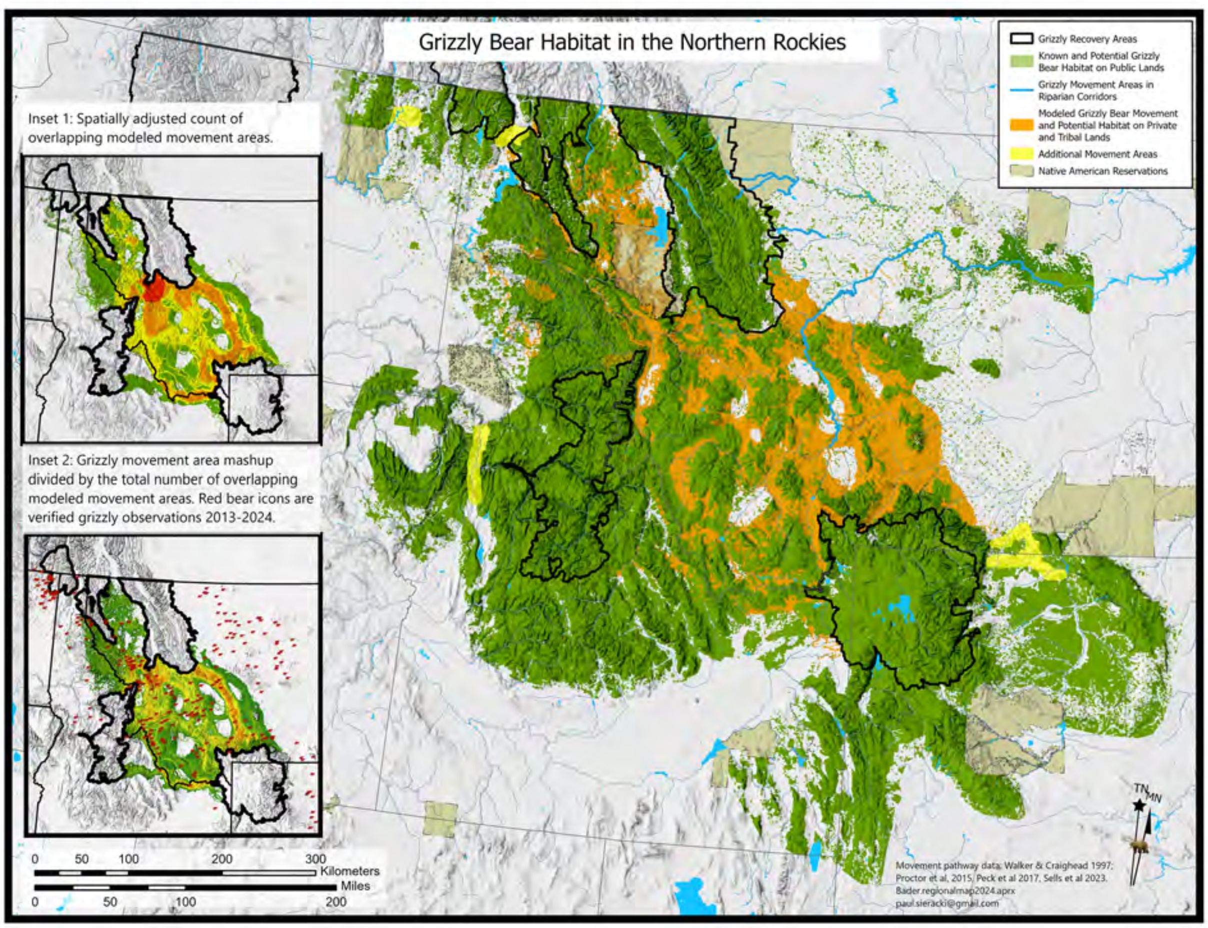


Figure 5. Known and Potential Grizzly Bear Habitat in the Northern Rockies. Bear Observations are Those Generally Beyond Estimated Occupied Areas.

Table 3. Protected Areas Outside of Grizzly Bear Recovery Areas

Type	Area (km^2)	IUCN Class
Wilderness	14,268	Ib
Wilderness Study Areas	3596	Ib
Inventoried Roadless Areas	63,555	Ib
National Park	838	II
National Monument	1538	III
National Wildlife Refuge	423	IV
State Wildlife Management Areas	3496	IV
National Recreation Area	6325	VI
	Total 94,039	

