HEART OF THE GRIZZLY BEAR NATION

An Evaluation of the Status of Northern Continental Divide Grizzly Bears

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The Grizzly Bear Recovery Project

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Introduction

This document is a work in progress. It was inspired by deep curiosity about the past, present circumstances, and future prospects of grizzly bears and grizzly bear habitat in the Northern Continental Divide Ecosystem (NCDE). I was also motivated by skepticism about official narratives that offer an implausibly simplistic and rosy picture of NCDE bears and the ecosystem they occupy.

According to official narratives, the NCDE grizzly bear population has steadily grown, expanded its distribution, and, because of these trends, is in need of punitive measures to prevent any further increase or expansion. In service of this end, Endangered Species Act (ESA) protections presumably need to be removed and grizzly bears turned over to Montana's wildlife managers, who would then oversee implementation of a sport hunt and more aggressive lethal management of grizzly bear-human conflicts. Moreover, the state and federal managers who promote this narrative have assured the public that they have reliable, accurate methods in place to monitor and manage bear mortality—as well as the population itself. They also assure us that, because grizzly bears are omnivores, there is no need to monitor grizzly bear foods or the habitats that produce those foods. On a related note, they further argue that the only feature of relevance to managing mortality risk for bears is the physical imprint of roads and recreational facilities on federal lands—as of 2011. All of this can be found in the draft Conservation Strategy being promulgated by the US Fish & Wildlife Service in support of removing ESA protections.

What follows is an overview of history, current conditions, and future forecasts of relevance to both understanding the ecology and demography of NCDE grizzly bears, as well as judging the merits of official narratives. More to the point, the contents that follow, taken together, collectively offer a basis for judging whether removal of ESA protections is warranted. It is a critique, a primer, and necessarily a perspective. Given my visual orientation, what follows is organized around maps and graphs that summarize relevant patterns of relevant features. The associated text provides context and explanation. Throughout, I refer to reports and research papers by author and date (e.g., Costello et al. [2016]), with further details in the references section of this publication.

The Grizzly Bear Recovery Project

Table of Contents

Deep History 1
Diets 5
Habitat Dynamics 12
Habitat Monitoring 18
Population Dynamics 23
Spatial Demography 32
Fragmentation 42
The Future 46
Summary of Critique 52
References 56

The Grizzly Bear Recovery Project

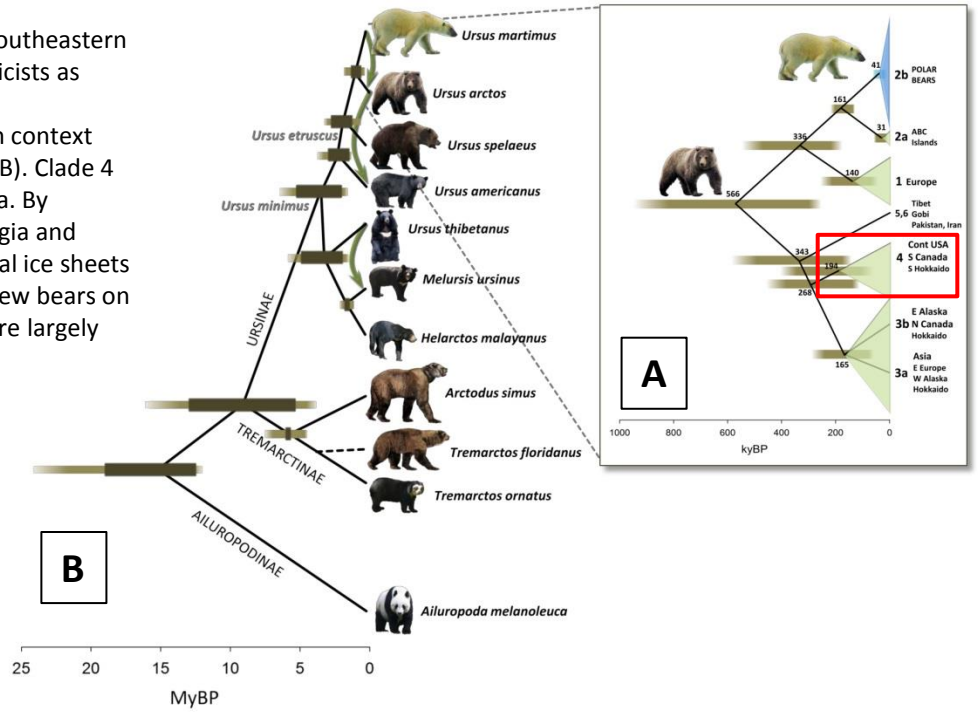
DEEP HISTORY

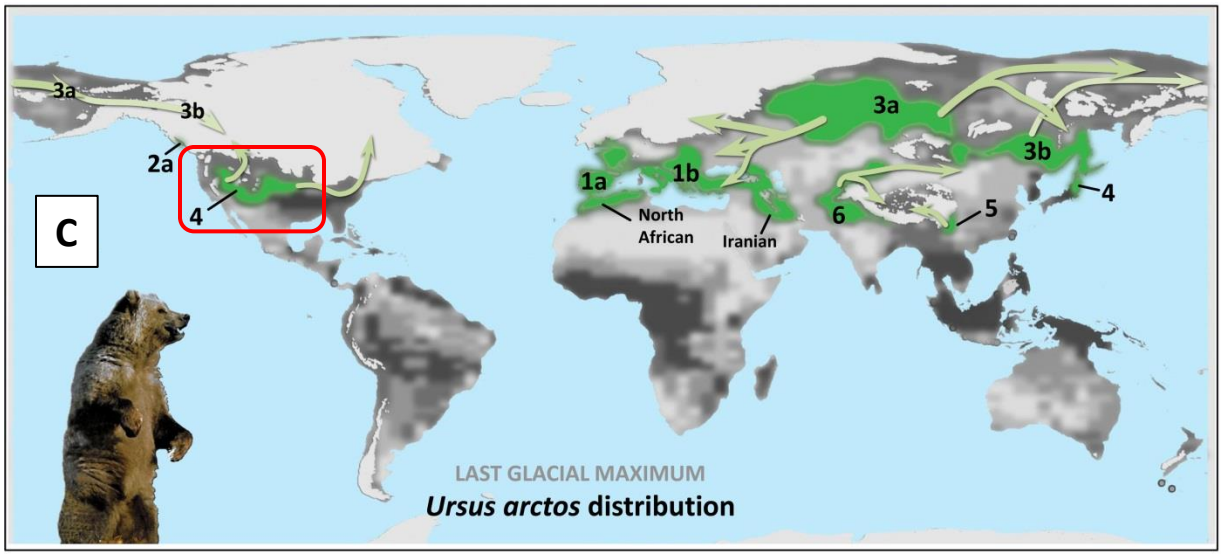
The Grizzly Bear
Recovery Project

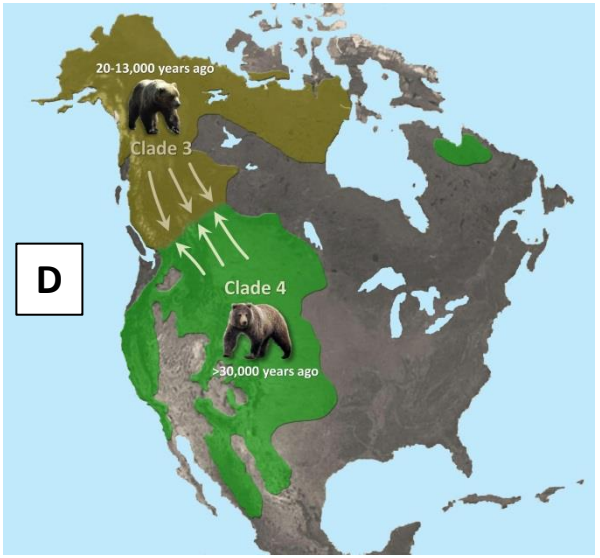
Unique Evolutionary Lineage

All of the grizzly bears in the Rocky Mountains south of central Alberta and southeastern BC are part of a unique genetic lineage of grizzly bears known by phylogeneticists as 'Clade 4'; where clades are the approximate equivalent of a subspecies. The phylogenetic tree at far right (A) shows the Clade 4 lineage (in the red box) in context not only of other grizzly bear clades, but also the entire family tree of bears (B). Clade 4 diverged from Clade 3 about 200,000 years ago during the Pleistocene in Asia. By around 50,000 years ago, Clade 4 bears had crossed from Asia through Beringia and made their way south to mid-latitudes, prior to coalescence of the continental ice sheets during the last glacial maximum (LGM). Meanwhile, with the exception of a few bears on the Japanese island of Hokkaido, all other Clade 4 bears went extinct and were largely replaced by bears of the Clade 3 lineage.

The map in C, below, shows the approximate distribution of the various grizzly bear/brown bear lineages during the LGM, highlighting the fact that Clade 4 bears were at that time (and thereafter) unique to mid-latitudes of North America. The light green lines show dispersal of the lineages during the early Holocene, between roughly 15,000 and 2,000 years ago. In North America, newly arrived bears of the Clade 3b lineage spread south at the same time that resident Clade 4 bears spread north (D). Of importance to conservation and recovery of grizzlies in the western contiguous US, all of our bears were—and continue to be—part of what has become a rare and globally endangered genetic lineage (see Page 3).

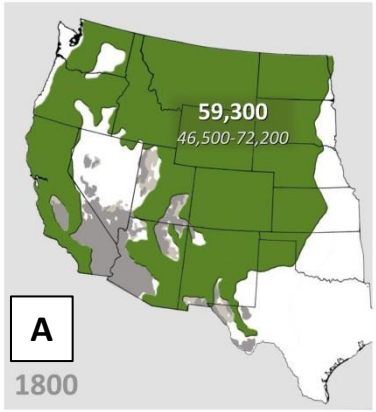


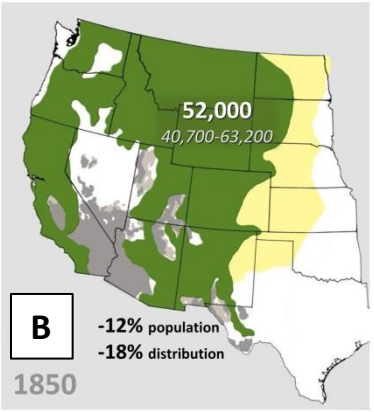


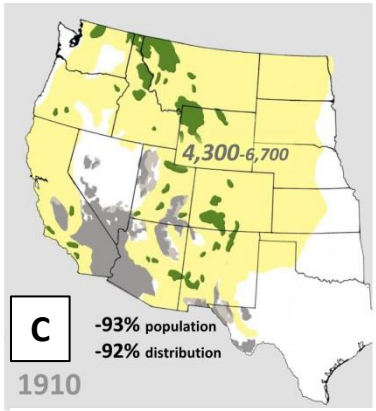


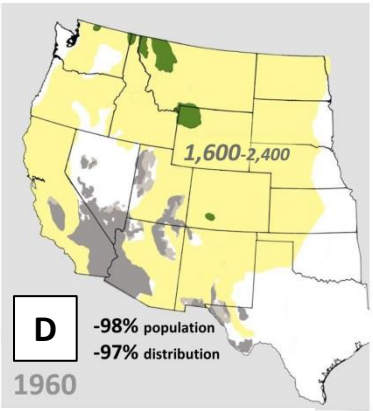
Extirpation of Clade 4 Grizzly Bears

The Clade 4 grizzly bears that occupied mid-latitudes of North America at around 1500 bore the brunt of the slaughter perpetrated by European settlers. Maps A-D show a time series of grizzly bear extirpations between 1800 and 1960, with the grizzly bear distribution at each time step shown in green; areas where grizzlies had been extirpated are shown in yellow. I've also provided an estimate of grizzly bear numbers at each time step (in white) as well as the cumulative estimated percent loss of numbers and distributions. By 1850 (B) grizzlies were gone from the central and southern Great Plains. Sixty years later, by 1910 (C), 93% had been extirpated from 92% of the places they once lived. By 1960 (D), extirpations had culminated at between 97 and 98% of the total. Taking into account Clade 4 bears that had once occupied southwestern Canada, fully 95% of this Clade was killed off by Europeans, largely within a 100-year period. The graph in E casts these losses as a linear trend, showing bear numbers plummeting from roughly 52,000 to around 2,000 between 1850 and 1960.



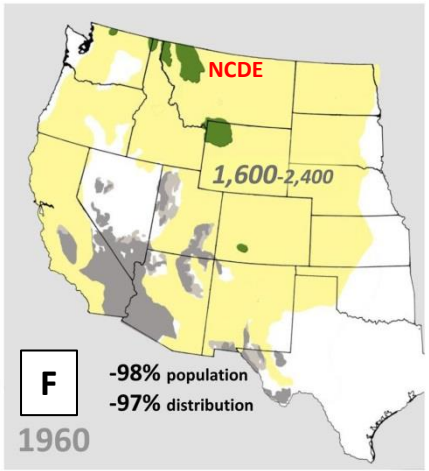


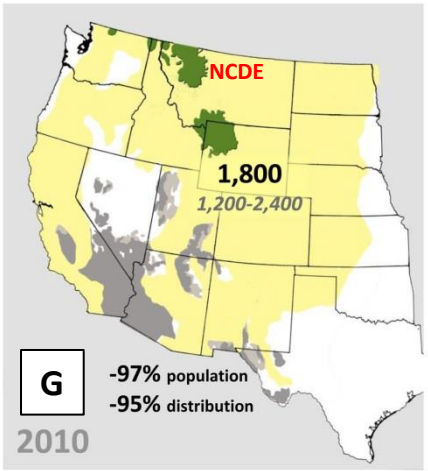


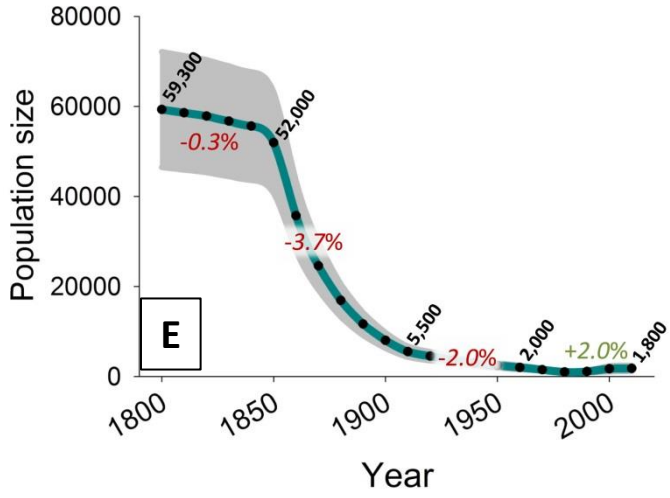


'Recovery' of Clade 4 Grizzly Bears

The maps below show the extent of 'recovery' for Clade 4 grizzlies in the western contiguous US since 1960, most of which occurred after Endangered Species Act protections were instituted in 1975. Numbers 'increased' from perhaps as few as 1,100 at low ebb around 1960 (F), to around 1,800 in 2010 (G). These gains amount to a trivial percentage of the total lost between 1800 and 1960 (E). Perhaps more to the point, the grizzly bears occupying the NCDE and other Northern Rockies ecosystems remain threatened, if not endangered, and represent some of the last bears of the Clade 4 lineage left on Earth.







Summary & Implications: Deep History

- Grizzly bears that occupy mid-latitudes of western North America, south of central Alberta and southeastern British Columbia, are part of a unique genetic lineage (Clade 4) that has gone extinct everywhere else on Earth except for a small isolate on the Japanese island of Hokkaido.
- Clade 4 grizzly bears were among the very first wave of colonizing brown bears arriving in North America across Beringia from Eurasia roughly 70,000 years ago. Clade 4 grizzlies thence moved south to mid-latitudes through an ephemeral ice-free corridor in the Pleistocene Cordilleran and Laurentide ice sheets between 70,000 and 32,000 years ago.
- Clade 4 grizzly bears bore the brunt of extirpations perpetrated by European settlers between 1800 and 1950. Roughly 95% of all bears of this lineage in North America were wiped out, including around 98% of all Clade 4 bears in 97% of their ancestral distribution in what was to become the contiguous United States.
- The US Fish & Widlife Service does not recognize the modern scientific consensus on taxonomy and phylogeny of *Ursus arctos* that has emerged since the early 1990s, and instead relies on an outdated schematic produced during the 1960s and 1970s. As a consequence, the Service also ignores the current scientific consensus on paleogeography of *Ursus arctos*, including the unique evolutionary and more recent history of Clade 4 grizzly bears.
- In part because of these failings, the Service fails to conceive of or plan Recovery for grizzly bears in the contiguous United States as a unique and globally endangered genetic lineage with a distinctive shared history, ecological niche, and historical distribution.