Table 4. Habitat Areas Specifically Managed for Grizzly Bear Presence

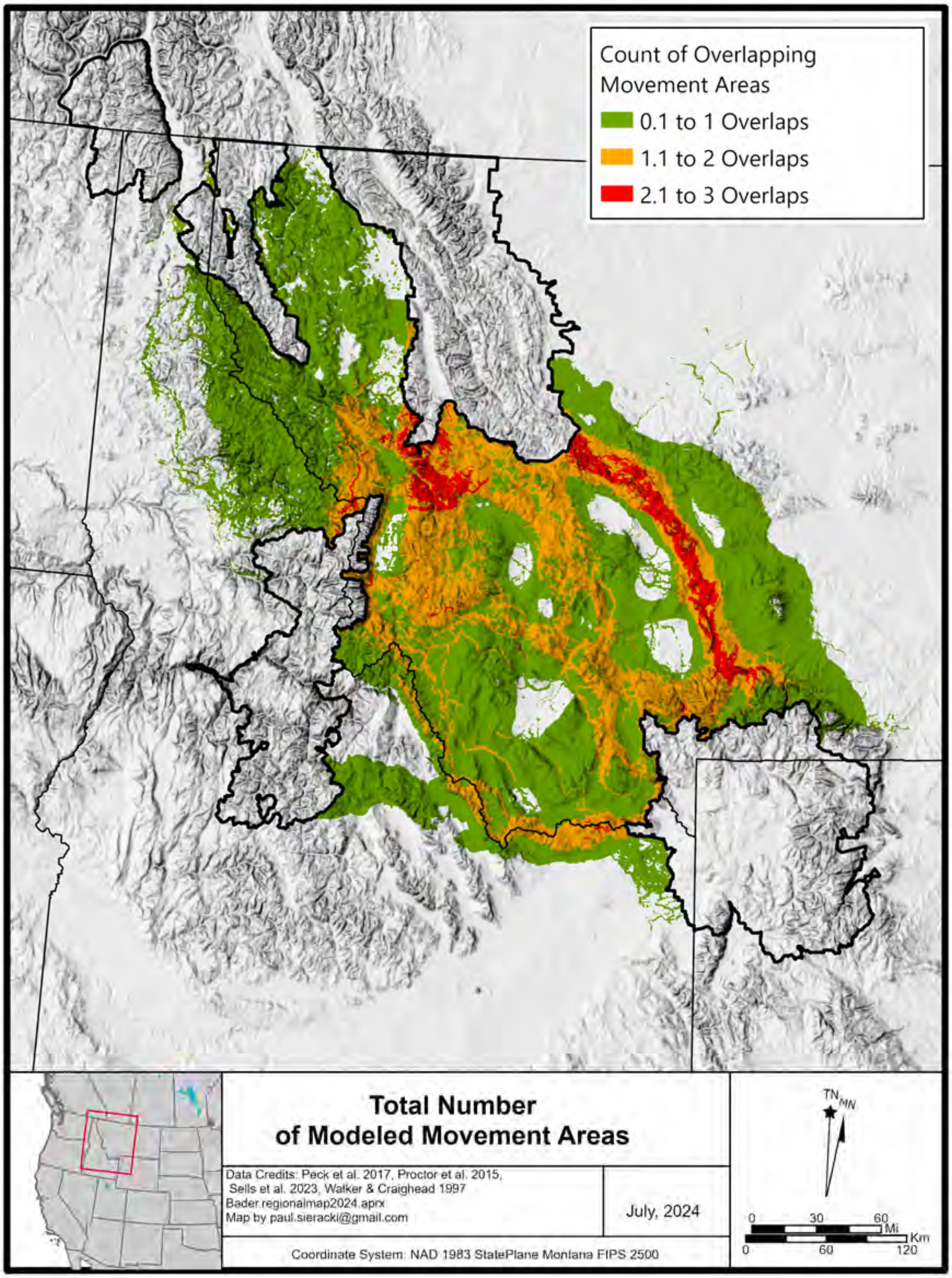
Area	Management	Area (km^2)
Recovery Areas	Specific standards for habitat secure core, 0.6km/km^2 Open Motorized Route Density, limit on developments	80,662
NCDE Zone 1	1.2km/km^2 Open Motorized Route Density. No required secure areas. No permanent road miles above 2011 level. No limit on developments.	19,484
Bears Outside Recovery Areas (BORZ) CYE/SE	Minimal standards	4,429
Private Forestland Conservation Easements	No permanent roads, limits on clearcutting, no homesites	1,854
American Prairie Reserve	Open space, wilderness	1,873
		Total: 108,302

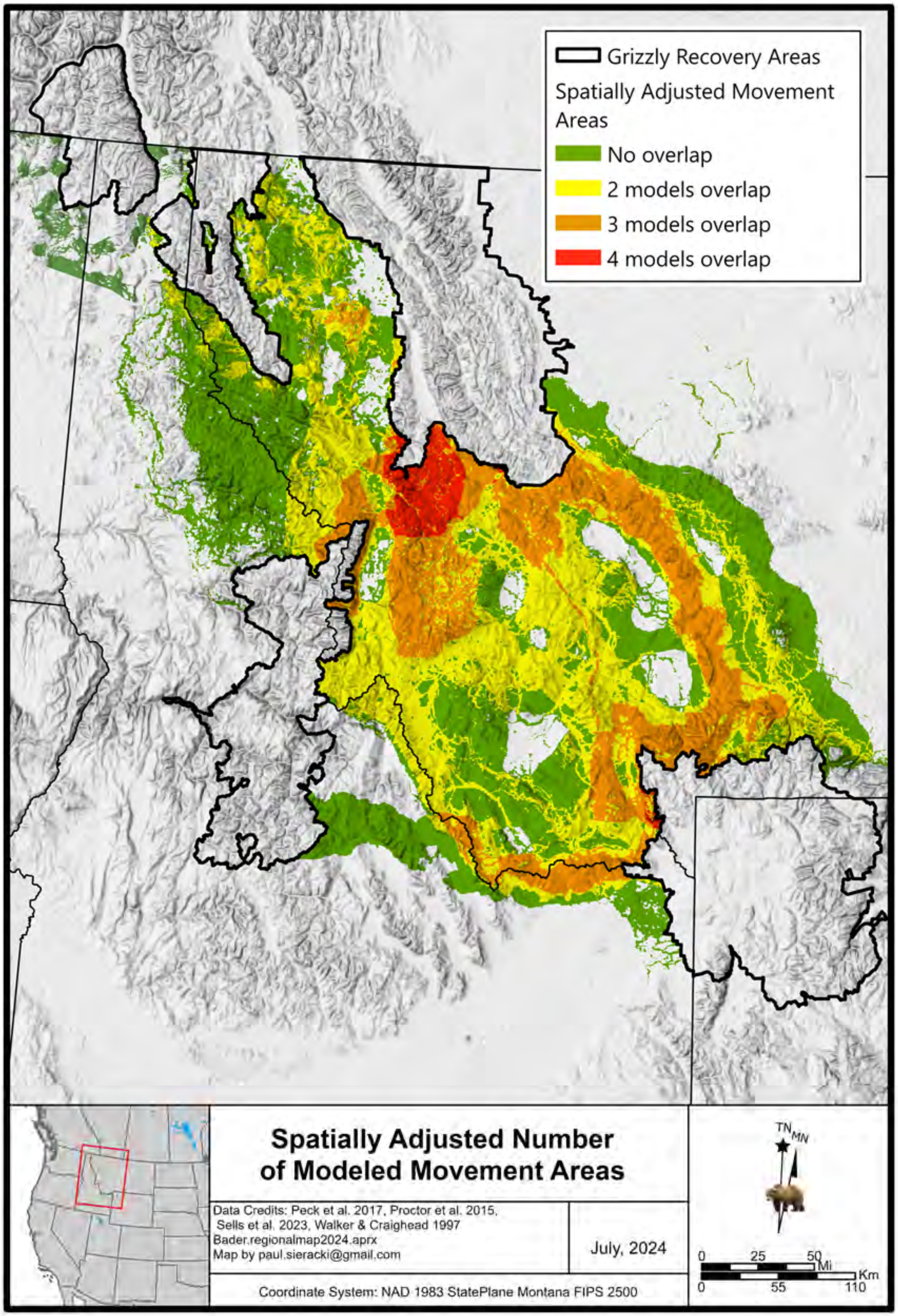
Frequency Analysis of Modeled Movement Pathways

Opportunistically detected grizzly bear observations outside of estimated occupied areas exceed the compilation of modeled pathways. Models that show broader results including all of the Sapphire Mountains (Walker and Craighead 1997) are more inclusive of the observation data.

The illustrated results from the data mashup of modeled movement pathways are shown in Figures 6a and 6b.

Figures 6a and 6b. Combined Grizzly Bear Pathway Analyses.




Grizzly Recovery Areas
Spatially Adjusted Movement Areas
No overlap
2 models overlap
3 models overlap
4 models overlap
Spatially Adjusted Number of Modeled Movement Areas
Data Credits: Peck et al. 2017, Proctor et al. 2015, Sells et al. 2023, Walker & Craighead 1997
Bader.regionalmap2024.aprx
Map by paul.sieracki@gmail.com
July, 2024
Coordinate System: NAD 1983 StatePlane Montana FIPS 2500
TN
MN
0 25 50 Mi
0 55 110 Km

Protective Status of Grizzly Bear Habitat

The area being monitored for grizzly bear population data in the GYE and NCDE has been expanded through Demographic Monitoring Areas (DMAs). In the NCDE, the DMA is the Recovery Area and an area called Zone 1, (≈ 16 km buffer around the Recovery Area). The GYE does not have a Zone 1. The habitat standards for Zone 1 are substantially less stringent than in the Recovery Area. In the Recovery Area open motorized route density (OMRD) is limited to 0.6 km/km^2 ($1mi/mi^2$). Open motorized routes are generally roads and trails open to public use. Administrative use by agency personnel is limited to a set number of trips per season (often 30). If this limit is exceeded, the route must be counted as an open route for density calculations.

Secure core habitat is defined as areas at least 500 m from an open motorized route and 10 km^2 (2500 acres) in size which must constitute a minimum of 60% of each Bear Management Unit (U.S. Fish & Wildlife Service et al. 2018). In Zone 1, open motorized route density (OMRD) of 1.24 km/km^2 ($2mi/mi^2$) is allowed and there are no secure core requirements. At 1.24 km/km^2, adult female survival rate is about 80%, density is about 1/3 of what it is in roadless areas and den selection is about 1/3 that of lower road density areas. (see Table 5).

Table 5. Road Density Impacts on Grizzly Bears.

Road Density km/km^2	Adult Female Survival Rate	Population Growth Rate	Density $Bears/1000km^2$	Den Selection Probability
0	≈100%	Positive	30	N/A
0.6	95%	Static	≈ 30	70%
1.2	85%	Negative	10	30%
1.4	75%	Rapid Decline	Lower	N/A
1.6	< 75%	Rapid Decline	Lower	N/A
2.0	Lower	Rapid Decline	Very Low	≈ 0%

Sources: Proctor and others (2019), Boulanger and Stenhouse (2014), Pigeon and others (2014).

Data from McGloughlin and Stenhouse (2021) suggests OMRD in secondary conservation areas should be no more than $0.75km/km^2$ ($1.2mi/mi^2$). To achieve this standard in NCDE Zone 1 would require a 40% decrease in OMRD. However, Proctor et al. (2019) recommend that in connectivity areas OMRD be no more than $0.6km/km^2$ which would require a 50% decrease in OMRD in NCDE Zone 1. The best model score in Proctor et al. (2023) suggests that grizzly bears best tolerated no more than $0.3km/km^2$ OMRD ($0.48mi/mi^2$).

Within the Recovery Areas, conflicts between bears and humans are expected to be resolved in favor of bears. In Zone 1 there is no administrative or legal requirement that conflicts between humans and grizzly bears on public lands be resolved in favor of the grizzly bear and are often not.

Moreover, much occupied grizzly bear habitat has no management standards at all. For example, the Lolo National Forest, which has land in three recovery areas has high connectivity value. It only has habitat protection standards that apply to the Recovery Area and the minimal standards for Zone 1. All of the Lolo is either "occupied habitat" or "may be present" (Costello et al. 2023; U.S. Fish & Wildlife Service 2024). The southern and western 62% of the Forest has no standards specific to grizzly bears and there are no limits on OMRD or new permanent roads. Only 19% of the Forest has full protections for grizzly bears within a Recovery Area (Lolo National Forest Draft Assessment 2024). The same situation exists on many other National Forests throughout the region including portions of the Colville and Idaho Panhandle National Forests.

The NCDE Conservation Strategy allows one new major development or expansion of an existing development within the Recovery Area every ten years in each of the 23 Bear Management Units. This could result in dozens of new developments that elevate mortality risk to grizzly bears (McLellan 2018). There are no limits on developments in Zone 1.

Discussion

How Many Bears for How Long?

Because grizzly bears are often secretive and elusive animals, research sample sizes tend to be small. As a result, achieving absolute precision regarding population trends and determining the exact number of bears required to ensure long-term viability is not attainable. Scientifically-derived benchmarks provide a best available science view of the numbers, time, space and protective standards required to achieve and sustain natural grizzly bear recovery in the northern Rockies. Unfortunately, the current Recovery Plan and Conservation Strategies do not adequately incorporate these metrics.

As the science of population viability analysis matured, the estimates for minimum number of individuals has steadily increased (Craighead 2019). Shaffer and Samson (1985) estimated 50-90 grizzly bears over 100 years might be a minimum number. Allendorf et al. (1991) estimated 1,670 grizzly bears while Metzgar and Bader (1992) suggested 2,000 in a connected metapopulation. Allendorf and Ryman (2002) estimated as many as 5,000 grizzly bears in a single population may be necessary for long term viability of grizzly bears.

Reed et al. (2003) define viability as a 99% chance of survival for 40 generations, approximately 400 years for grizzly bears which have a generational time of ≈ 10 years (Miller and Waits 2003). Traill et al. (2007) reported mean Minimum Viable Population (MVP) for 212 species was 4169 individuals. Reed et al. recommend that conservation programs for wild populations be designed to conserve habitat capable of supporting ≈ 7000 adult vertebrates.

MVP is a *minimum* estimate. Managing for minimums entails much greater risk. A superior approach is to plan for more than the minimum, which then reduces extinction risk. Therefore, $N_e > 500$ would provide necessary protection and greater confidence.