The Grizzly Bear Recovery Project

DIETS

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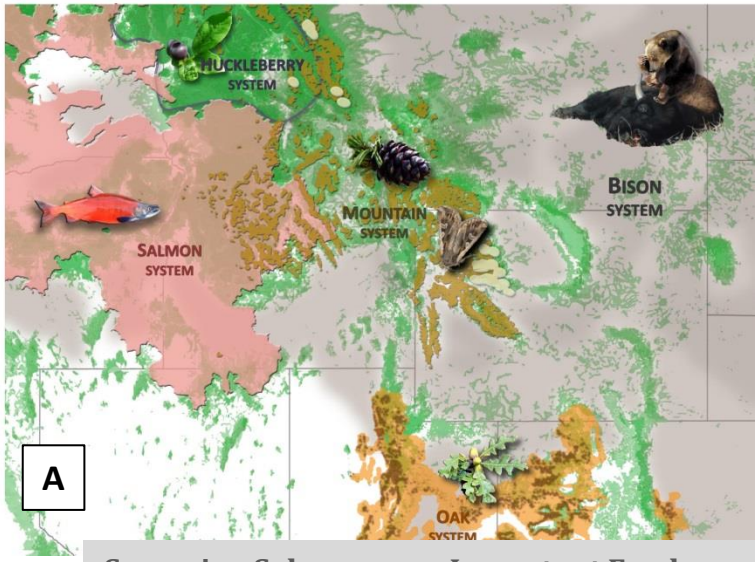
DIETS

Ancestral Grizzly Bear Dietary Economies

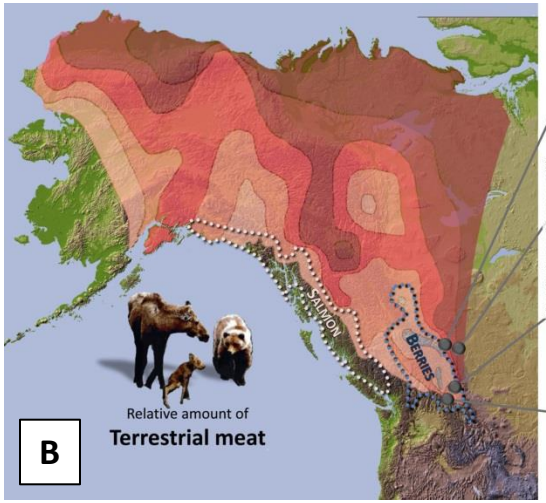
The ancestral diet of grizzly bears in the northern Rocky Mountains of what was to become the United States exhibited a pronounced gradient from west to east to south—most of which has been preserved until recent times, although with some details profoundly recast. The map at right (A) shows pre-European dietary mainstays. West of the Continental Divide, grizzly bears existed in a salmon-berry economy. On the Great Plains, their economy was organized largely around scavenging bison. Along the drier colder eastern margins of the Rocky Mountains, seeds of whitebark pine were a staple. Farther south acorns from Gambel's oak growing in dense shrub communities was a mainstay. Shades of green at right denote relative abundance of berry-producing shrubs; purple, whitebark pine distribution; and, tan, core pre-European distribution of bison.

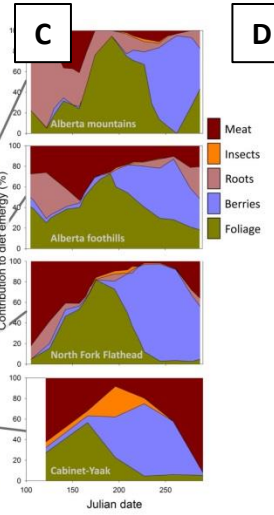


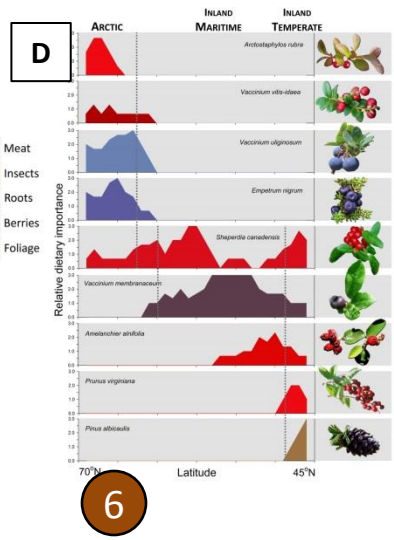
Unique Berry-Centered Economies in Wet Interior Mid-Latitudes

The map below left (B) shows current levels of meat consumption among grizzly bears in North America (darker red denotes greater consumption; from Mowat & Heard 2006) in juxtapose with areas where, by contrast, spawning salmon and fruit are dietary mainstays (delineated by a white and blue dashed line, respectively). The percent occurrence of fruit is also denoted by blue in the diagrams of seasonal diet to the right of the map (C) for study areas ranging from the Alberta mountains and foothills south to the North Fork of the Flathead and Cabinet-Yaak ecosystem. The main point here is that the extent to which grizzly bears rely on berries in the US Northern Rockies and adjacent Canada west of the Continental Divide is relatively unique in North America, as well as historically novel—largely due to losses of salmon in the current NCDE and Cabinet-Yaak Ecosystems (see E and F at right).

To further reinforce the uniqueness of these wet interior regions, the diagrams in D show the relative extent to which fruits of different species are consumed by grizzlies in North America from the highest latitudes, at top, to mid-latitudes, at bottom. Mid latitudes are unique in the extent to which bears here consume huckleberries, serviceberries, and chokecherries.

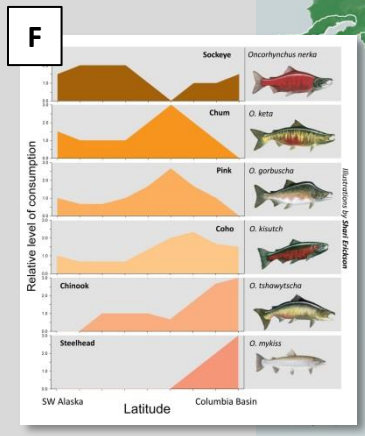


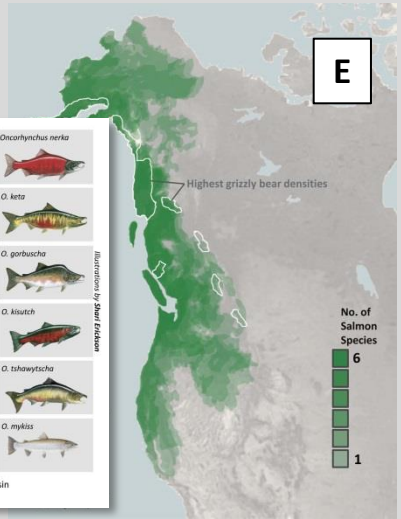




Spawning Salmon were Important Food

The map in E, below, shows the pre-European distributions of spawning salmonids in North America. Darker green denotes greater species diversity, maxing out at 6. As per map A, spawning salmon were amply available to grizzlies pre-historically in western reaches of what is now the NCDE. The diagram in F furthermore shows the distribution of different salmon species from high (top) to low (bottom) latitudes. The basic point here is that NCDE grizzlies once probably consumed lots of Chinook salmon and steelhead trout—but no longer.

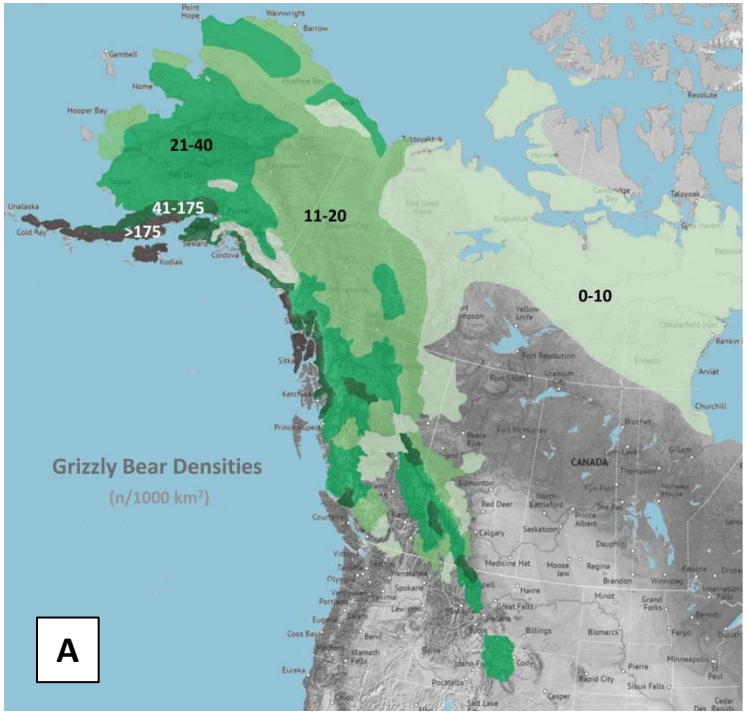




Grizzly Bear Densities Vary by Orders of Magnitude

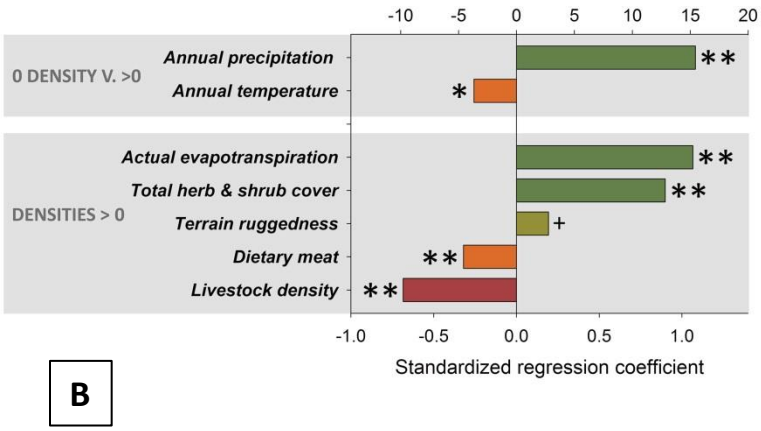
It is a basic ecological truth that animal densities reflect habitat productivity. This holds as much for grizzly bears as for any other animal. Even so, there seems to be confusion about this link between habitat and densities stemming from the fact that grizzlies are omnivores. As in the NCDE Conservation Strategy, the argument is: "because grizzly bears are omnivores, their diets are flexible and, because of this, one food can be substituted for another with little effect on the population." This argument is nonsense. Not all foods are equal, and food abundance and quality matters.

The map at right (A) summarizes current grizzly bear densities in North America. My sources include official maps published by the Provinces of Alberta and British Columbia, a dataset assembled by Mowat et al. (2013), several papers on grizzly bear densities in Alaska (including a seminal monograph by Miller et al. [1997]), a review of grizzly bear status in Canada by COSEWIC (2012), plus other papers and reports. Perhaps the most obvious pattern is very high grizzly bear densities along the Pacific coast (in excess of 40 and, in places, 175 bears per 1000 km^2), unambiguously associated with availability of abundant spawning anadromous salmonids. Bear densities along the coast are as much as 10-20 times higher than densities in most parts of the interior. But even in the interior, grizzly bear densities vary by 5-fold. The lowest densities are found in the Barren Grounds of Canada and along the southern margins of grizzly bear distribution in areas with a combination of high human, livestock, and black bear densities. More to the point here, grizzly bear densities in interior North America systematically vary according to differences in habitat and available foods.



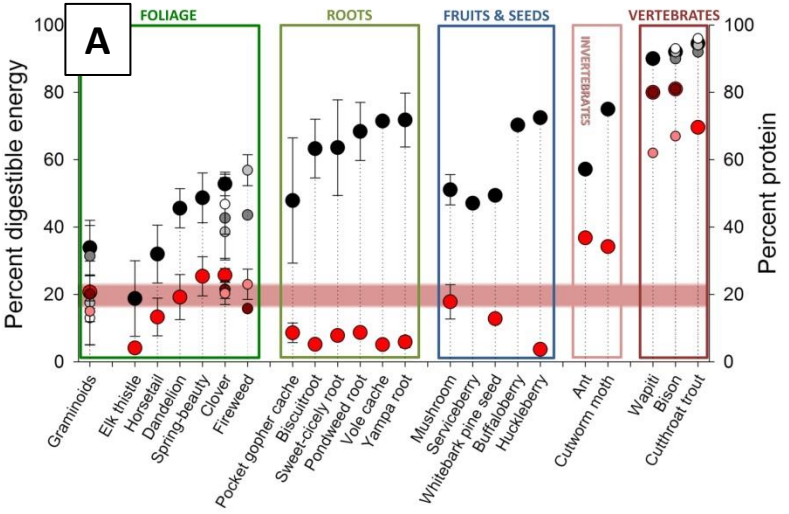
Densities Are a Function of Habitat Conditions

Mowat & Heard (2006) assembled and made publicly available a dataset containing all the density estimates made for grizzly bear populations in North America, along with a number of measures that potentially explained variation in these densities. They published the results of their analysis in the journal *PLoS One*. I reanalyzed their data to develop a model for interior of North America that consisted of two parts. The first part contrasted areas that had grizzlies (density >0) with those that did not (density=0); the second part modeled density as a continuous variable where density was >0. Significant explanatory variables are shown in the bar chart at right (B) as standardized regression coefficients. Areas with grizzlies were strongly differentiated from areas without by being much wetter and somewhat colder. Otherwise, bear population densities were higher (R^2 = 0.70) in areas with greater evapotranspiration, greater herb and shrub cover, somewhat more rugged terrain, lower livestock densities, and where grizzlies ate less terrestrial meat (either ungulates or rodents). In other words, grizzly bear densities tended to be lower in flat, more arid areas with comparatively greater forest cover, where the bears also tended to rely more on meat (e.g, drier interior boreal forests). Of relevance to the NCDE, these conditions, minus the forest cover, correlate with areas east of the Rocky Mountain Front.



Not All Bear Foods are Equal

Contrary to tacit assertions made in the NCDE Conservation Strategy, not all grizzly bear foods are equal or substitutable. Apropos, the graph at right (A) shows the percent of energy in different foods that can be digested by grizzly bears (the black, gray, and white dots). The varying shades of gray, from black to white, correspond to digestibilities during different seasons in instances where there is documented seasonal variability: black for spring, dark gray for estrus, light gray for early hyperphagia, and white for late hyperphagia. The reddish dots represent the percent of each food comprised of protein, again with seasonal variation denoted by varying shades: bright red for year-round or spring values; burgundy for mid-season; and white for late-season. Most of these foods are specific to the Yellowstone ecosystem, but a number also occur in the NCDE. The upshot is that meat from any source is more digestible than other types of food. Roots, insects, and fruits and seeds are comparable, but with roots and fruits offering far less protein. Most of the digestable energy in these vegetal foods is contained in sugars and starches, with the proviso that much of the protein in insects is bound up in chitin. The digestible energy in foliage varies widely, with forbs such as clover, fireweed, and dandelion offering more than elk thistle, horsetail, and grasses and sedges (i.e., graminoids).

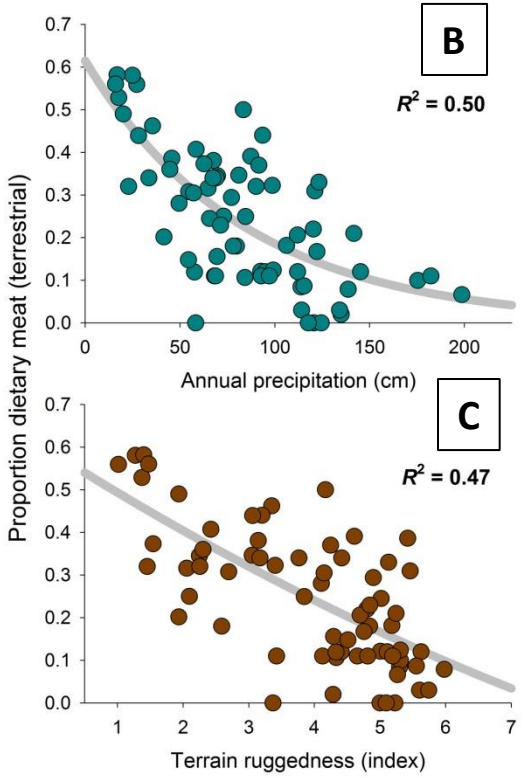


Grizzly Bear Diets Vary with Climate & Habitat

Garth Mowat analyzed variation in grizzly bear diets in North American, with an emphasis on explaining consumption of terrestrial meat (Mowat & Heard 2006). He found that terrestrial mammals were a major –if not majority—part of the diet in interior regions from Canada's Barren Grounds south throughout the eastern extremities of current grizzly bear distribution (see Page 7, Map C). In other words, as you move out onto the Plains or deeper into interior boreal forests, meat from mammals becomes all the more important. Unfortunately, in temperate latitudes much of this meat currently comes from livestock—as in the NCDE (Page 9, A)—although, historically, it came from bison (see Page 6, Map A).

The x-y graphs at right (B & C) show two of the strongest relations between terrestrial meat consumption and landscape features. Grizzlies clearly consume more terrestrial meat in drier flatter regions, which coincides with the Barren Grounds, interior boreal forests, and the Great Plains, probably because meat from ungulates is comparatively more abundant in these environments. By contrast, there are fewer large herbivores but more fruits and other vegetal foods in areas characterized by a combination of greater vegetal productivity (e.g., precipitation) and more diverse habitats (e.g., greater terrain ruggedness), as in wetter mountainous ecosystems of interior British Columbia and adjacent NCDE where berries dominate grizzly bear diets (Page 6, Map C).

Put another way, grizzly bear diets are not random. Rather, they vary systematically with environmental conditions, with implications for density and size of the NCDE grizzly bear population—past, present, and future.