Regardless of which figure for MVP is applied, the existing Grizzly Bear Recovery Plan and Conservation Strategies seek to maintain maximum populations of 800-1000, far below any of these science derived thresholds.

How Much Habitat Area for a Viable Grizzly Bear Population?

Grizzly bears need a large habitat area relative to other species due to their large individual life ranges of up to ≈ 900 km^2 or more (Blanchard and Knight 1991). Carroll et al. (2003) found that increasing network size has the greatest effects on population viability for grizzly bear.

Bader (2000c) estimated spatial needs of northern Rockies grizzly bears ≈ 148,000-185,000 km^2 for N_c = 2,000-2,500. Wielgus (2003) proposed reserves for grizzly bear populations in south-central British Columbia with a 16 km buffer that totaled 17,843 km^2 for 250 bears. He proposed linking 6 of these reserves together to equal 107,058 km^2 for N = 1,500. Adjusting for 3,000 bears this reserve area would equal 214,116 km^2 which is within the range presented here.

Grizzly bear population density in the interior northern Rockies was not high even before human settlement by European immigrants. Mattson (2018) estimates a historical continental US population N = 47,300 with a gross density of 16.5/1000km^2 and in interior areas peaking at density 22.5 in Montana, 22.8 in Idaho and 13.0 in Wyoming.

“Patterns of geospatial variation unambiguously link grizzly bear densities not only to levels of conflict with humans, but also differences in habitat productivity” (Mattson 2021) and bear density in general is negatively correlated with human presence and activities (Mattson and Merrill 2002).

The scientific literature shows that grizzly bear populations in interior areas seldom exceed density 20.0-30.0/1000km^2 outside of protected reserves (Mowat, et al. 2013; Kendall, et al. 2008; Mattson 2021) because there is high grizzly bear mortality outside reserves. National and Provincial Parks subsidize high mortality areas with dispersing bears (Lamb et al. 2023) and often have density twice that outside reserves (Auditor General of British Columbia 2017, Kendall et al. 2008).

This analysis provides possible scenarios based on plausible values. A population of 3,000-5,000 bears could have a higher N_e which could exceed the minimum N_e = 500. For example, a population of 5000 with N_e = .20 would have N_e = 1000. In fact, Frankham et al. (2014) suggest $N_e \geq 1000$ to maintain evolutionary potential for fitness in wild populations.

Just as important as the extent of designated or prospective landscapes are the levels of protection within the recovery area. The protection category should be based on the primary management objective(s), which should apply to at least three-quarters of the protected area – the 75% rule (IUCN, Dudley 2013). Thus, 75% of a northern Rockies grizzly bear recovery area (≈ 185,000 km^2) should be within protected area categories.

There are currently ≈ 108,000 km^2 of areas protected and/or managed to support grizzly bear presence, which is 58% of the way towards meeting the IUCN recommendations. Additionally, 96,000 km^2 are in protected areas that can see improved habitat security conditions and within dispersal distances of other habitats.

Climate Change

There are no explicit references to climate change in either the Recovery Plan or the Conservation Strategies. Evidence shows that climate change is altering denning chronology with bears generally entering dens later and emerging earlier (Pigeon et al. 2014, Fowler et al. 2019). Plant phenology and distribution are also affected. Corradini et al. (2023) wrote in regards to grizzly bears: "…synergistic effects of continued climate change and increased human impacts could lead to more extreme changes in food availability and affect observed population resilience mechanisms."

Grizzly bear habitat productivity shifts over time shaped by events such as wildfire and bioclimatic variations including drought and climate change. McLoughlin et al. (2003) found grizzly bear density decreased with the amount of exposed bedrock and other marginal habitats. Reserve size must be large enough to absorb these variations.

Habitat Suitability

The analysis area has been analyzed for grizzly bear habitat productivity, habitat selection probability and denning habitat with multiple overlapping results (Merrill et al. 1999, Carroll et al. 2001, 2002, 2003, Hogg et al. 2001, Podruzny et al. 2002, Merrill and Mattson 2003, Boyce and Waller 2003, Proctor et al. 2015, Mattson 2020, Bader and Sieracki 2022, 2024a, Sells et al. 2022, 2023a, 2023b). Much of the currently unoccupied or sporadically occupied habitat area has been found to have high quality habitat for grizzly bears, although the precise amount across the entire grizzly bear range has not been specifically quantified using uniform methodology.

Examples of landscape scale grizzly bear habitat assessments are shown in Figures 6a. and 6b. These are just some of the grizzly bear related habitat analyses. Many are done at the scale of a timber sale or other project.

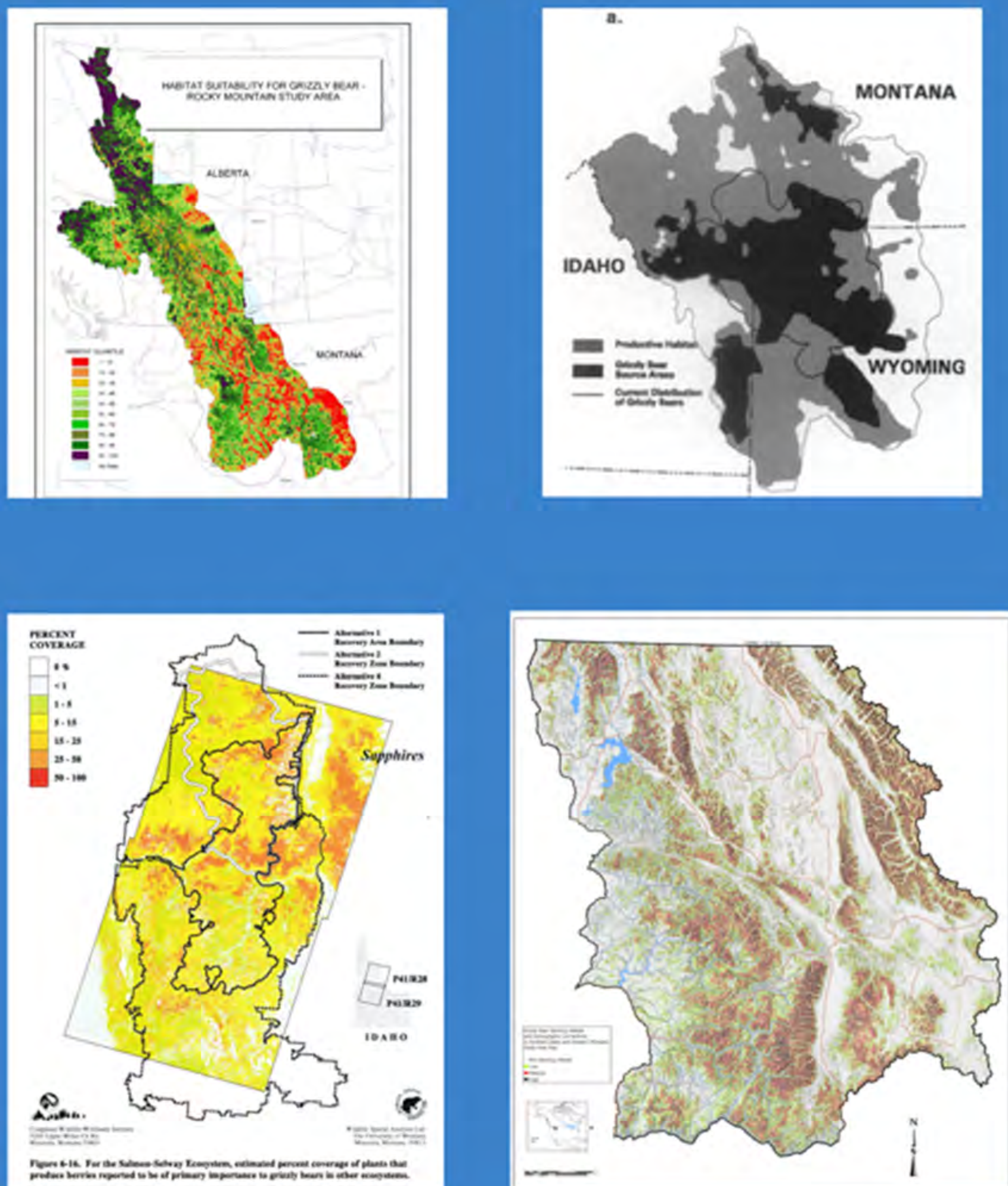


Figure 6a. Habitat Analysis Results in Northern Rockies. Top Left: Carroll et al. 2003, Top Right: Merrill and Mattson (2003), Bottom left: Hogg, et al. (2001), Bottom Right: Bader and Sieracki denning (2022).

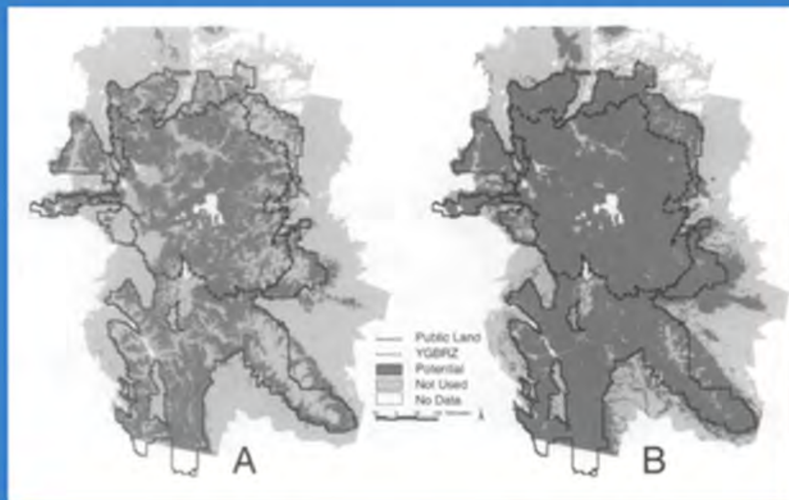


Figure 6b. Habitat Analysis Results in Northern Rockies. Top: Podruzny et al. (2002) Denning. Bottom: Mattson (2020).

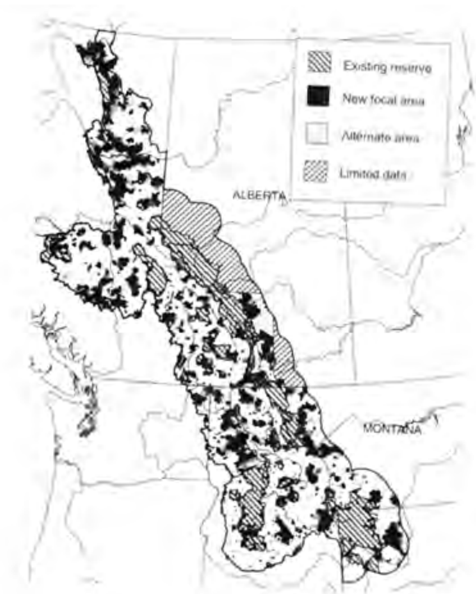


Figure 7. Grizzly Bear Habitat and Additional Focal Areas. Carroll, et al. (2023).

In addition to the core suitable habitat areas there are other areas with grizzly bear habitat. Carroll et al. (2003) identified new focal areas for grizzly bear that included the Kettle Range, the Missouri Breaks and the Bighorn Mountains (see Figure 7).

There have been two recent verified observations of grizzly bears in the Bighorn Mountains in north-central Wyoming and two others in the adjacent Pryor Mountains, a habitat bridge between the Bighorns and the GYE. The Upper Missouri River Breaks which has over 1 million acres of protected public lands, has had several recent verified observations including a female with cubs. There is now a reproducing population on the plains and the adjacent Breaks according to Montana Fish, Wildlife & Parks Region 3 Bear Specialist Wesley Sarmento (2024) who said "There is a breeding population of grizzlies on the plains, and it's more and more every year," he said. He also says there are ample natural foods. As shown in Figure 8, grizzly bears are using riparian river corridors to reach these habitats.

Figure 8. Grizzly Bear Observations Along Rivers to the Missouri Breaks.

The Hells Canyon-Wallowa Mountains area in northeast Oregon are an extension of the Rockies with hundreds of thousands of acres of Wilderness and other protected lands. The last verified grizzly bear in Oregon was killed in this area in 1937 and grizzly bears have recently been verified on the Idaho side.

Grizzly bears are also actively managed on the Flathead, Blackfeet and Wind River Reservations. These sovereign nations have their own plans and grizzly bear management is important in these areas.