NCDE Diets in a Regional Context

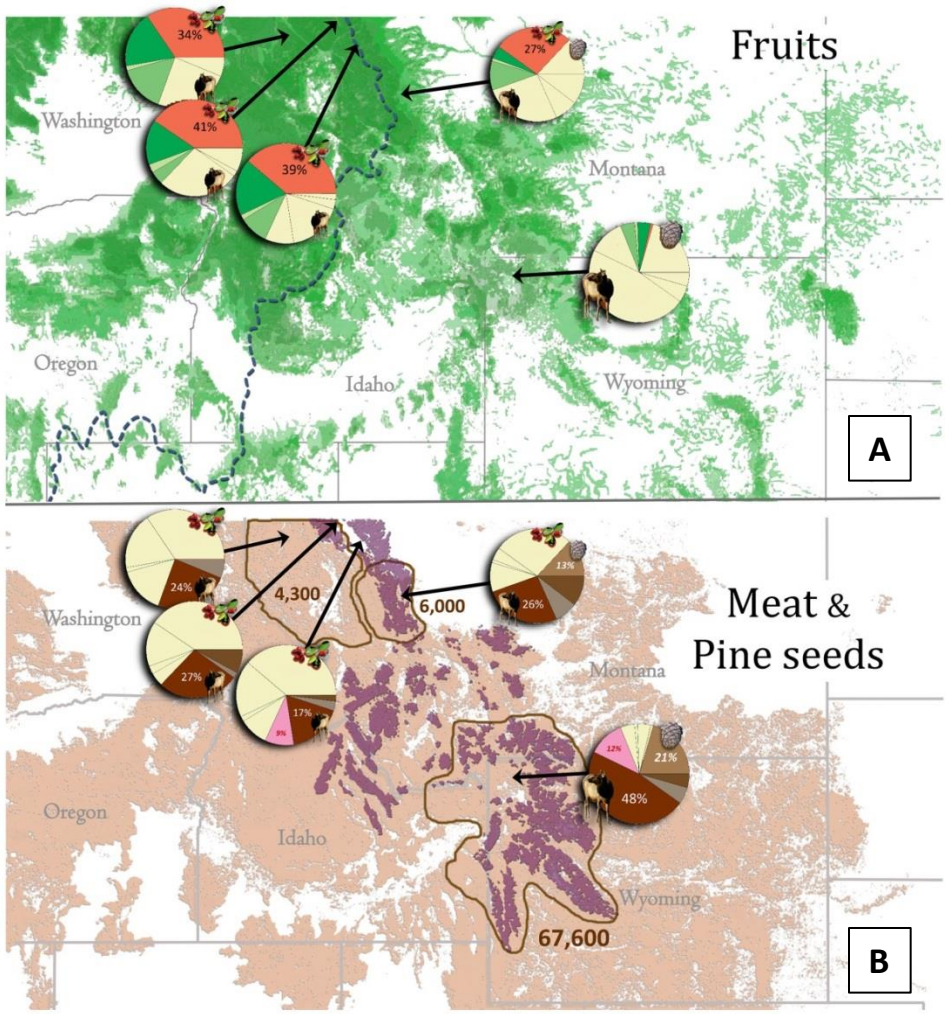
Contemporary grizzly bear diets in the northern US Rockies are differentiated primarily by amounts of fruit and herbaceous vegetation consumed compared to the amounts of meat and pine seeds. Insofar as meat sources are concerned, bison are gone everywhere other than in the Yellowstone ecosystem, replaced by domestic cattle every where else, but with elk and deer remaining abundant in the mountains and nearby lowlands.

The maps at right (A & B) feature contemporary distributions of major foods, along with synoptic representations of five grizzly bear diets each represented by a pie-diagram. These diagrams are based on the results of analyzing literally thousands of scats from different study areas, corrected to represent ingested diets. Diagrams in the top figure (A) are highlighted to show contributions of fruits (orange) and grazed foods (shades of green), whereas those in the bottom map (B) are highlighted to show meat (dark brown), roots (next-darkest brown), pine seeds (brown), fish (pink), and insects (gray).

The basic trend is from fruit being the single largest dietary component to the north and west (roughly 35-40%), to meat and pine seeds being dominant to the south and east (20% pine seeds and near 50% meat). Yellowstone represents the extreme end of this gradient, with the East Front farther north intermediate.

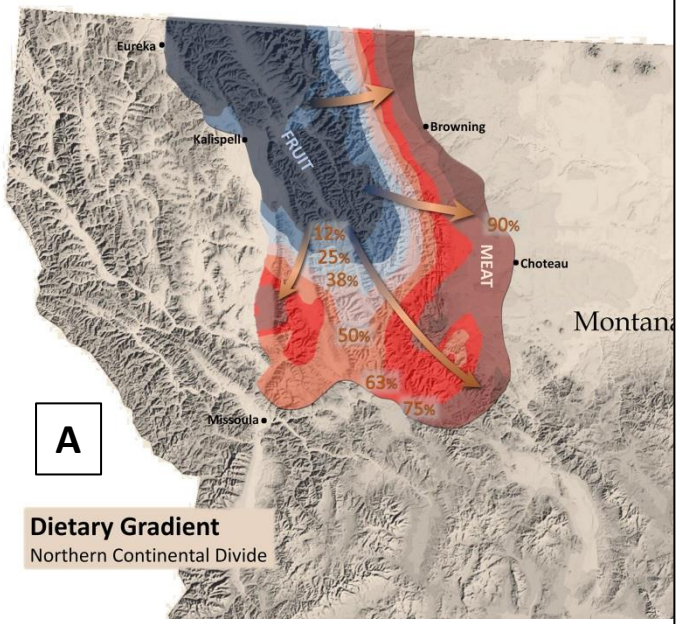
These trends manifest differences in abundance of berry-producing shrubs (greatest in northwestern Montana), whitebark pine (historically greatest in the Yellowstone region), and numbers of elk and bison. Potential elk habitat is denoted by areas shaded tan (B). Estimated elk populations are given for each region, with fewest in northwestern Montana (c. 4,300) and most in Yellowstone (over 67,000). These differences in numbers of elk reflect differences in grazing resources, which reflect, in turn, amounts and timing of precipitation (see Page 8).

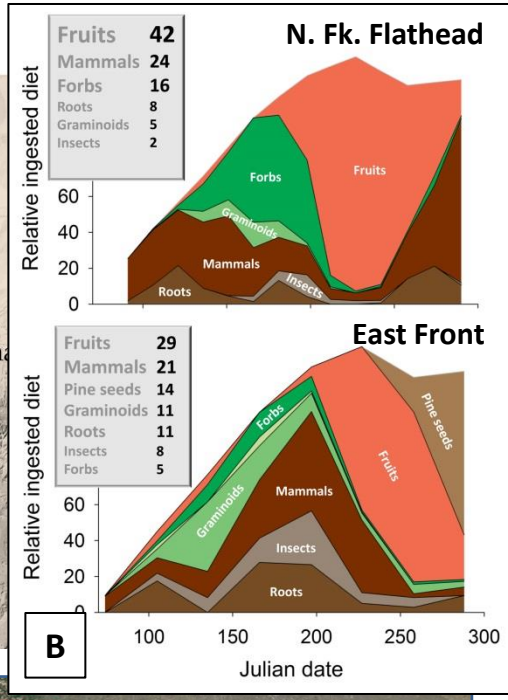
One key proviso to all of this is that the world of grizzly bears has not remained static, even during recent decades. Estimates of diet all come from data collected primarily during the 1970s, 80s, and 90s. Since 2000 whitebark pine has been functionally eliminated as a bear food in most places by disease and insects (Page 15, Figures B & C). The cutthroat trout that comprised roughly 12% of ingested foods in Yellowstone (the pink slice) are also functionally gone. Likewise, Kokanee salmon in Flathead Lake, which grizzlies consumed while spawning in McDonald Creek, are functionally extinct (Page 16, Figure B).



NCDE Diets Vary

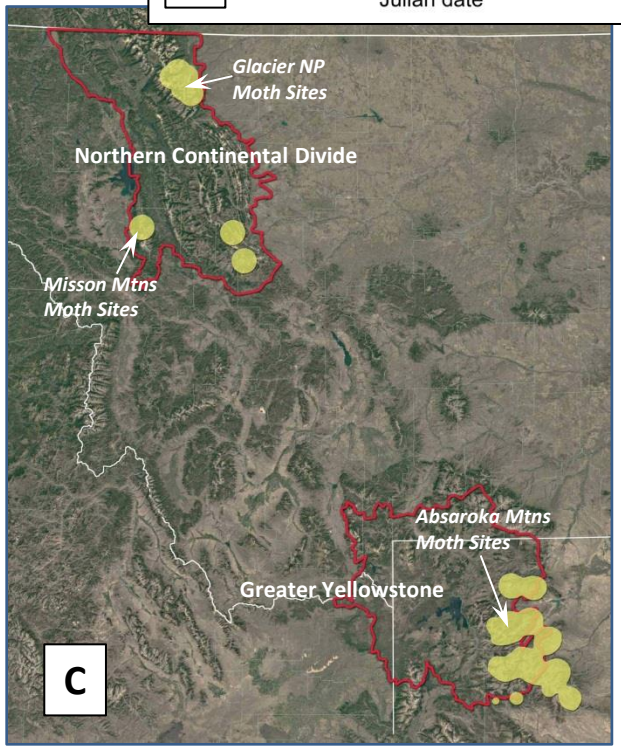
Current grizzly bear diets differ substantially from the West to the East side of the NCDE. Mace & Roberts (2012) provided a map showing a gradient in meat consumption from the west to east side based on analysis of isotopes in hairs collected from captured bears (A). In and around Glacier NP and the North Fork of the Flathead, meat comprised <25% of the total diet, in contrast to near 90% of the diet for grizzlies ranging out onto the grasslands of the East Front. Aune & Kasworm (1985) estimated that during the mid-1980s around 54% of this meat came from livestock, a fraction that has probably increased rather than diminished since then. Estimates of dietary meat from analysis of isotopes are consistent with estimates based on analysis of scats (B), which show that grizzlies on the West side consumed roughly 1.5 times more fruit compared to grizzlies on the East side.





The Neglected Phenomenon of Moth Feeding

Grizzly bears in the NCDE are also known to eat army cutworm moths in alpine talus, although probably not to the same extent as bears do in the Absaroka Mountains of the Yellowstone ecosystem. The yellowish blobs in the map at right (C) encompass all of the sites where grizzly bears are known to consume moths in the Northern Rockies. With the exception of the Mission Mountains, all of these sites are in eastern portions of the mountain massifs facing towards the Great Plains, which support the migratory adult moths during non-adult life stages. Of relevance to the NCDE, the phenomenon of moth-feeding has largely been neglected by managers, which translates into a lack of any protections for these sites as well as the absence of any monitoring. Because efforts to inventory these sites have been far less exhaustive in the NCDE than around Yellowstone, it is possible that additional sites exist in the NCDE not shown on the map to the right, and that moths are a more important dietary item than is currently thought.



For More Information on Grizzly Bear Diets in the Northern Rockies

https://www.mostlynaturalgrizzlies.org/fruit
https://www.mostlynaturalgrizzlies.org/ungulates
https://www.mostlynaturalgrizzlies.org/whitebark-pine
https://www.mostlynaturalgrizzlies.org/army-cutworm-moths
https://www.mostlynaturalgrizzlies.org/herbaceous-foods

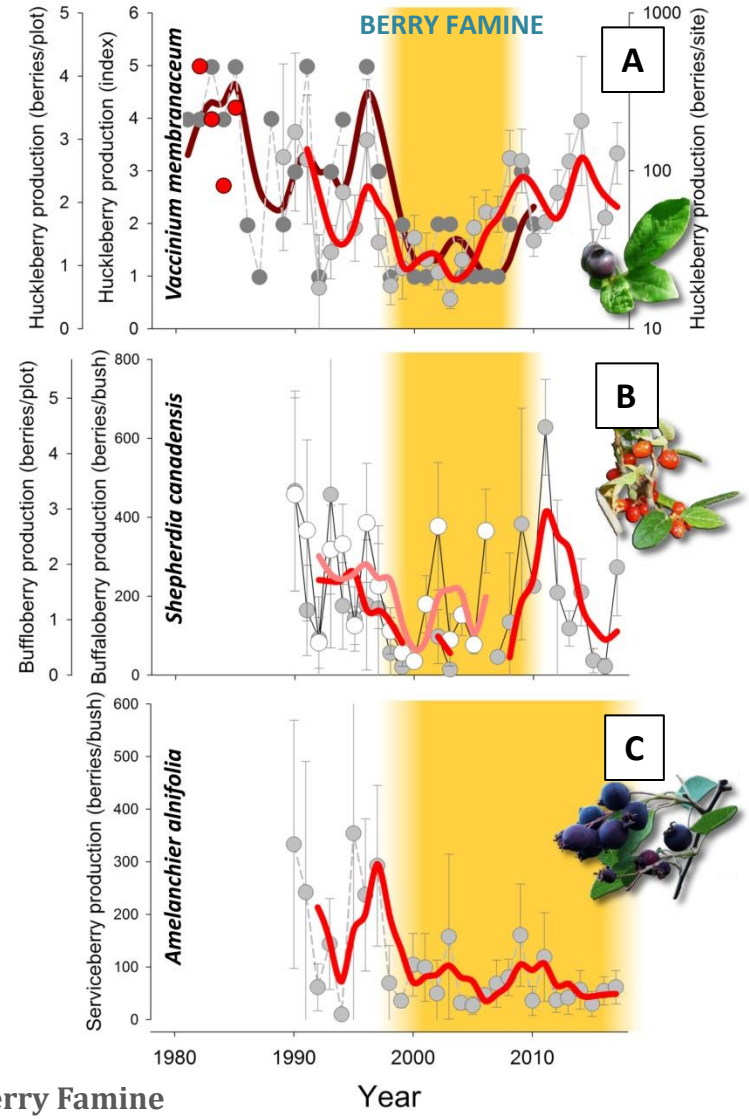
Summary & Implications: Diet

- Grizzly bears that occupied the U.S. Northern Rockies at the time of European settlement had a unique and varied diet that reflected underlying environmental gradients, including dietary economies centered on spawning salmon and fruit to the west; fruit, whitebark pine seeds, army cutworm moths, and lesser amounts of meat from elk in the drier mountains; and bison and fruit east onto the Great Plains .
- These sorts of variation in diet and underlying habitat productivity have profound effects on grizzly bear densities, historically and contemporaneously, with densities highest in areas typified by greater diversity of habitats, greater vegetal productivity, and access to spawning salmon.
- Effects of diet on grizzly bear demography and densities partly reflect orders-of-magnitude differences in digestibility and nutrient content of foods. Herbaceous foods offer the least energetic benefit and fatty foods the most, albeit with constraints imposed by the need to balance nutrients, especially energy with protein.
- As a consequence—and despite being adaptable omnivores—environmental changes that lead to gains or losses of abundant high-quality foods have major implications for both the productivity and survival of individual grizzly bears, with consequences manifest in population-level demography and densities.
- Taken together, these facts lead to the predictable conclusion that variations in food availability and diet of grizzly bears in the Northern Continental Divide Ecosystem(NCDE), both geographically and temporally, have major ramifications for demography and distribution of this population.
- The US Fish & Wildlife Service dismisses all of these facts out of hand in its recovery planning by invoking omnivory, claiming that, because grizzly bears are omnivores, environmental and dietary changes are inconsequential. As a presumed logical derivative, the Service then goes on to contend that it is relieved of any burden to monitor foods and habitats in the NCDE.

The Grizzly Bear Recovery Project

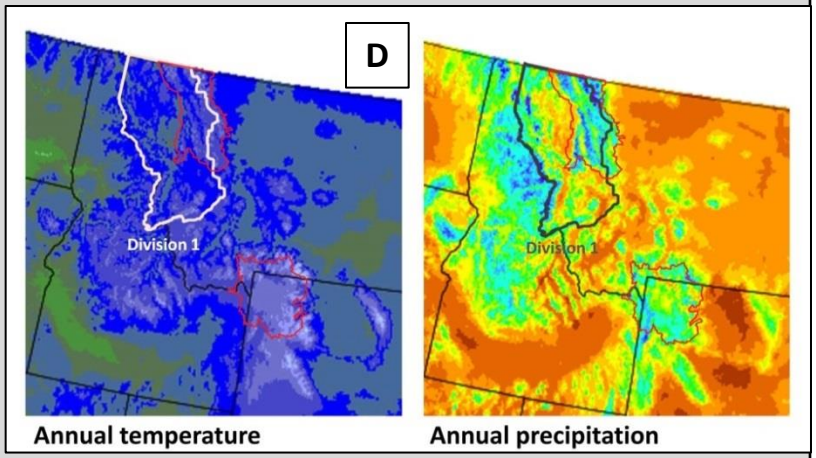
HABITAT DYNAMICS

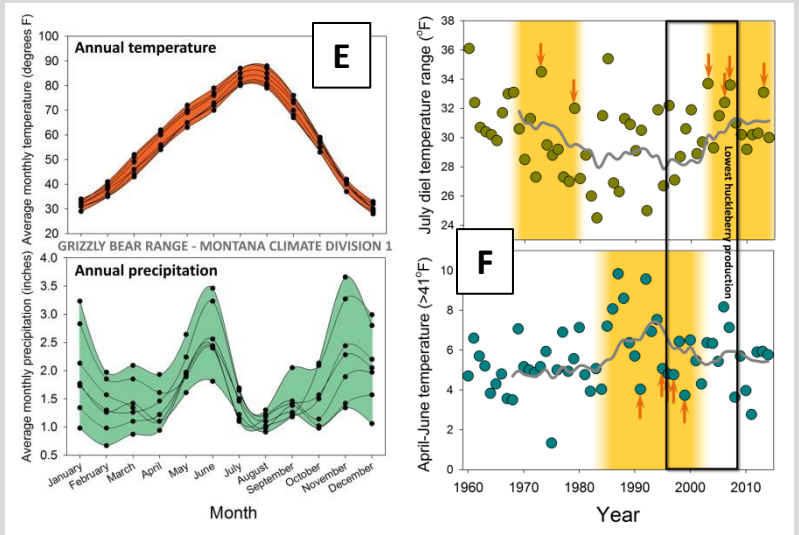
The Grizzly Bear Recovery Project



A Berry Famine

Systematic monitoring of fruit crops by Bruce McLellan in the North Fork of the Flathead and by Wayne Kasworm in the Cabinet-Yaak documented a decade-long "berry famine" that lasted roughly 1998-2009 in northwestern Montana. Both McLellan and Kasworm are consistent in showing a dearth of huckleberries during this decade (A). On top of this, results from the Cabinet-Yaak show a coincident lack of both buffaloberries (B) and serviceberries (C). This "berry famine" coincides with and probably drove a sustained increase in grizzly bear deaths (Page 28, Fig. A).