Configuration, Edge Effects and Habitat Restoration

The protective status and configuration of reserves is equally important as the size (Reed et al. 2003; Wielgus 2003, Woodroffe and Ginsburg 1998). van Nouhuys (2016) wrote: "Reserve design that is based in metapopulation ecology emphasizes networks of sites rather than isolated sites, with the implicit or explicit understanding that regional persistence of species will be greater in a network of patches within dispersal range than in isolated sites (unless very large)." Thus, isolated reserves, even large ones, suffer reductions in habitat effectiveness because they are surrounded 360^{o} with edge effects and population sinks which consistently and permanently attract and remove animals from the core (Wielgus 2003; Woodroffe and Ginsburg 1998; Lamb et al. 2023).

Narrow, peninsular reserves like the Cabinet-Yaak and Selkirk Recovery Areas have cherry-stem road corridors on both sides and high edge exposure. These areas have a very dense road footprint as shown in Figure 9 which represents resistance to both occupancy and movements between the Recovery Areas. The road network facilitates excessive mortality through illegal poaching, small isolated core areas and extensive habitat fragmentation (Bader and Sieracki 2022).

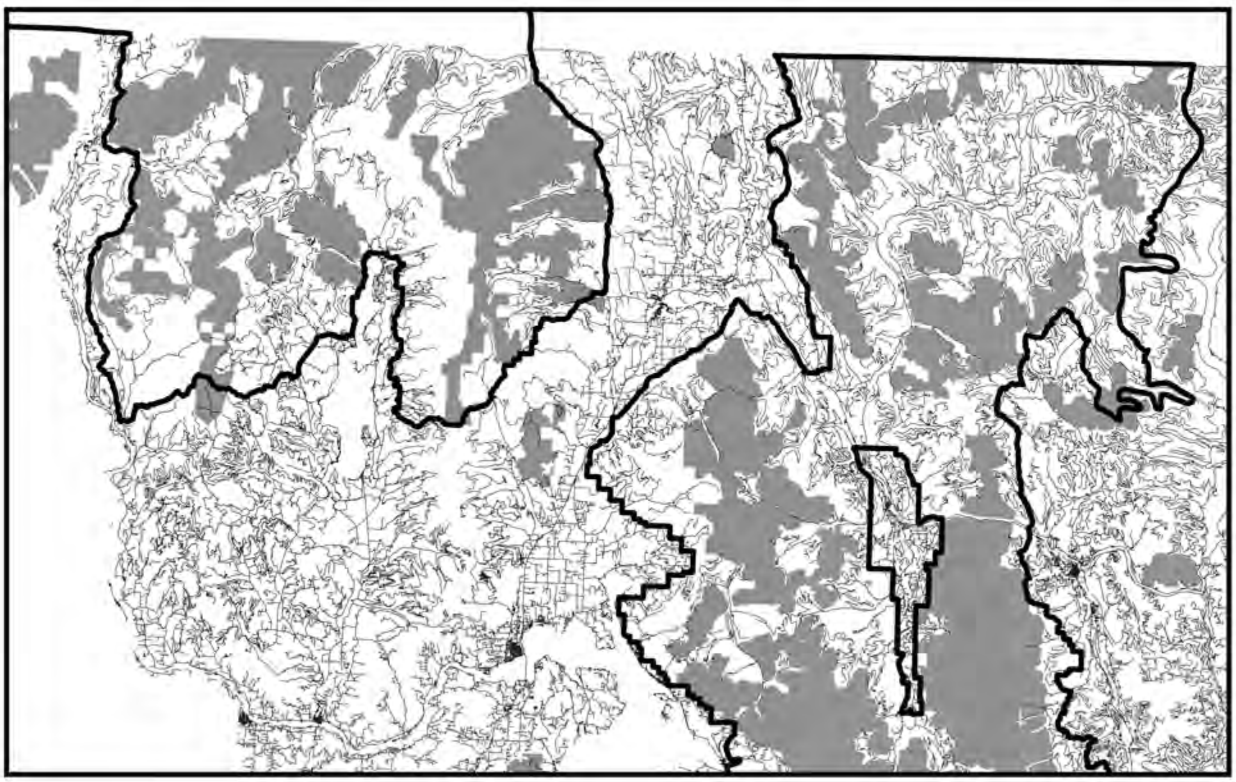


Figure 9. The Extensive Road Network in the Selkirk and Cabinet-Yaak Areas Presents Resistance to Grizzly Survival and Movement Between Recovery Areas.

Motorized access leads to increased mortality in grizzly bears. McLellan (2015) found 84% of mortalities occurred within 182m of an open road. Disturbance effects in productive habitats displace bears which increases stress, competition and reduced fitness including lower breeding success (U.S. Fish & Wildlife Service 2023b).

Due to these effects, current gross grizzly bear density in the Cabinet-Yaak = 3.2-3.5/1000km^2 is comparable to the 3.3-4.0 estimated by Kasworm and Manley (1988) and 4.3-4.5 (Kendall et al.

2015). The population estimate has increased but so has the estimated occupied habitat area (U.S. Fish & Wildlife Service 2023). High road densities, loss of cover and a hostile human population have prevented this population from significant growth in population or density. Kendall et al. (2015) report there is no genetic connectivity between the populations in the Yaak and Cabinet Mountains and the Cabinet bears are subjected to serious inbreeding. The loss of just one adult female might be enough to stall growth or cause decline in these populations.

An important component of achieving a unified northern Rockies grizzly bear population is reestablishment of both core area and connectivity in the CYE and SE. Extensive habitat restoration through road reclamation and limits on motorized vehicle access are the only realistic means of increasing bear population size and density. A hypothetical schematic of how this might occur (Della Sala et al. 1996) is shown in Figure 10. A realistic goal for these highly fragmented landscapes is represented in Plate III showing conditions after 50 years. This model can be applied to other areas including the Ninemile and northern Bitterroot Divide. In less fragmented areas, conditions shown in Plate IV may be achievable.

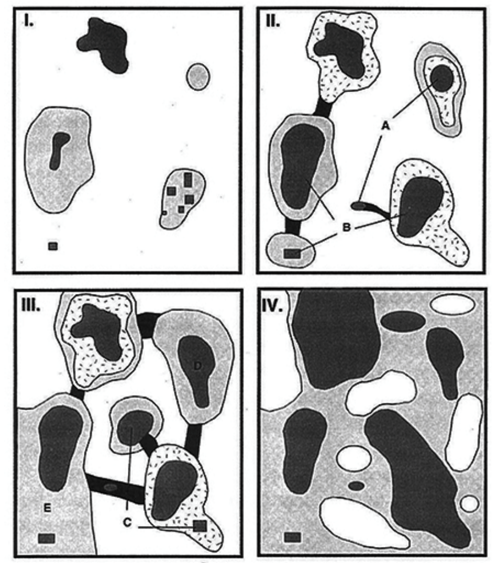


Figure 10. Restoring Habitat Security Over Time. Della Sala et al. 1996

Regional Connectivity

Connectivity is important in restoring fragmented landscapes and also has a regional role. Providing habitat connectivity between Glacier and Yellowstone National Parks increases persistence time of large mammals by 4.3 times or ≈ 682 generations (Newmark et al. 2023). Linking the isolated northern Rockies grizzly bear populations would greatly increase persistence time (Boyce et al. 2001, Allendorf et al. 2019).

Opportunistic verified observations of grizzly bears suggest a broader view of potential habitat and population connectivity. These observations almost certainly understate the frequency of movements and occupancy as there is no systematic monitoring of grizzly bears between the recovery areas. Evidence of denning (Montana Fish, Wildlife & Parks 2024) also indicates residential occupancy.

Our interpretation is that potential connective habitats exceed the modeled results. Replication of modeled results is not necessarily a strong indicator of where the best habitats are. The studies each had different purposes, used different methodology and variables as shown in Table A-1, Appendix. There was some subjectivity and results were constrained by model variables and parameters. For example, the shortest paths between Recovery Areas were emphasized while many of the verified observations occurred in different areas.

We note Sells et al. (2023) did not include distance to roads or road density as variables and that some of the highest estimated value connectivity habitat is within riparian areas bisected by road systems which represent higher mortality risk. This approach does not include survivability in each step and uses habitat selection from occupied areas. Similarly, the Proctor et al. (2015) results would require road reclamation and increased access restrictions.

We presented the mashup of model results for general information and as a measure of where verified observations have occurred. The cumulative weight of the results are generally confirmatory and reveal several opportunities for demographic connectivity.

Bader and Sieracki (2022) evaluated suitable denning habitats in the context of demographic connectivity finding areas with high value for connectivity and residential occupancy by adult females. The Sapphire-Pintler-Flint Mountains have high potential for residential occupancy and in fact, several grizzly bears have been recently verified to have over-wintered in dens there (Montana Fish, Wildlife & Parks 2024). Walker and Craighead (1997) estimated high connectivity potential for grizzly bears in the area between the Pintler and Mission Mountains area in the Sapphires. Hogg et al. (2001) found high ground cover by berry-producing shrubs favorable to grizzly bears here. The Sapphire-John Long-Flint-Pintler Mountains are a high priority landscape for grizzly bear recovery with more than 3000 km^2 of essentially contiguous secure core habitat area (Bader and Sieracki 2022).

Hunting, Management Removals and Other Sources of Human-Related Mortality

The states of Montana, Wyoming and Idaho intend to implement trophy hunting seasons for grizzly bears. Hunting would target bears outside of National Parks and have a significant impact on grizzly bears between recovery areas which are of high significance to regional recovery and persistence (Servheen et al. 2024).

Hunting has been a major driver of grizzly bear extirpations (Mattson 2020). Hunting of grizzly bears lowers N_e (Allendorf and Harris 1989). The cessation of hunting in the GYE in 1974 and in the NCDE in 1992 was a leading factor in preventing extirpation in the 48 states. In the years following cessation of hunting through 1998 (NCDE = 7 yrs, GYE = 24 yrs) annual mortality was reduced 58.4% in the GYE and ≈ 32% in the NCDE, respectively (Bader 2000a). That mortality has since been replaced by other human-related mortality. Resumption of hunting would be additive, not compensatory mortality.

Wyoming officials, based on estimates of the GYE population, would allow hunters to kill 10 females and 19 males in its first hunting season inside the DMA. Hunting would also occur in large areas outside the DMA that are within the occupied habitat area and Wyoming would allow up to an additional 78 grizzlies to be hunted. Montana intends to allow hunting within five years of legal protections being removed. Alberta has recently authorized a grizzly bear hunt that may interfere with efforts to rebuild effective population connectivity with the U.S.

In 2019, the U.S. Forest Service re-approved livestock grazing allotments in the Bridger-Teton National Forest in the headwaters of the Green and Gros Ventre Rivers. The U.S. Fish & Wildlife Service approved it, allowing for up to an additional 72 grizzlies to be killed in order to reduce predation on cattle. Hunting would be additive to this and other sources of mortality so the odds of keeping the population above 800 would be significantly diminished.

Moreover, Montana, Wyoming and Idaho have already increased mortality through other means including less tolerance for bears in first time management conflicts. Montana will also allow livestock producers to shoot grizzly bears who are "threatening" their livestock on both private and public lands. Montana now allows hunting black bears with hounds for the first time in 100 years and wolf and coyote trapping in occupied grizzly bear habitat. This is certain to cause conflicts including mortality risk to people and bears (Director, U.S. Fish & Wildlife Service letter to Montana Fish, Wildlife & Parks 2023). The U.S. Fish & Wildlife Service (2023) has also expressed concerns about the states establishing "no bear zones." State agencies have stated that grizzly bears do not belong in the Bighorn Mountains and other areas in Wyoming and do not belong in the St. Joe watershed in northern Idaho.

Baiting of black bears is allowed in Idaho and many opportunistic verified observations of grizzly bears have been documented at bait stations (see Figure 11). These include a grizzly killed at a bait station by a black bear hunter after the bear was incorrectly identified as a black bear by Idaho Fish & Game.

Figure 11. Grizzly Bear Investigates Black Bear Bait Site, Idaho.

Conclusions and Recommendations

The benchmarks presented here provide an adequate basis for recovery planning for grizzly bears. An argument in favor of broader benchmarks is that overly technical plans and wording are not effective because concepts that cannot easily be understood by the public and decision makers have little chance of becoming policy (Shafer 2022).

The results of Population Viability Analysis based on genetic effects alone cannot describe the total amount of mortality and extinction risk to species like grizzly bears. Habitat must also be factored in (Boyce et al. 2001). Reserve size, configuration, edge effects and levels of protection also drive extinction risk and persistence time (Woodroffe and Ginsburg 1998, Wielgus 2003). Climate change will continue to affect grizzly bears which lends additional support for a broader connected conservation area. The Recovery Plan and Conservation Strategies are not in the same arena as scientifically derived estimates for numbers, time and space for grizzly bears.