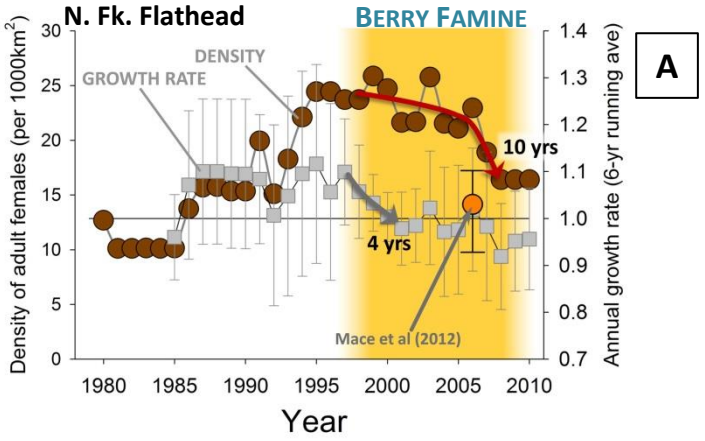




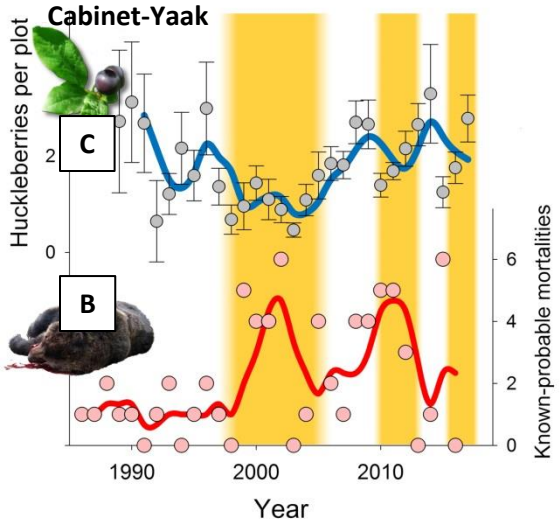
The entire West side of the NCDE probably experienced a "berry famine" during 1998-2009. All of the grizzly bear ecosystems in northwestern Montana are contained within a single National Weather Service Climate Division (D, above), within which annual trends in temperature and precipitation are quite similar across all climate stations within occupied grizzly bear habitat (E; each line represents a different station). The "berry famine" also coincides with or closely lags weather conditions that Holden et al. (2012) correlated with poor huckleberry crops: unusually warm April-June temperatures coupled with dampened diurnal temperature fluctuations during July (F; data are for the Division 1 average).

Berry Famine in the North Fork of the Flathead & Cabinet-Yaak

The 1998-2009 Berry Famine evident in the sustained dearth of fruit documented by Bruce McLellan and Wayne Kasworm had demonstrable effects on the demography of grizzly bears occupying the west side of the NCDE. Perhaps most definitively, McLellan (2015) documented a decline in bear densities and related population growth rate that was temporally and statistically related to the crash in huckleberries (see Page 13, figure A). Figure A, at right, shows these trends in density and growth rate (as a running mean for lambda) in the North Fork of the Flathead based on data presented by McLellan. There were notable lags in response of both demographic metrics to onset of the famine, with 4 years elapsing before growth rate finally turned negative and 10 years elapsing before there was a substantial downturn in bear densities. Of relevance to extrapolation, McLellan's North Fork study area straddled the US-Canadian border, including portions of the US NCDE.



Reinforcing McLellan's conclusion, Kasworm has repeatedly noted the correlation between annual numbers of known-probable grizzly bear mortalities (B) and numbers of huckleberries (C) in the Cabinet-Yaak Ecosystem. According to his data, there were two major and one minor peak in mortalities that coincided with comparatively small huckleberry crops, but with a sustained dearth in berries during 1998-2005, similar to what McLellan observed in the North Fork.

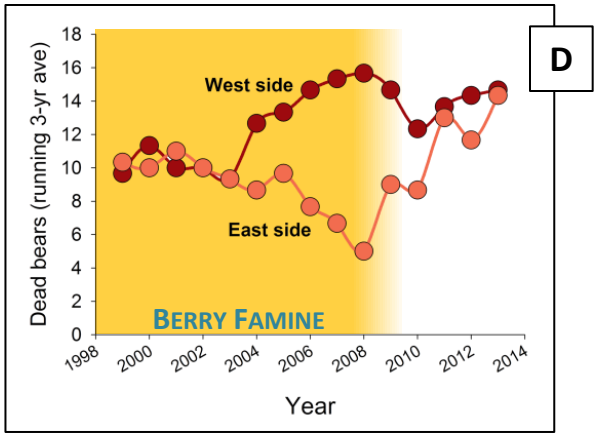


Mace's Anomalous Estimate of Growth Rate

Of relevance to judging the merits of various estimates of population growth (Page 24, Fig. B; Page 25)—the gray arrow in (A) labeled "Mace et al. (2012)" points to an orange dot representing the estimate of annual population growth rate that I derived from McLellan's data, coinciding with the 5-year period during which Rick Mace collected data that he used, in turn, to estimate 2004-2009 growth of the NCDE population. Mace's estimate of 3.1% per annum (Page 24, figure C) is the highest of any produced so far and was probably an artifact of the anomalous growth evident during this 5-year period relative to what came before and after. In other words, Mace's estimate of population growth rate cannot be defensibly extrapolated before or after 2004-2009, which is consistent with the fact that Costello et al (2016) produced a lower annual growth rate (Page 24, figure C) when data from 2010-2014 were pooled with data collected during 2004-2009.

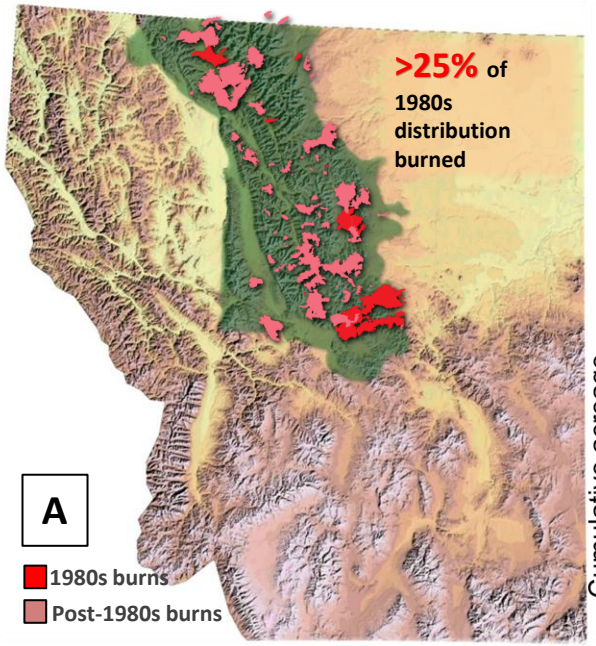
Other Evidence of A West-Side Berry Famine

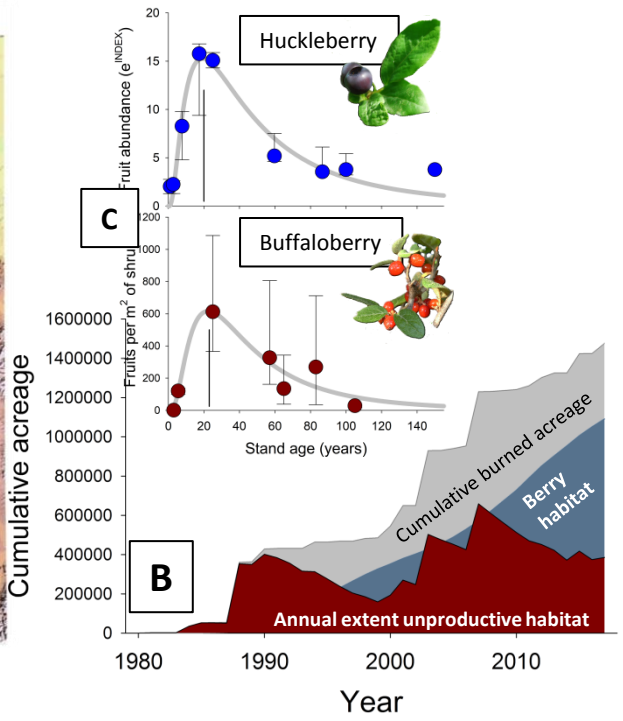
Differences in overall trends of grizzly bear mortality between the West and East sides of the NCDE lend weight to the conclusion that a Berry Famine did occur, and that it affected the portion of the population that was most reliant on fruit for energy and nutrients—on the West side (Page 10, figures A & B). Figure D, at right, shows mortality trends for the two different portions of the NCDE with reference to the Berry Famine. As can be seen, West-side mortality ***increased*** substantially toward the end of the Berry Famine. By contrast, mortalities on the East side were simultaneously ***declining***.



Berries & the Forest Fire Factor

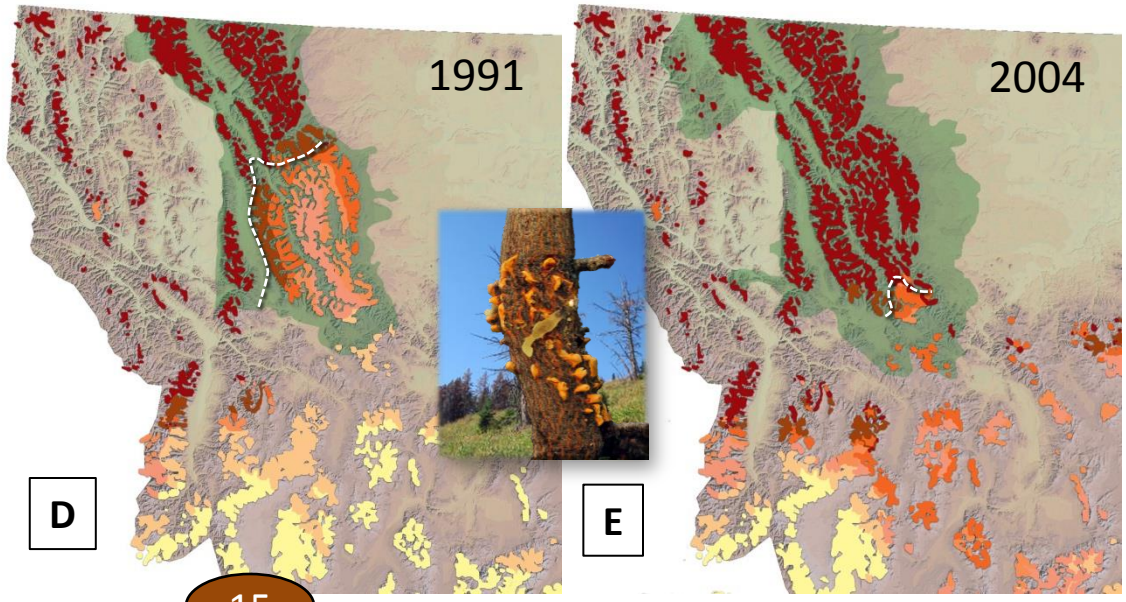
There has been a veritable explosion in fire activity in NCDE grizzly bear habitat since 2000. The map in A shows the extent of forest fires overlain on the 1980s NCDE grizzly bear distribution, differentiating fires that burned during the 1980s from those that burned after. Roughly 25% of the 1980s distribution burned up through 2016. Figure B shows the cumulative acreage burned since 1980, by year. A large area burned during 1988, followed by little additional acreage until a major sustained increase between 2000 and 2009. This fire activity potentially enhanced berry productivity, but only after an approximate 20-year hiatus. Apropos, figure C shows fruit production for huckleberry and buffaloberry as a function of stand age. Productivity of both species peaks around 20 years. As a result of this hiatus, unproductive post-fire habitat can accumulate, as shown in burgundy in figure B. Peaks in these transitional habitats have occurred during 1988-1994 and 2002-2017, at the same time that productive berry habitat has slowly increased, as per the blue shading in figure B. All of these habitat changes plausibly affected grizzly bear densities and distributions (as per Page 7).





Loss of Whitebark Pine

Whitebark pine seeds were once an important bear food in the NCDE, most recently east of the Continental Divide south of Glacier (Pages (& 10) and, before that, in lesser amounts up to the Canadian border. However, by 1991 white pine blister rust, a non-native pathogen, had killed most of the whitebark pine in northern portions of the NCDE. Results from the survey that reported this loss (Keane & Arno 1993) are shown in D, with burgundy denoting areas where almost all whitebark pine were already dead; yellow denoting areas with minimal losses. At this time, East Front grizzlies were still eating substantial amounts of whitebark pine seeds. By 2004, however, almost all of the whitebark pine in the NCDE was dead (Map E). Fiedler & McKinney (2014) reported that 70% of mature trees were dead, and 90% of the remainder infected with blister rust and doomed to die. Loss of this key food along the East Front almost certainly affected distributions of grizzlies in the mountains and adjacent plains (Page 33).



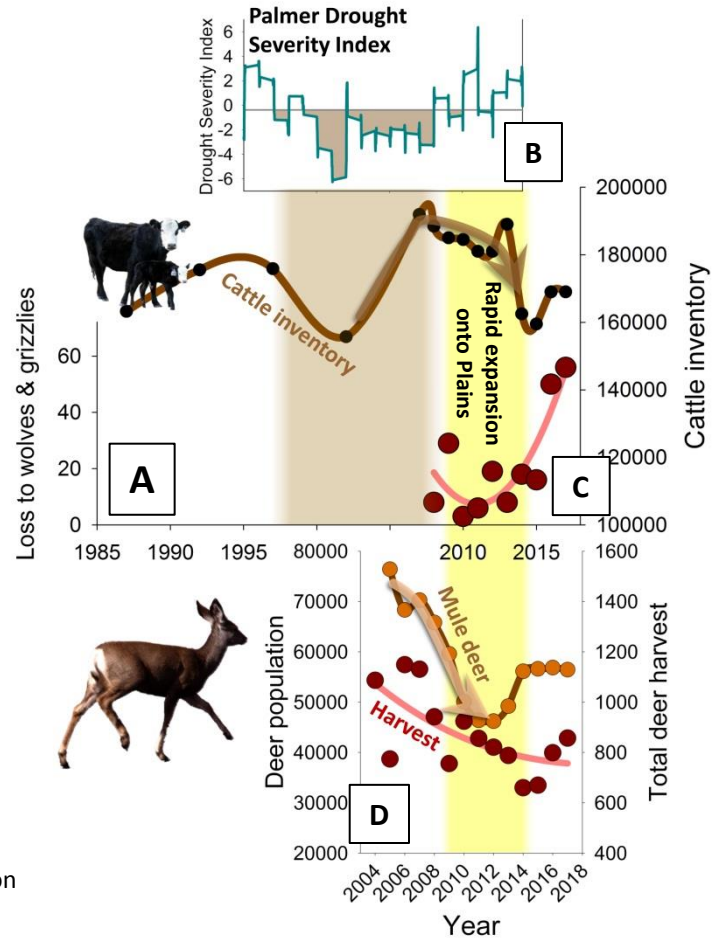
Changes in Meat Resources Along the East Front

Meat from terrestrial herbivores is the dominant source of energy for grizzly bears living along the Rocky Mountain East Front—as much as 70-90% of all digested energy for bears living on the plains farthest east (Page 10. As early as the mid-1980s, grizzlies in this area were obtaining more than ½ of the meat they ate from domestic cattle, mostly by scavenging boneyards (Aune & Kasworm 1985). Deer were the second-most prevalent source of meat.

Since the 1980s, numbers of cattle and deer have varied substantially along the East Front, almost certainly with consequences for the diets and distribution of grizzly bears. Figure A, at right, summarizes temporal trends in cattle inventories in Glacier, Pondera, Teton, and Lewis & Clark Counties, along with, in D, trends in deer populations and deer harvest in MFWP Region 4. Of relevance to trends in stocking rates, B also shows trend in the Palmer Drought Severity Index for Montana's North-Central Climate Region.

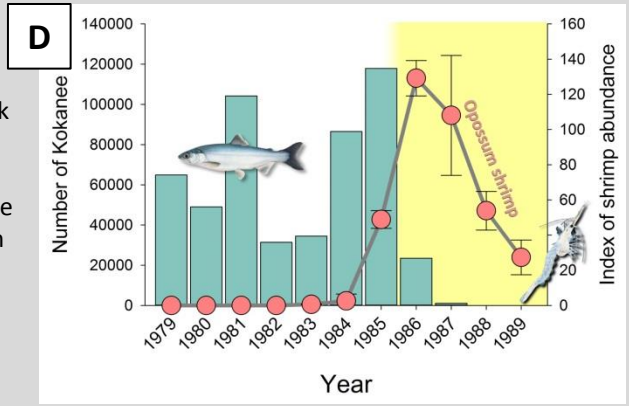
The patterns are clear. Cattle inventories dropped substantially during the sustained severe drought of 1998-2008, followed by a dramatic increase in cattle numbers with alleviation of drought during 2009-2013. In fact, cattle numbers reached levels unprecedented in modern times. For somewhat opaque reasons, this increase in livestock numbers coincided with a substantial decline in especially mule deer numbers that was reflected in total hunter harvest and presumed number of gut piles available to scavenging grizzlies.

The net result of these changes is not too hard to imagine. Most likely, grizzlies had become more rather than less reliant on meat from deer and elk during a drought period that amplified wildfires (Page 15, Figures A-C) and hammered berry crops (Page 13). With a decline in deer numbers, coincident with burgeoning cattle, grizzlies likely switched to eating more meat from cows, with a resulting increase in livestock-related depredation and conflicts (shown in C). Moreover, with increasing reliance on livestock, grizzlies were likely drawn farther out onto the plains, with expansion accelerated through the funneling effect of riparian corridors (Page 34).



The Extirpation of Kokanee Salmon

During the 1920s-1980s Flathead Lake supported a substantial population of introduced land-locked sockeye salmon called Kokanee that were exploited by grizzlies while the fish spawned in McDonald Creek inside Glacier NP. According to scat analyses presented by Kendall (1986; Page 9), kokanee accounted for roughly 9% of year-round ingested volumes for grizzlies in the Park. However, a misguided attempt to enhance kokanee food supplies through introduction of opossum shrimp during 1968-1975 resulted in the unintended collapse of the main plankton food base for kokanee, with the resulting functional extirpation of this grizzly bear food (D, turquoise bars). The upshot is that grizzly bears in the NCDE have not eaten spawning salmonids since the late 1980s. Perhaps not by coincidence, the yellow-tinted area in D corresponds with a period when distributions of grizzlies in the NCDE began to rapidly expand.



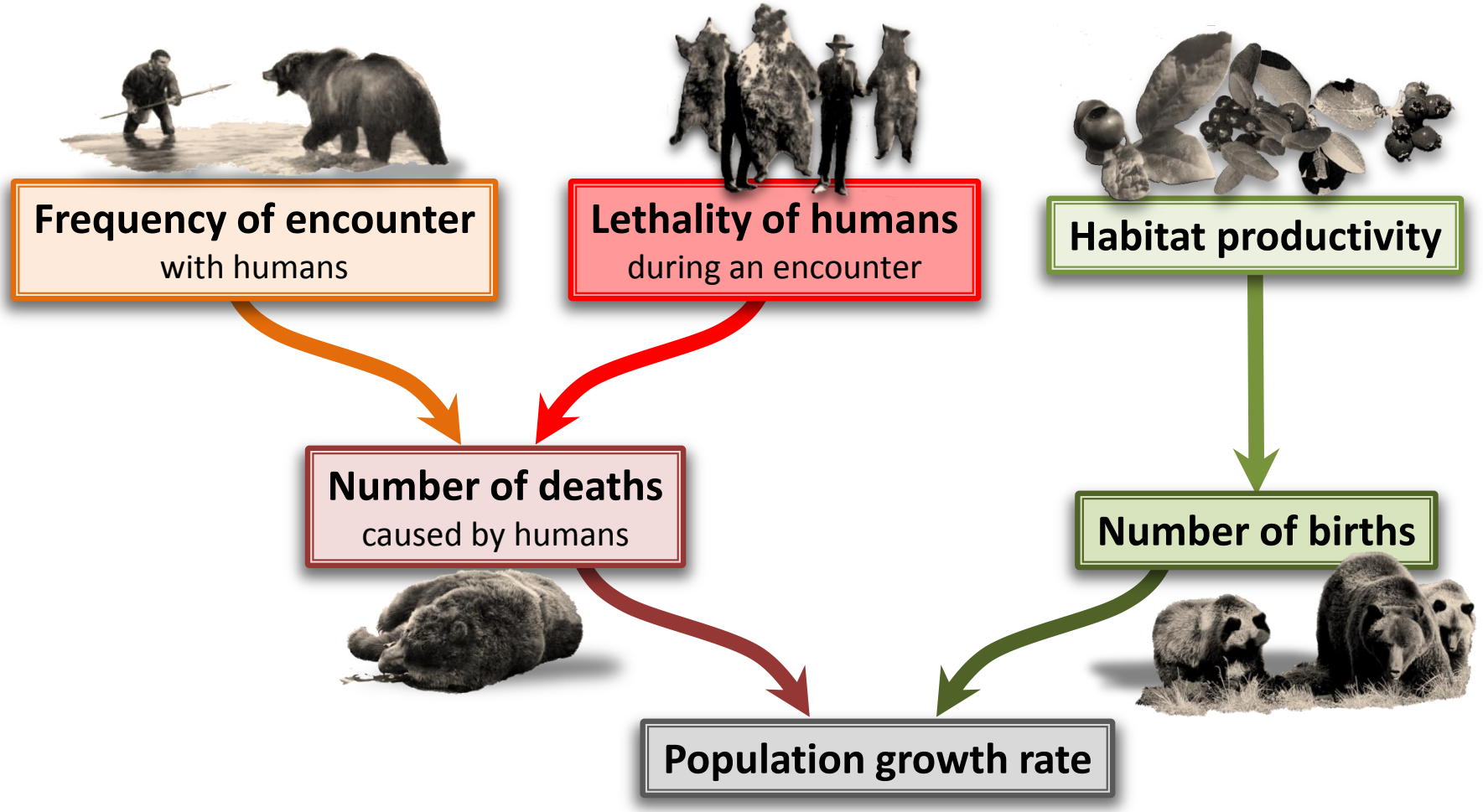
Summary & Implications: Habitat Dynamics

- Grizzly bears in the Northern Continental Divide Ecosystem (NCDE) have experienced major environmental changes during the last 40 years that have led to corresponding changes in diets, with resulting effects on demography and distributions.
- During 1998-2009 crops of fruits important in bear diets were at sustained low levels throughout western portions of the NCDE, resulting in what could be fairly called a “berry famine”. Huckleberry crops were especially hard hit, but serviceberry crops never recovered, even after 2009 when the main part of the Famine had ended.
- The Berry Famine had major effects on grizzly bear demography, especially in western portions of the NCDE. Numbers of bear deaths increased substantially, not only in the NCDE, but also in the Cabinet-Yaak Ecosystem. As a consequence, population growth rate and densities declined significantly in at least the North Fork of the Flathead River and probably throughout northwestern Montana.
- A pronounced increase in wildfires resulted in the cumulative burning of >25% of occupied bear habitat post-1980, with most acreage burned during the epic drought of 1998-2010. Although these fires resulted in enhanced berry productivity 20-years post-fire, transient unproductive conditions rapidly accumulated, especially during the 2000s.
- Whitebark pine was functionally extirpated as a source of bear food in the NCDE by 2004, with most losses occurring along the East Front between 1985 and 2000. Prior to the mid-1980s, whitebark pine seeds had been a major fat-rich food of bears that they exploited in remote high elevation habitats.
- Densities of cattle along the East Front declined to historically unprecedented lows during the 1998-2010 drought, but recovered to record high levels between roughly 2009 and 2014, coincident with major declines in numbers of mule deer—the most important native source of meat for grizzly bears. These dynamics almost certainly resulted in bears exploiting cattle more heavily after 2009, not only to compensate for a lack of deer, but also because cattle were that much more abundant.

The Grizzly Bear Recovery Project

HABITAT MONITORING

The Grizzly Bear
Recovery Project



The schematic above offers a conceptual framework for thinking about phenomena that drive growth of grizzly bear populations. The emphasis for death rate is on human-related factors given that pretty much everywhere—as in the NCDE—humans are the main cause of death for bears once they've reached the age of 3. More precisely, in the NCDE roughly 90% of all radio-marked bears that died did so because a human had killed it. An estimate such as this one based on fates of radio-marked animals is comparatively reliable and much less affected by biases in detection compared to what gets recorded solely on the basis of public reports.

Deductively, grizzly bears will be killed by humans based on (1) the frequency with which they encounter people and (2) the likelihood that any given encounter will turn deadly for the involved bear (i.e., encounter "lethality"). This distinction is critical when partitioning human-related factors for monitoring and management. Some factors (e.g., peoples' attitudes and whether they are armed or not) will affect lethality whereas other factors (e.g., densities of open roads and humans in residence) will affect encounter frequencies. More to the point, efforts to manage encounter frequency can be negated by heightened human lethality, or the converse, as in National Parks, where encounters are quite frequent, but the involved people typically benign and unarmed.

Frequency of encounter
with humans

Road densities

Secure habitat

Lethality of humans
during an encounter

Armaments

Attitudes

ATTRACTANTS

Beehives
Calving areas
Boneyards
Livestock allotments
Poultry/small animal operations
Garbage/other attractants
Hunters afield

Numbers & locations **Managed?**

This schematic represents an approximate list of human-related factors that NCDE mangers would ideally be monitoring and managing when attempting to, in turn, manage levels of human-caused grizzly bear mortality. The vertical orange bar represents the conceptual domain of factors affecting frequency of encounters between bears and people; the light burgundy bar is the same for factors affecting encounter lethality. The NCDE Conservation Strategy (CS) focuses on monitoring road densities and habitat security on federal lands—to the virtual exclusion of everything else. There is certainly no overt indication that peoples' attitudes or armaments can be important factors—as they certainly are. But the other major gap in the CS has to do with human-related attractants, which is the other facet of habitats driving both frequency and lethality of contact between bears and people. The yellow box spanning the "frequency" and "lethality" domains contains my first approximation of attractants that would ideally be the focus of explicit monitoring protocols. Of this list, the only one given overt attention in the CS is livestock allotments. Even so, an additional consideration for all of these potential attractants is not only how many there are and where they are located, but also, as important, whether they are managed so as to reduce likelihood of conflicts. For example, electric fencing is a key factor with beehives, calving areas, and small animal operations. Husbandry of livestock is a major factor in management of livestock allotments. Yet none of these ameliorative interventions is featured in any part of the CS.

Habitat productivity

17	**Productivity**	R-S NDVI/greenness/AET
17	**Avalanche chutes**	Aerial photography/AVHRR
10	**Shrubfields (*Berries*)**	R-S NDVI; ***berry transects***
5	**Mesic habitat**	R-S greenness/NDVI
4	**Rock fellfields (*Moths*)**	***Observed use*** *of mapped locations*
-5	**Grasslands/wetlands**	R-S NDVI
-7	**Regenerating cutblocks**	USFS inventories/R-S NDVI
-11	**Closed canopy forests**	R-S NDVI
-18	**Human infrastructure**	Roads, residences, campsites, etc

Linking landscape characteristics to local grizzly bear abundance using multiple detection methods in a hierarchical model

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5 University of Montana Cooperative Ecosystem Studies Unit, Glacier Field Station, Glacier National Park, West Glacier, MT, USA

GRIZZLY BEAR HABITAT SELECTION IN THE SWAN MOUNTAINS, MONTANA

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Predicting Grizzly Bear Density in Western North America

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HABITATS SELECTED BY GRIZZLY BEARS IN A MULTIPLE USE LANDSCAPE

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Landscape Evaluation of Grizzly Bear Habitat in Western Montana

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Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana

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L. JACK LYON† and HANS ZUURING‡

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ESTIMATING GRIZZLY BEAR DISTRIBUTION AND ABUNDANCE RELATIVE TO HABITAT AND HUMAN INFLUENCE

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Predicting Spatial Variation in Grizzly Bear Abundance to Inform Conservation

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Finally, the distribution, attractiveness, and productivity of numerous natural habitat features will determine, not only levels of female grizzly bear productivity, but also where bears will be relative to people. The CS willfully and almost completely ignores this aspect of the grizzly bears' environment in the NCDE despite the fact that there has been ample research showing the critical role of natural habitat in configuring the distribution and productivity of bears in this ecosystem. The box above contains a summary of this research relative to the various factors that were collectively considered by the involved researchers (see at left). Each of these habitat features is identified in the central column, with the various metrics used to measure and monitor each in the column to the right. Briefly, 'R-S' signifies 'remotely sensed'; 'AET' denotes 'actual evapotranspiration'; and 'AVHRR' denotes 'Advanced Very High Resolution Radiometer'. The numbers in the left-hand column are a quantitative summary of the relative importance of each factor, summed over all studies, including whether the associated factor was found to be positively or negatively associated with distributions of grizzly bears. Vegetation productivity, in the abstract, as well as avalanche chutes and shrubfields were consistently found to be the most attractive features of natural habitats. By contrast, regenerating cutblocks, closed canopy forests, and human infrastructure were consistently found to be least attractive; i.e., most repulsive. By implication, all of the habitat features listed above should be candidate for monitoring and management under terms of the CS, with the metrics to the right plausible means by which the monitoring could be accomplished.

Summary & Implications: Habitat Monitoring

- Humans are responsible for roughly 90% of all adolescent and adult grizzly bear deaths in the Northern Continental Divide Ecosystem (NCDE). As a result, most bear deaths are dictated by the rate of encounter with humans (encounter frequency) and the likelihood that the encounter will turn lethal (encounter lethality).
- Frequency of encounters with people is partly dictated by shear numbers of people, densities of road and trail access, numbers of human residences, and the nature of human activities. All of these human-related features warrant being monitored to inform grizzly bear conservation efforts.
- Frequency of encounters between bears and people is also dictated by the number and nature of attractants near where people are active, including unsecured garbage, bird feeders, dog food, beehives, small livestock (e.g., chickens), boneyards, and calving and lambing areas, among others. All of these human-associated features warrant being monitored.
- Productivity of the NCDE grizzly bear population is contingent on the abundance and distribution of high quality foods and the habitats that produce them. Availability of foods and habitats also determine, in part, the extent to which grizzlies spend time near people in search of food and resulting odds that they will be involved in conflicts with humans and end up dead.
- Known high-quality foods and habitats include shrubfields and other environments that produce huckleberries, buffaloberries, serviceberries, chokecherries, and hawthorn; alpine talus sites that host concentrations of army cutworm moths; avalanche chutes that produce abundance cow-parsnip and other preferred herbaceous foods—along with berry-producing shrubs; and mule deer, white-tailed deer, elk, and cattle populations. All of these foods and associated habitats warrant being monitored to inform grizzly bear management and conservation in the NCDE.

POPULATION DYNAMICS

The Grizzly Bear
Recovery Project

Following the logic tacit to the projections in (B), below, the graph at right (A) shows the most likely trajectory of the NCDE population between 2004 and 2018. Based on the 3 culminating population estimates, I also show the derivative annual percent rate of change for each of the 3 relevant periods. The ***negative rate*** for 2014-2018 is noteworthy.

Projected Population Sizes

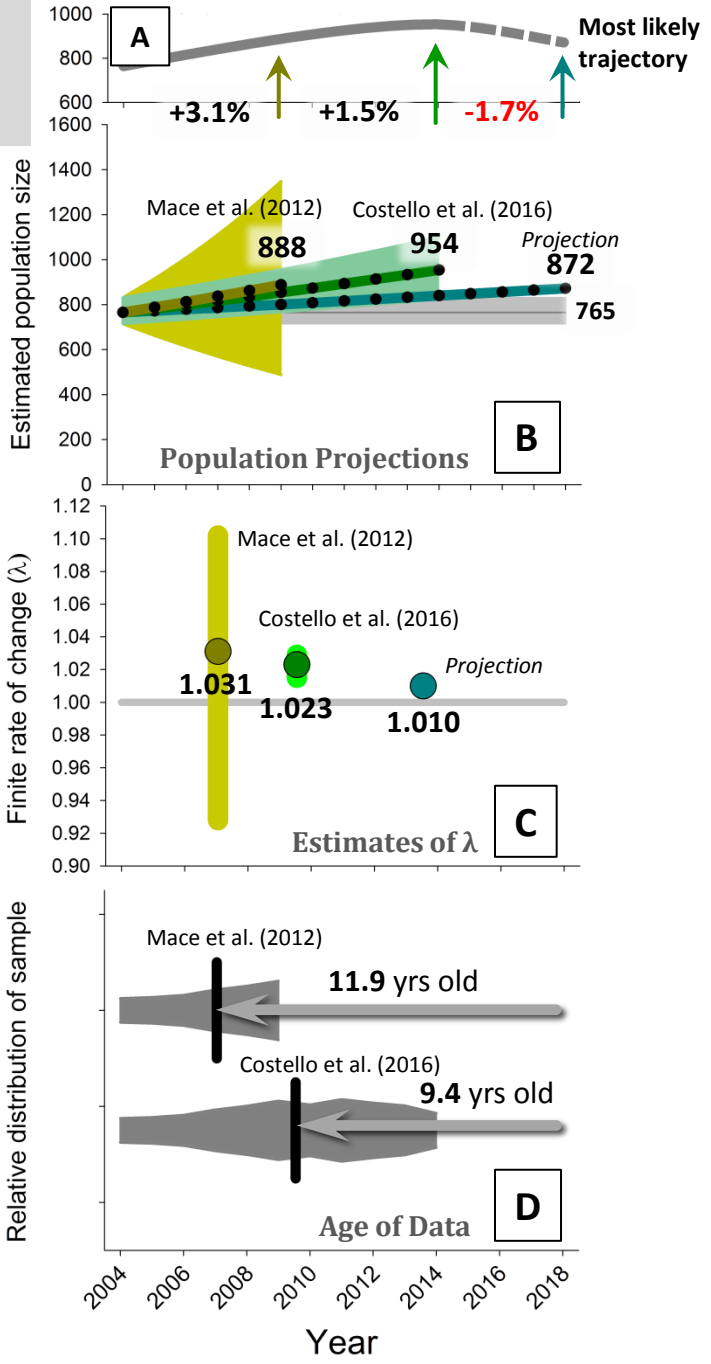
The graph at right (B) shows projected population sizes applying the growth rates estimated by Mace et al. (2012), Costello et al. (2016), and myself (as per in [C], below) to the 2004 estimate of population size by Kendall et al. (2009). The colored bounds were derived by applying the growth rates defining upper and lower confidence intervals to the upper and lower bounds of the 2004 population estimate. The horizontal black line and gray band project out the 2004 population estimate to establish a point of reference. Assuming that the growth rate tethered to a starting year of 2004 continued to decline commensurate to what had occurred between 2006 and 2009, culminating population size estimated for 2018 would be less that that estimated by Costello et al for 2014—implying a ***decline*** in population size during the last 4 years.

Estimated & Projected Growth Rates

Costello et al. (2016) estimated a finite rate of change for the NCDE population that was ***less than*** the rate estimated by Mace et al. (2012) using all of the Mace et al data plus data collected during 2010-2014. Despite the Costello et al claim that there was no trend in vital rates during this period, mean survival of COY, yearlings, and independent females dropped, coupled with a lengthening of reproductive intervals and decline in mean litter size. Even though the differences may not have each been "statistically significant," taken together they were self-evidently enough to yield a decline in estimated growth rate. Absent a more recent estimate of vital rates, I projected a rate of increase, assuming the passage of an additional 4 years, based on the rate of decline between the Mace et al and Costello et al estimates of λ. The result for 2004-2018 was λ = 1.010.