Our focus here is on the spatiotemporal dimensions of grizzly bear recovery. A host of actions including a prohibition on hunting of grizzly bears, improved sanitation, conflict reduction on private lands, highway passage infrastructure, improved habitat security and increased public support will be necessary to establish and maintain a viable population. Effective demographic connectivity protected by an accountable regulatory structure must be reestablished with grizzly bear populations north of Highway 3 in British Columbia and Alberta as recommended by Carroll et al. (2003) and Proctor et al. (2015).

The 1993 Grizzly Bear Recovery Plan and Recovery Areas are an anachronism. Many of the boundaries remain unchanged since the first draft in 1982. In the 42 intervening years much more has become known about the spatial requirements and population numbers for a viable grizzly bear population and there have been substantial changes in the size and distribution of the human population.

The demographic model based on residential occupancy by female-cub groups with protected habitat is the most appropriate population unification strategy for the Northern Rockies. The U.S. Fish & Wildlife Service must produce a Northern Rockies Grizzly Bear Recovery Plan using the best available scientific information.

The approximations for space defined as known or potential habitat are available to grizzly bears if people support their presence. There is reason for cautious optimism that if we make the right decisions with staying power measured in decades and centuries, grizzly bears will have a significantly increased chance of survival in the wilds of the northern Rocky Mountains.

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Table A-1. Methods and Major Variables Used for Grizzly Bear Movement Analyses

Source	Primary Method	Variables
Walker & Craighead (1997)	Least Cost Path of Pre-defined areas Min Euclidean Distance	Habitat quality, road density, forest/shrub/grassland interface
Proctor et al. (2015)	Resource Selection Function, Circuit Theory	Forest cover, land cover, ecological (terrain, wetness, elevation) highways, forest roads, developments
Peck et al. (2017)	Step Selection Function based on collared bear data (males)randomized shortest path algorithim, circular moving windows	Land cover, distance to highways, distance to forest, home density, terrain ruggedness
Sells et al. (2023)	Integrated Step Selection Function based on collared bear data (males & female) from core NCDE	Vegetation Index, terrain ruggedness, density of forest edge and riparian areas, building density, distance to secure habitat

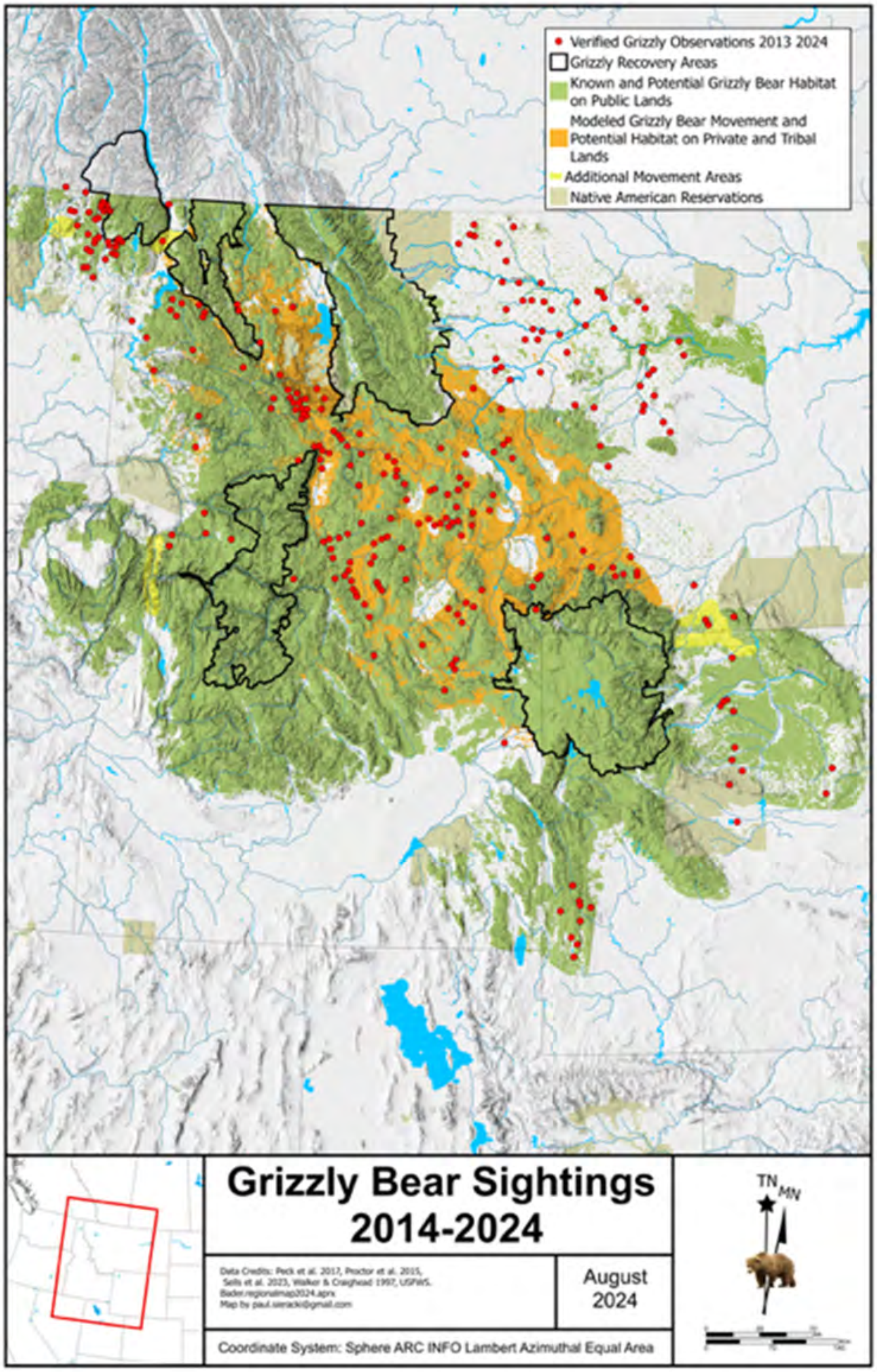

Figure A-1. Grizzly Bear Observations are Those Generally Beyond Estimated Continuously Occupied Habitat.