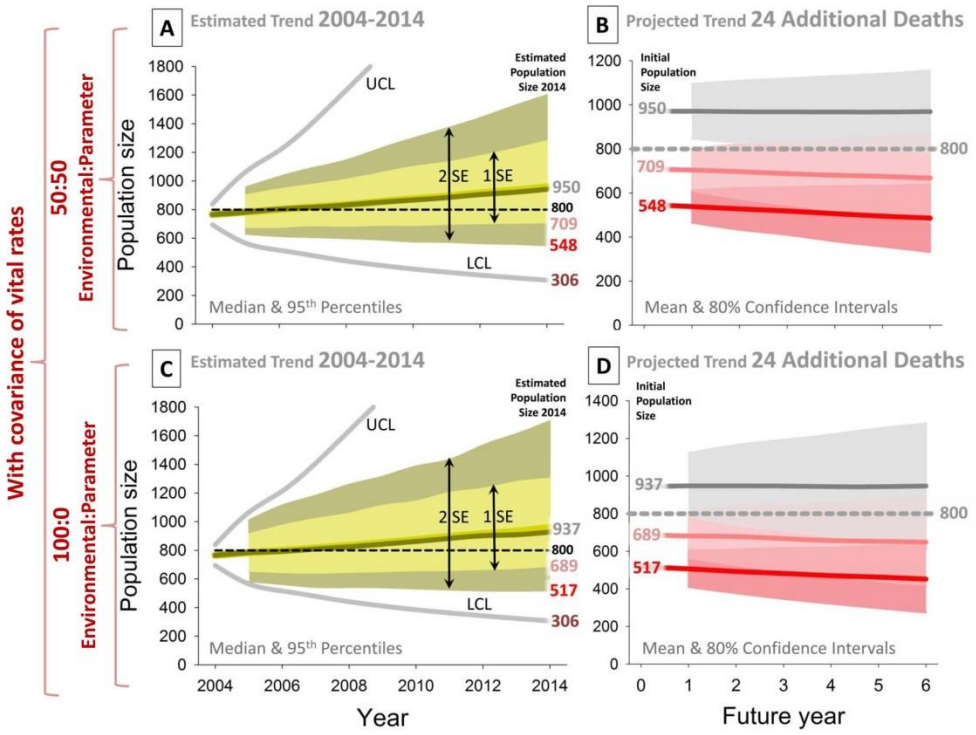
Antiquated Data

The age of the data being used to assess current status of the NCDE population is noteworthy. The graph at right (D) shows the sample distribution, by year, as well as the mean weighted age of data used by Mace et al. (2012) and Costello et al. (2016) to estimate vital rates and related growth rate of the population. (I obtained the sample distribution from NCDE Annual Reports.) I could not find any indication that updated estimates, post Costello et al, were being used in any delisting-related analysis. Note, then, that the most recent analysis uses data that are an ***average 9.4-years old***, of which none are fresher than 4 years old. The staleness of these data as well as the staleness of derivative estimates is partly what led me to project trends in growth rate. Regardless, this reliance on aged data by the State of Montana and US Fish & Wildlife Service does not inspire confidence.



Playing Games with RISKMAN

RISKMAN is a software package that projects population sizes based on birth and death rates input by the user, with explicit provision for estimating the effects of additional increments of mortality (e.g., hunter-caused). RISKMAN also provides options by which users can account for uncertainty in vital rate estimates through a stochastic process that samples uncertainty intervals. Additional features include an option to partition uncertainties between so-called "parameter" and "environmental" effects which, in practice, amounts to nothing more than two different methods by which uncertainty intervals are sampled and the results projected forward in time. Variation in the different vital rates can also be treated as if they are uncorrelated or correlated (e.g., high birth rates occur when death rates are low). As a result, there are multiple ways that uncertainty can be treated by users, some more plausible than others, with substantial effects on the variance of projected population sizes. One somewhat surprising feature of RISKMAN is that it uses Standard Errors (SE, a measure of uncertainty in the estimated mean) rather than Standard Deviations (SD, a measure of dispersion in the data) for simulating the effects of varied vital rates.



The NCDE Conservation Strategy proposes to use RISKMAN for managing mortality so as to maintain a population of 800 bears with an 90% probability of exceeding this threshold during a 6-year forecast period. Costello et al (2016) also used RISKMAN to estimate the mean and associated SE of population size for 2014. They projected the 2004 point estimate of 765 bears forward 10 years using the mean and SEs of vital rates estimated from data obtained during 2004-2014 from radio-marked animals. As a bottom line, successful use of RISKMAN to achieve probabilistic outcomes depends almost entirely on how uncertainty is treated within this modeling framework. Of relevance to NCDE grizzly bears, Costello et al (2016) consistently low-balled uncertainty and thereby substantially understated the risks attached to their methods.

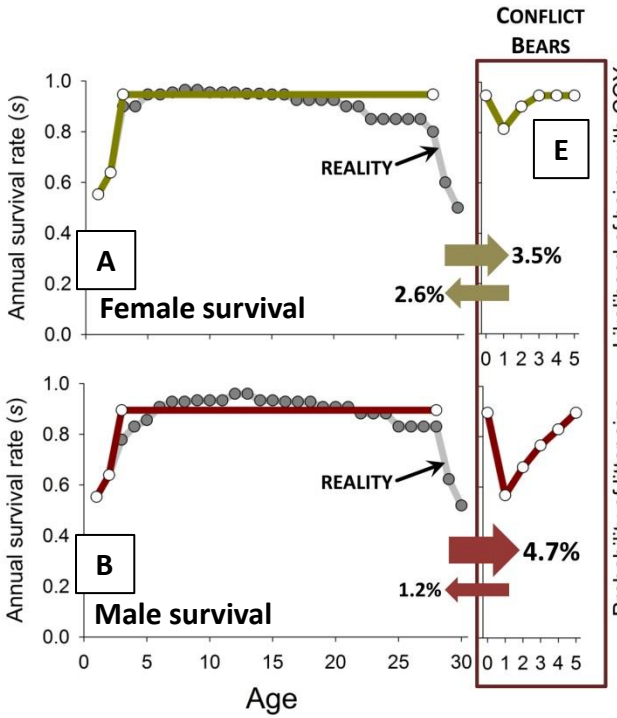
Notably, Costello grossly overstated the certainty of her NCDE population estimate for 2014 (putatively between 825 and 1100), with profound implications for any projected effects of additional mortality. I attempted to remedy the many failings in her projections by varying allocations of variance between "parameter" and "environmental," treating all vital rates as correlated, and specifying variance as both 1 SE (as per Costello) and 2 SE (better capturing dispersion). I also projected population size setting all parameters either at lower (LCL) or upper (UCL) bounds of confidence intervals. My results are in A & C—notably lower bounds of the 2014 population estimate range from 517 to 709 (14-37% lower) and average uncertainty is 2.7-times greater. More starkly, if all parameters were, indeed, at the lower bounds of Confidence Intervals, projected population size would be 306. When my 2014 estimates are fed into 6-year projections (B & D), contentions that the population could be managed to exceed 800 bears with certainty (90%) are rendered absurd. Even starting with an initial population of 937-950 (B & D), odds of dropping below 800 are between 9% and 55%, even without considering the bias introduced by including bears residing outside the DMA (Page 26, Figure F).

Failure to Account for Structure & Senescence

In addition to the problems with methods and applications that I describe on previous pages, the demographic models employed by Mace et al (2012) and Costello et al (2016) are compromised by lack of realism and failure to include critical population structure. More specifically, their models do not account for any source-sink dynamics, whether behavioral or spatial, which invariably leads to bias in application and only spurious explanation of fundamental dynamics.

Costello et al make clear that there is a source-sink dynamic organized around behaviors that lead to certain bears being first trapped in response to conflict situations rather than for research purposes. These authors then go on to over-simplify this dynamic in their estimation of population growth rate by setting death rates at a weighted mean that presumably accounts for the conflict-trapped versus research-trapped population segments.

One problem with either ignoring source-sink dynamics or subsuming them in a weighted average is that the resulting models fail to account for rates of flow into and back out of sinks , whether geospatial or behavioral. These rates are critical to both understanding and projecting population dynamics , in the latter case because overall population growth rate can be substantially affected by changes in the rates at which bears are recruited to and from sinks.

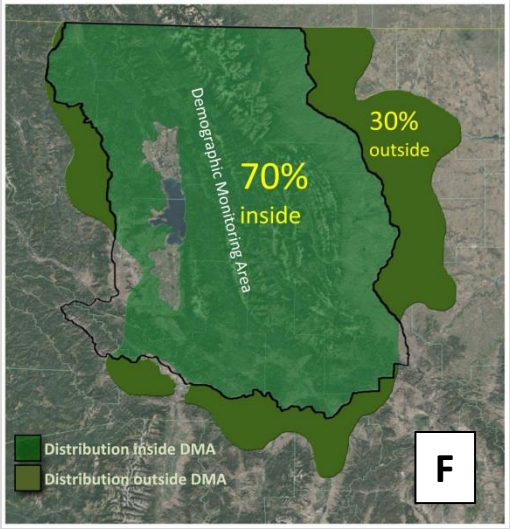


The models employed by Mace et al and Costello et al also do not include the axiomatic effects of senescence and late adolescence on death and (in the case of females) birth rates, and instead pool data from old and young bears with data from prime age individuals, ostensibly rationalized in terms of statistical arcana rather than biological realism. Again, the problem with such pooling is that the resulting models are biased, usually in ways that produce overly-optimistic estimates of population growth (Doak & Cutler, 2014a, 2014b). Costello et al ostensibly tested for senescence-related structure—albeit obliquely—by comparing age structures of populations derived from their capture data with age structures derived from their models. Crucially, the tables presented by Costello et al show that their models ***over-estimated*** numbers of old bears; i.e, over-estimated survival rates of older animals. Similar bias is evident in their estimates of birth rates, whether litter sizes or age-specific odds that a female would have reproduced.

Graphs A-D contrast the age-specific estimates of survival and reproduction used by Costello et al (yellowish-green for females; burgundy for males) with more realistic age-specific estimates based on results of comprehensive and in depth investigations of grizzly bear demography reported by researchers elsewhere. Importantly, adjustments for realism end up accounting for what would otherwise be anomalies in data reported by Costello et al. I also show the estimates reported by Costello et al of annual survival rates and annual reciprocal flows from the 'conflict' to 'research' bear population segments in E. Again, these rates of exchange are important to achieving useful insights and realistic projections. Moreover, it is not that difficult to build models to accommodate such structure.

Inflated DMA Population Estimates

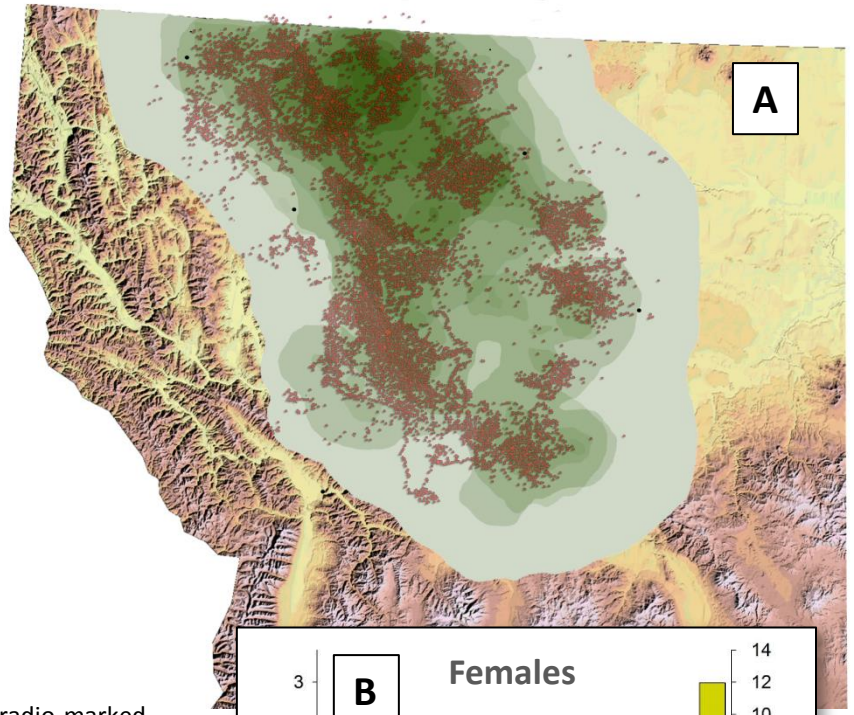
The size of the NCDE population is estimated by projecting a 2004 point estimate forward in time based on the 2004-2014 estimate of growth rate (Page 24). The result holds for the entire population, without explicit reference to distribution. As a consequence, some of the estimated bears live outside the DMA—perhaps as many as 30% (F, at right). The prospective methods for managing mortality *inside* the DMA do not correct for the inflation cause by including bear from *outside* the DMA; i.e., we don't know how many bears actually live wholly or partially *within* the DMA.



Unrepresentative Sample of Radio-Marked Bears

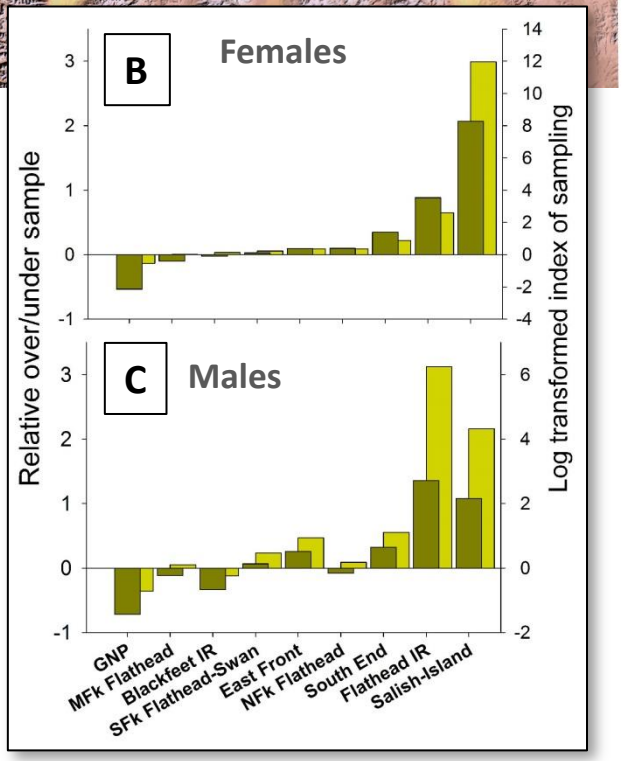
Both Mace et al (2012) and Costello et al (2016) assert that, because their efforts to capture grizzly bears were guided by prior knowledge of grizzly bear densities, their sample of bears and bear fates was thereby representative if not 'random.' On the face of it, this invocation of 'random' is an unabashed perversion of the concept, especially in reference to statistical considerations. Using prior knowledge of densities to guide capture effort in no way axiomatically leads to a sample that is truly 'representative' of the entire population for the entire sample period, without taint from any intervening factors attributable to spatial configurations of habitat, subpopulations, features of individual bears, annual variability in habitat productivity, annual variability in human lethality, etc., etc.

In other words, there is no way that either Mace or Costello could have fulfilled the statistical requirement of randomness, which is technically guaranteed only with the random assignment of 'treatments' by the involved researchers to a population comprised of entities representing the full spectrum of conditions relevant to the research question—where 'treatments' are, in this case, exposure to various levels of habitat productivity as well as numbers of people, permuted by their relative lethality to bears (see Page 19).



Aside from this *prima facie* consideration, there is ample evidence that the sample of radio-marked bears used by Mace et al and Costello et al to estimate vital rates and, from them, population growth rates was not, in fact, an unbiased sample of the total population—certainly not geospatially. The map in A shows all of the telemetry locations obtained from radio-marked bears during 2004-2012 (red dots) overlain on top of the relative density map that Mace and Costello claim to have used to dictate successful bear captures (shades of green; darker denoting higher densities).

Visual inspection of the map in A shows that radio-telemetry locations of sampled bears do not even approximately correlate with the underlying map of bear densities derived from data produced by Kendall et al (2009) for the year 2004. Locations are disproportionately concentrated on the periphery. The bar graphs in B and C more explicitly show the extent to which different management subunits in the NCDE were over- or under-sampled relative to a priori densities for females (B) and males (C; from Costello et al). The light yellowish-green represents untransformed ratios whereas the darker green bars are derived from transformations to minimize distortions introduced by small denominators.



These results, among others, call into question claims that estimates of vital rates made by Mace et al and Costello et al are truly representative of 'the population'. Almost certainly not.

Trends in Mortality

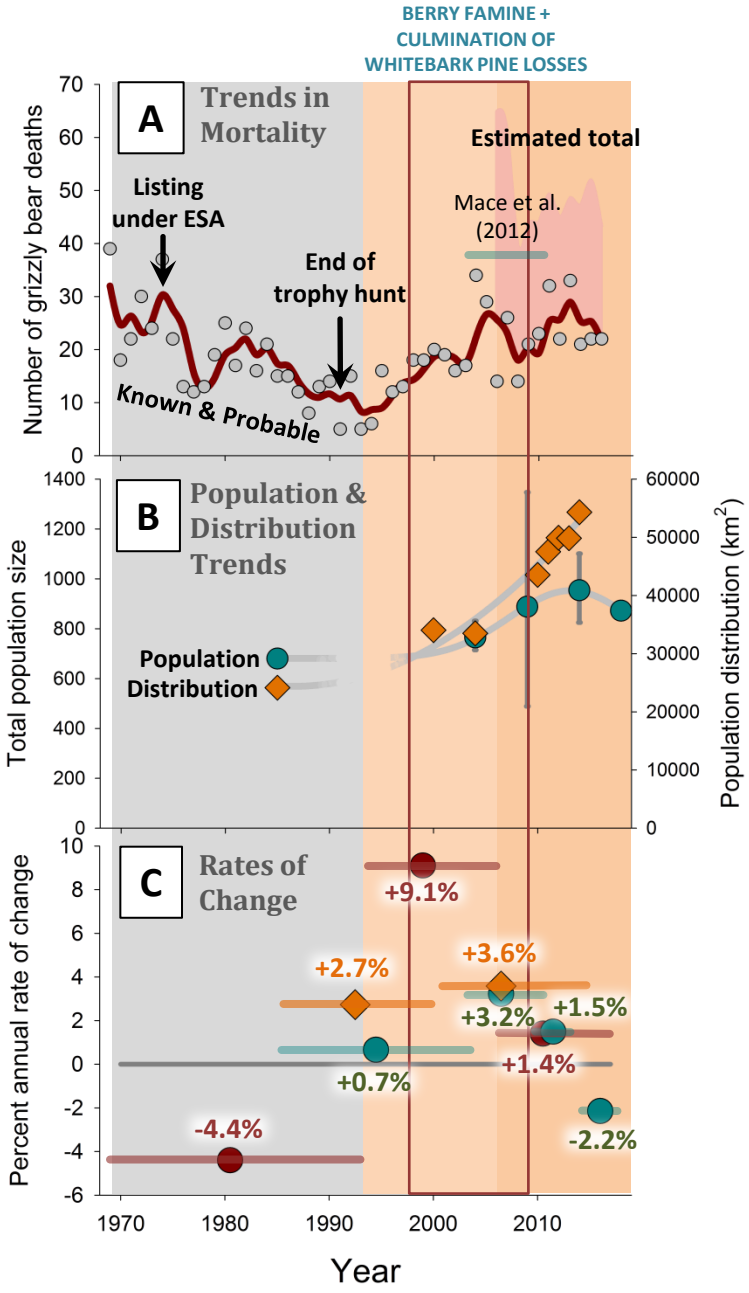
Trends in numbers of known and probable mortalities have been dramatic for the NCDE grizzly bear population. The figure at right shows a 3-year moving average (dark red line) as well as raw counts for numbers of dead bears (gray dots) plus the estimated total for 2004-2016 that accounts for unknown and unrecorded deaths (pink). Numbers of deaths declined at a steep -4.4% annual rate between 1969 and 1993; increased an even steeper 9.1% rate between 1994 and 2003; and at a lesser rate of 1.4% after that (see [C] below). Unknown/unrecorded deaths amount to roughly as many as those that are recorded. Paradoxically, deaths began to climb shortly after when Montana's trophy hunt was ended due to litigation by environmental groups. The increase in deaths during 1994-2003 was probably due to the "berry famine" that occurred during this decade (see Pages 13 & 14).

Trends in Population & Distribution

Interestingly enough, at the same time that numbers of deaths were declining and then mounting thereafter, there was apparently a small increase in both population size and distribution (the turquoise dots and orange triangles at right, B). After 2003, the population apparently increased and then decreased modestly in size, coincident with a lessening rate of increase in mortalities. At the same time, distribution increased rapidly between 2000 and 2014. Cause and effect are muddled here, but distribution continued to increase at the same time that population growth increasingly stalled and perhaps even turned negative, suggesting some sort of driver for increasing distribution other than a rote increase in numbers of bears (see Page 33).

Trends in Rates of Change

Rates of change for different time periods (C) synopsize all of the above trends. We have somewhat reliable rates for changes in distribution, population size, and numbers of deaths beginning around 2000-2004. During roughly 2000-2004, mortality was increasing at a heated pace (burgundy dots), preceding a decline in that rate that coincided with comparable but modest rates of increase in both distribution (orange dots) and population size (turquoise dots; +3.0-+3.5% per annum) during 2004-2009. After 2009, the rate of population increase lessened, and may have even entered negative territory during recent years (Page 24, Figure A), coincident with a continuing slight rate of increase in mortalities and sustained modest rate of increase in distribution. It is possible that the continuing positive rate of increase in mortalities has contributed to a population decline and that the continuing substantial rate of increase in distribution is more certainly being driven by habitat changes. Parenthetically, the data used by Mace et al. (2012) to estimate population growth rate for 2004-2009 coincided almost exactly with a fortuitous temporary decline in numbers of mortalities (see [A] as well as Page 24, figure A).



Summary & Implications: Population Dynamics I

- Estimates of population growth for the Northern Continental Divide Ecosystem (NCDE) grizzly bear population are entirely retrospective and, with passage of time, tethered to increasingly aged and irrelevant data that make these estimates progessively more insensitive to current population trend.
- Data used to produce a published estimate of population growth rate for 2004-2009 are now, on average, 12 years old. The current estimate of growth being relied upon by the US Fish & Wildlife Service is based on data averaging 9-10 years old, with none of these data more recent than 4 years old.
- Back-weighted and increasingly irrelevant estimates of population growth rate partly arise from government biologists conflating precision with relevance. Folding in ever-more (but increasingly aged) data allows for more precise estimates of birth and death rates, but at the cost of decreasing sensitivity to contemporaneous conditions.
- The data used to estimate birth and death rates are not representative of the NCDE grizzly bear population, protestations and assertions by government biologists not-with-standing. Some bears in some areas were over-sampled; other bears in other areas were under-sampled. As a result, for this reason alone, estimated growth rates are not representative of the population.
- Models used by government biologists to estimate population trajectory do not account for self-evident source-sink structures that are both spatial (Glacier NP and Middle Fork of the Flathead versus the remainder) and behavioral ('research-trapped' versus 'conflict-trapped'). Because of this deficiency, the models are biased and not sufficiently informative.
- Population models are also deficient because they do not realistically account for the effects of age (senescence) on birth and death rates. Age-specific estimates of both are notably lacking, again because government biologists conflate precision and statistical considerations with realism and relevance.

Summary & Implications: Population Dynamics II

- The software used by government biologists to simulate population growth (RISKMAN—which is also being proposed for future management of mortality) produces results that are substantially affected by options for treating uncertainty in vital rates. Vital rates can be treated as either correlated or uncorrelated. Uncertainty can be variously partitioned among the categories 'environmental' versus 'parameter', which are merely euphamisms for how Standard Errors (SEs) are introduced into simulations. And uncertainty can be treated simply as *precision* of vital rate estimates (SEs) or as *variability* in vital rates, better represented by measures of dispersion; for example, Standard Deviations (SDs).

- More realistic simulations treat vital rates as being correlated, and uncertainty as mostly or entirely 'environmental' (as a mechanistic consideration), as well as better represented by SDs rather than SEs. Government simulations do none of this and, as a result, produce estimates of population size that were not only unrealistic, but also implausibly precise for the ending year of simulation periods.

- Given the deficiencies in RISKMAN (including an inability to model source-sink structures), compounded by how government biologists simulate population growth, proposed methods for managing grizzly bear mortality in the NCDE contain substantial unacknowledged risks of over-harvest.

- Growth rate of the NCDE population was estimated at around 3% per annum for the period 2004-2009. However this period fortuitously coincided with a short-lived decline in numbers of grizzly bears dying each year, anomalous relative to what came before and after. As a result, this estimate of growth rate can not legitimately be extrapolated.

- When data from 2010-2014 were added to data for 2004-2009, estimated growth rate was revised downward to nearer 2% per annum. This decline is not surprising given that the period 2010-2014 saw a trend towards increasing numbers of bear dying each year. Even so, the 2% per annum estimate was not specific to the period 2010-2014 given that it was based on data from 2004-2009 as well as 2010-2014. A realistic estimate of growth rate specific to 2010-2014 would be <2% per annum.

The Grizzly Bear
Recovery Project

Summary & Implications: Population Dynamics III

- The NCDE population likely grew at no more than 1.5% per annum during 2010-2014. This estimate is based simply on accounting for the change in population size between 2009 (based on 3% per annum growth for 2004-2009) and 2014 (based on a 2% growth rate for 2004-2014).
- More speculatively, the NCDE population probably ***declined*** at near 2% per annum between 2014 and 2018 based on using a rate of change in the rate of change (second derivative) to project the decline between 2004-2009 and 2010-2014 into the more recent 4-year period.
- Projections of population size that more realistically account for uncertainty and variation in vital rates yield a range of population sizes for 2014 that are 200%-1000% greater than the range being used by government biologists as a basis for claims about population size as well as for prospective input into projections from which allowable (presumably sustainable) levels of mortality would be calculated.
- There is no credible basis for estimating current population size or recent population growth rate for the NCDE grizzly bear population, and therefore no credible input into calculations that would presumably yield estimates of allowable mortality.
- Annual rates of change in population growth and population distribution have rarely been synchronous for grizzly bears in the NCDE, suggesting that factors in addition to rote grizzly bear numbers have driven many changes in distribution.

SPATIAL DEMOGRAPHY

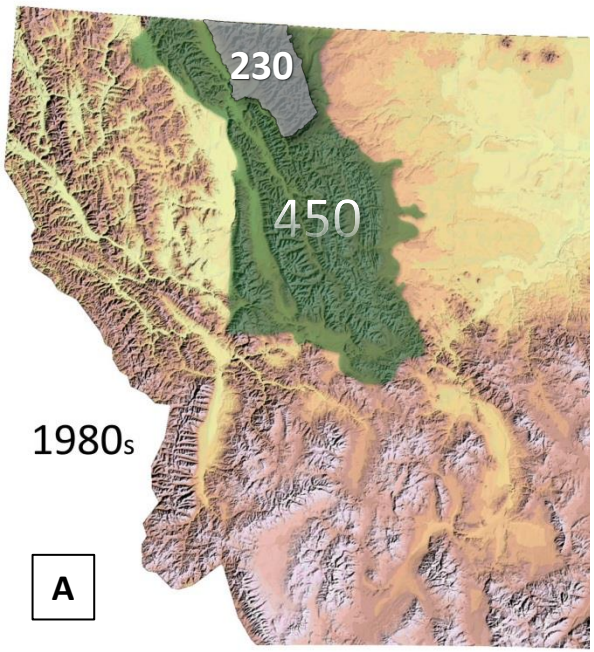
The Grizzly Bear Recovery Project

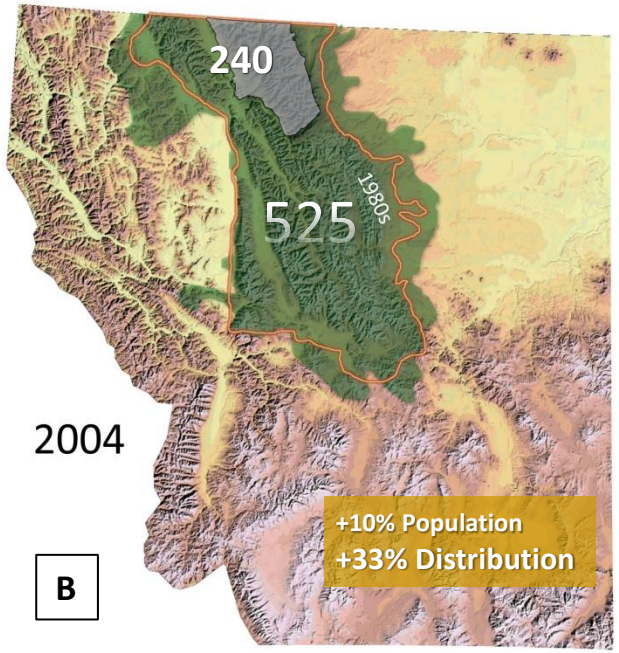
Uncoupled Trends in Population & Distribution

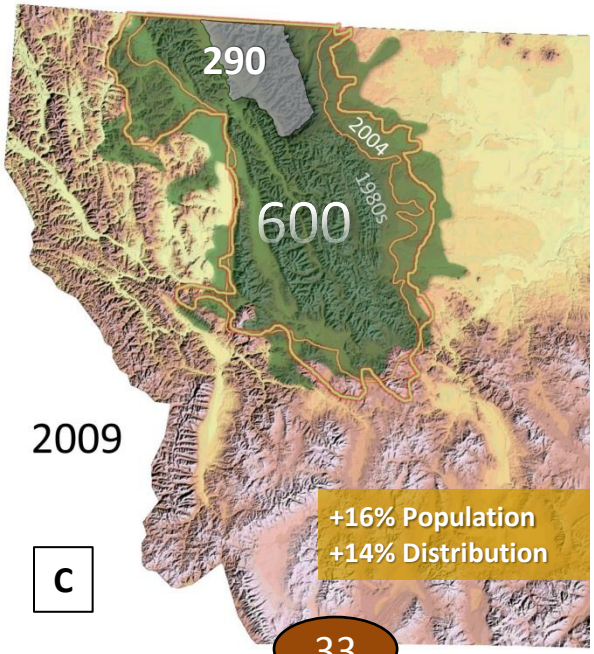
The maps at right translate the annual trends in population and distribution shown in figures A-C of Page 24 into geospatial form, summarized over three different time intervals for which we have beginning and end population and distribution estimates—with the 1980s as a benchmark (A); then, next, changes between the mid-1980s and 2004 (B); then changes between 2004 and 2009 (C); and finally changes between 2009 and 2014 (D). The inset numbers in B-D summarize total percent change in population and distribution for each of these intervals. I've also shown rough estimates for the source population centered on Glacier NP and adjacent portions of the Middle Fork of Flathead River, distinct from areas to the south that have historically been sinks (see Pages 36 & 38).

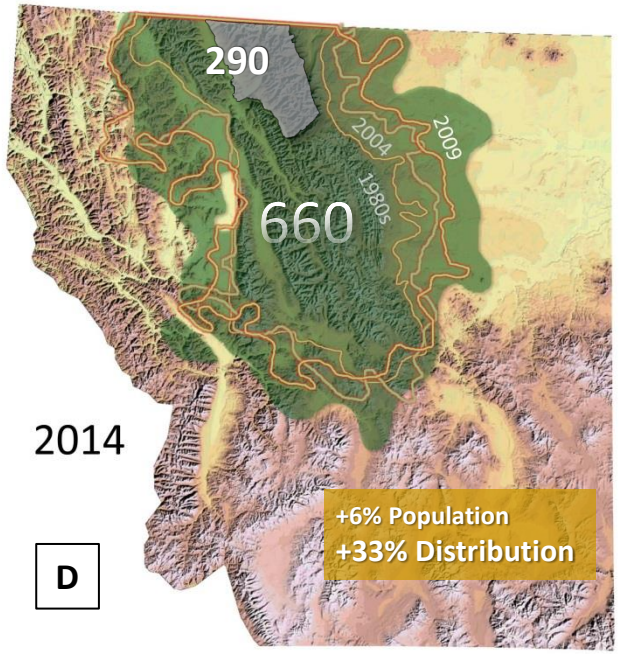
The main point here is that, at the same time bear numbers increased only modestly, distribution exploded, with the main periods of uncoupling between growth in distribution and population size occurring during 1980s-2004 and 2009-2014. By contrast, increases in bear numbers and distribution were relatively synchronous during 2004-2009, the period during which data were collected and then reported in the analysis by Mace et al (2012).

All of this begs the question why distribution would have been expanding at a much faster rate than population size during 1985-2004 and 2009-2014. The asynchrony during 1985-2004 was very likely driven by the Berry Famine on the west side (see Pages 13 & 14) and culminating losses of whitebark pine on the east side (Page 15, Fig. E), driving a reconfiguration of bear densities. The asynchrony during 2009-2014 was likely driven by shifts in sources of dietary meat along the East Front (Page 16, Figs. A-C) and habitat changes caused by a major increase in forest fires (Page 15, Figs. A & B). Whatever the reason, NCDE bear managers have not bothered to explore these asynchronies, and instead invoke phantom increases in bear numbers.





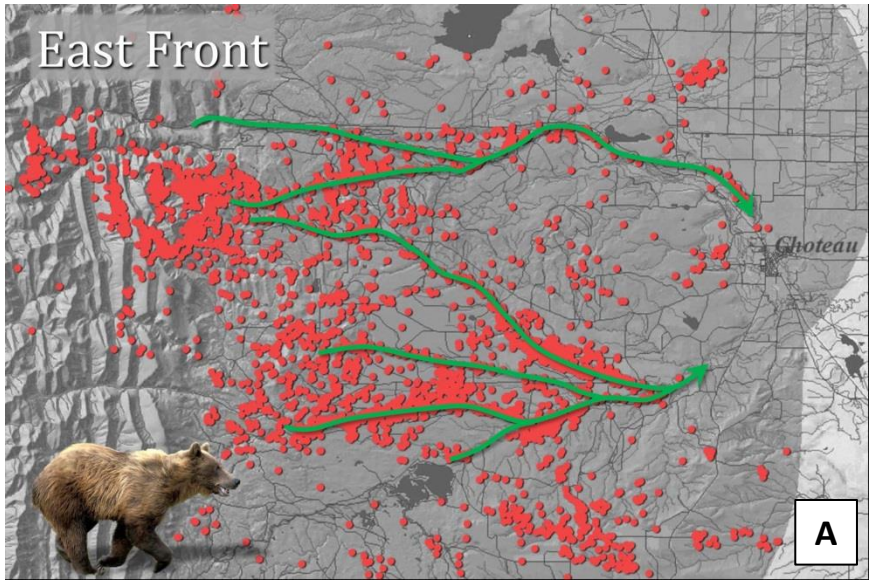




Acceleration of Dispersal by Riparian Areas and Consumption of Livestock

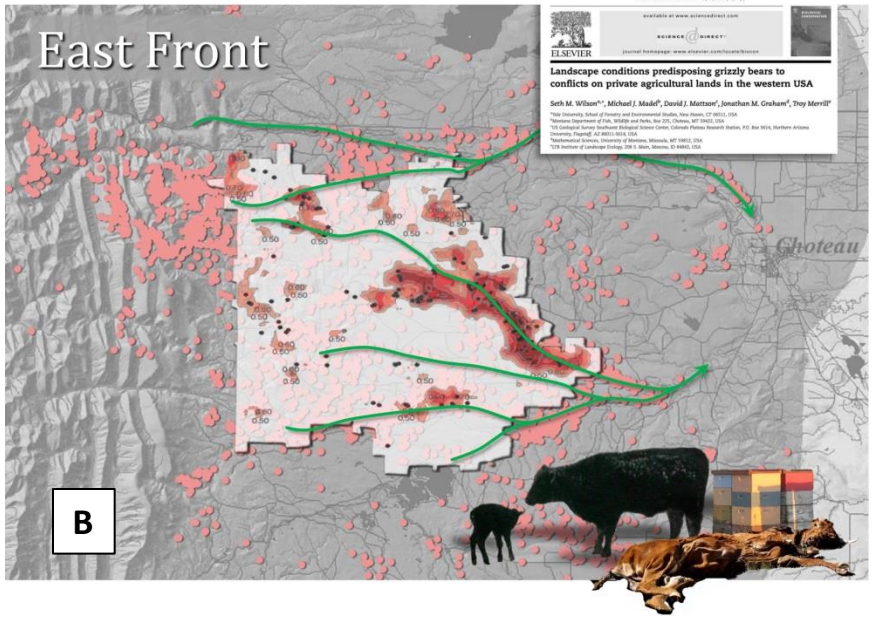
The maps at right, focused on areas west of Choteau, Montana, highlight some dynamics that have almost certainly accelerated the expansion of grizzly bears east from the Rocky Mountain Front onto the adjacent high plains.

The red dots in A each represent a telemetry location for grizzly bears radio-marked and tracked west of Choteau during 2004-2012. The green arrows highlight major riparian areas. The pattern is obvious and not surprising. Once grizzlies leave the mountains, they tend to concentrate in west to east trending riparian areas—which happen to be where most natural and anthropogenic bear foods are concentrated. The natural foods include fruits from serviceberry, hawthorn, and chokecherry, as well as herbaceous foods such as grasses, sedges, cow parsnip, clover, and angelica (Stivers 1988, Aune & Kasworm 1989). Anthropogenic foods include cattle carcasses in 'bone yards,' calving and lambing areas, and beehives, all of which tend to be concentrated near human residences, most of which are located in or near riparian areas (Wilson et al 2005, 2006).



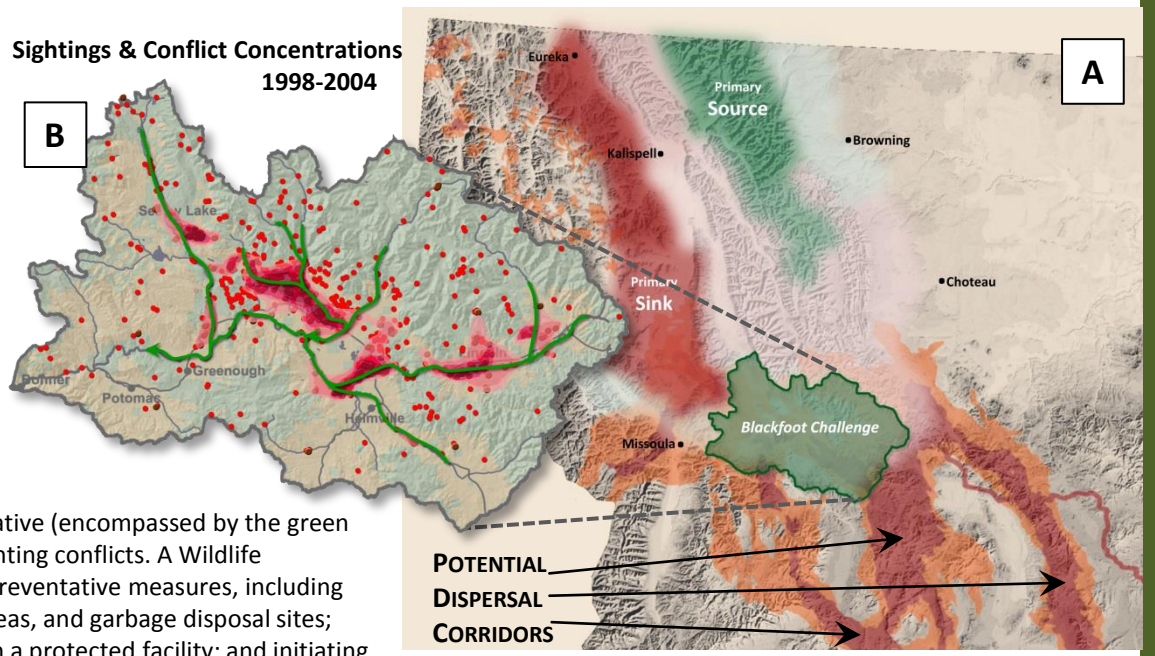
This juxtapose of naturally attractive habitats with humans and human-related attractants leads to a predictable pattern of human-grizzly bear conflicts along the East Front that organize primarily around agriculture and husbandry practices. The map in B, extracted from Wilson et al (2006), overlays isopleths of conflict densities on top of the grizzly bear locations and riparian corridors shown in A. The total area inventoried for conflicts is shown in white; areas of progressively higher concentrations of conflicts are denoted by progressively darker shades of red and burgundy. Not only are the causes of conflict predictable, so are the spatial configurations.

The upshot is that grizzly bears are funneled into and then concentrated along lineated riparian habitats that naturally draw bears out onto the plains, into agricultural areas. Moreover, this dynamic predictably leads to accelerated dispersal of bear eastward, contributing to the rapid expansion in grizzly bear distribution in this direction evident especially since 2004—to some extent independent of any increase in bear numbers, but also given predictable impetus by deteriorating habitat conditions in the adjacent mountains (Page 15), as well as proximal declines in deer populations and berry crops (see Page 16, Figures A-C).



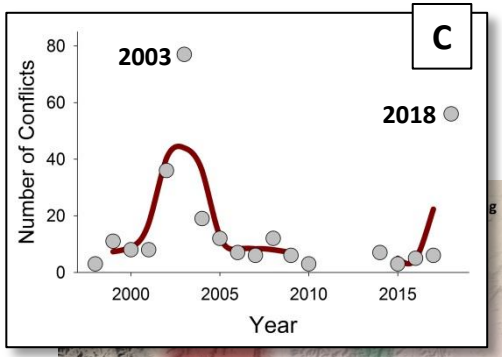
Coexistence in a Critical Landscape: The Blackfoot Challenge

The Blackfoot River drainage encompasses the southern-most portions of the NCDE Demographic Monitoring Area (DMA; A), in a watershed that has become a source for dispersing grizzly bears during 2004-2014 (Page 50). Between 1998 and 2003, sightings of grizzly bears and associated livestock and agriculture-related conflicts were increasing exponentially (B & C). As along the East Front, most of these conflicts were concentrated along riparian corridors. In the map at right (B), riparian corridors are denoted by green arrows, and greater concentrations of 1998-2004 grizzly bear-human conflicts by darker shades of burgundy shading (individual bear sightings during 1998-2004 are shown by red dots).

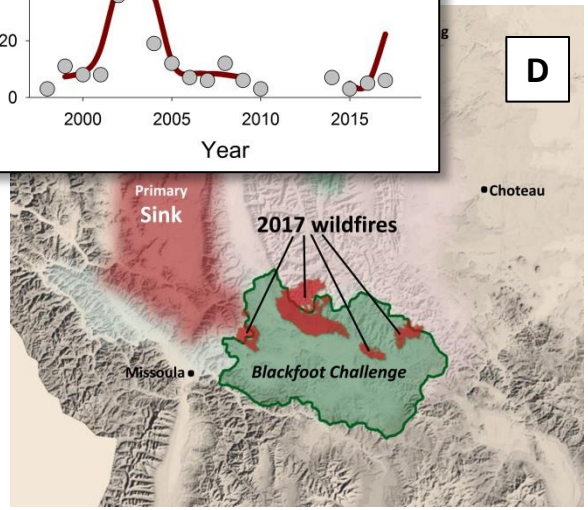


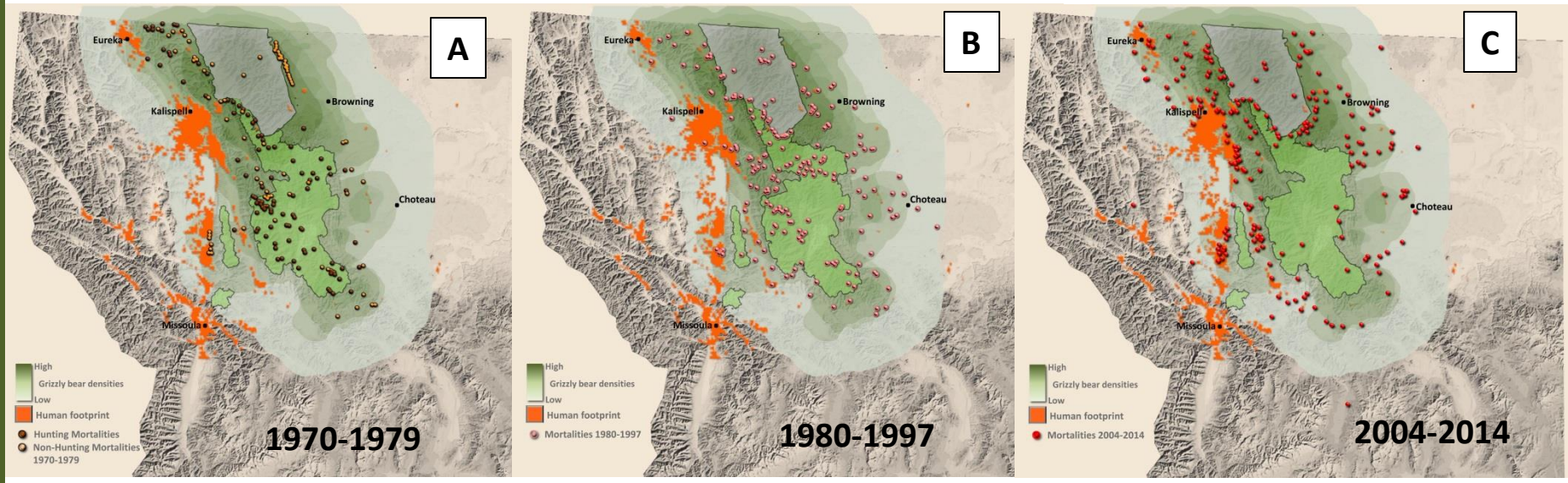
The Blackfoot Challenge, a multi-partner conservation collaborative (encompassed by the green at right [A]), was pre-positioned to tackle the challenge of mounting conflicts. A Wildlife Committee worked with members to implement a number of preventative measures, including installing electric fence around beehives, home sites, calving areas, and garbage disposal sites; removing livestock carcasses from bone yards for composting in a protected facility; and initiating telephone trees for timely notification of neighbors when grizzly bears were in the vicinity. By 2010, >90% of beehives were electrified along with 17 of the largest calving areas. Carcasses collected for composting had exceeded 400 per year.

The results were profound. Conflicts declined by >90% from 2003 to 2006 (C), along with numbers of grizzly bears killed because of those conflicts. As a probable result, the Blackfoot River drainage became a source for grizzly bears dispersing to the south and southwest towards the Greater Yellowstone and Selway-Bitterroot Ecosystems along corridors that had been identified by various research projects (A), with prospects for eventually colonizing the Selway-Bitterroot and establishing connectivity between the NCDE and GYE. This trend continued up through 2017.



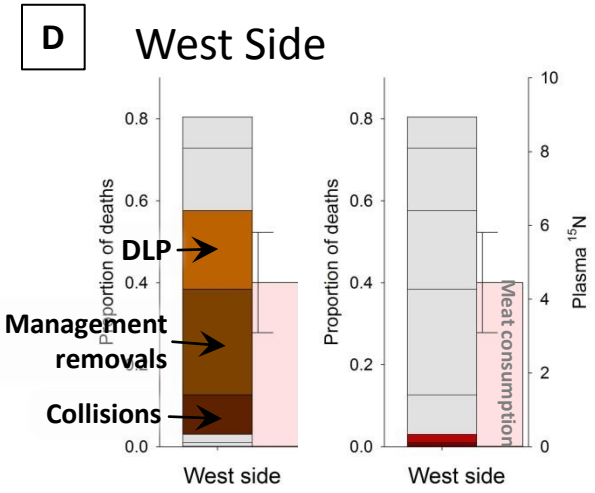
However, during 2017, extensive wildfires burned much of the northern mountainous portions of the Blackfoot River drainage (shown in D). These fires eliminated otherwise productive habitats (see Page 15, Figures A & B) and catalyzed an influx of commercial mushroom pickers shortly after. Consistent with the short-term (i.e., 20-year) affects of wildfires (Page 15, Fig. C), grizzly bear-human conflicts exploded during 2018 (C), presumably as a result of bears being displaced into lowland habitats by the fires. Adding credence to this explanation, local wildlife managers and residences speculated during 2018 interviews that the increase in conflicts was, in fact, attributable to the nearby wildfires. This probable role of wildfires and, by implication, environmental change, buts the lie to claims by NCDE managers that environmental conditions are irrelevant to monitoring plans or explaining demographic dynamics.





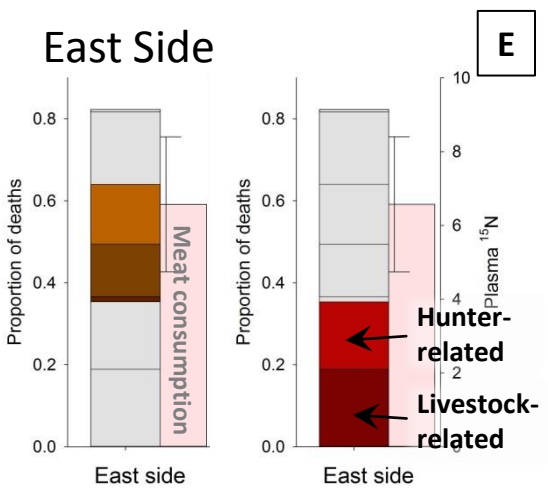
Changes in the Spatial Distribution of Mortalities

The distribution of grizzly bear mortalities in the NCDE has changed dramatically between 1970-1997 and years since. More specifically, mortalities during the earlier period were much more concentrated in the southern interior of the ecosystem, in the Bob Marshall Wilderness (A & B) compared to more recent years when mortalities have been concentrated on the periphery, in areas with embedded drivers of human-bear conflict (C). Aside from this major spatial shift, a concentration of mortalities along the US Route 2/BNSF railway corridor has persisted from 1970 up until the present. The earlier concentration of mortalities in remote wilderness was a direct function of a focus by grizzly bear trophy hunters on these areas (A), which ended with the termination of sport hunting in the early 1990s, but left a lasting legacy as a population sink to the south (Page 38, Fig. A).



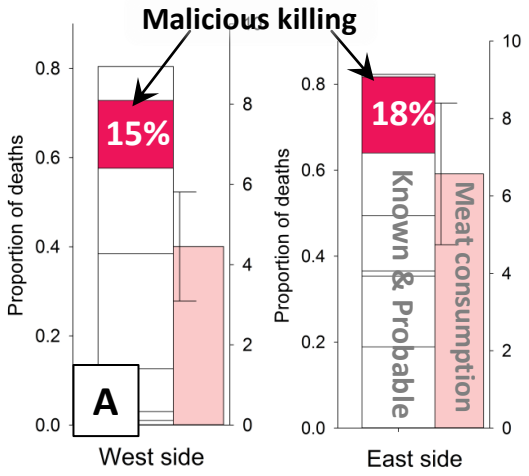
Differences in Causes of Mortalities

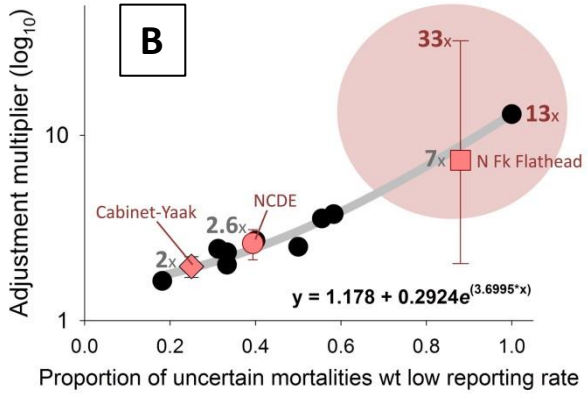
Proportional causes of grizzly bear mortality differ substantially between the West and East sides of the NCDE. Largely in reflection of the much higher densities of people and infrastructure on the West compared to the East side (25 versus 9 people/sq. mile), a much higher fraction of bear deaths on the West side is due to collisions with cars and trains, defense of life and property (DLP), and management removals, most of which are in response to conflicts over home-site attractants. By contrast, partly because of much higher densities of cattle on the East compared to West side (18 versus 8 cows/ sq. mile) and a much higher fraction of meat in the overall bear diet (54% from livestock), more bear deaths on the East side arise from conflicts with humans over meat, whether livestock or big game being pursued by hunters.



The Problem of Malicious Killing

Malicious killing of grizzly bears—i.e., poaching—was a major known or probable cause of death for grizzly bears in the NCDE between 2004 and 2014, accounting for roughly to same percentages of overall deaths on the west and east sides of the ecosystem (15 and 18%; A). Yet this is only the the proverbial tip of the iceberg, primarily because poaching is notoriously hard to document, especially in contrast to other causes such as removal by managers (all of which are documented) or collisions with vehicles and mistaken ID by black bear hunters (most of which are documented).

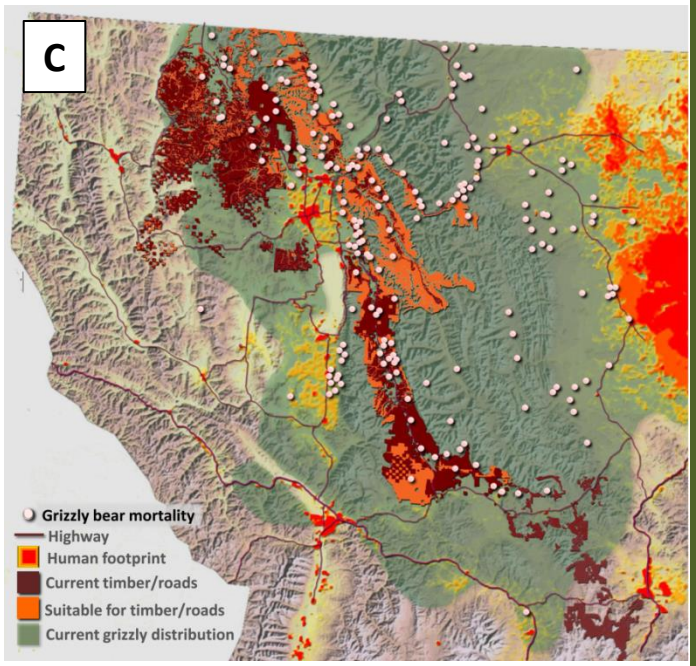




This bias towards under-reporting poaching is widely recognized, with the resulting development of methods for estimating numbers of unreported mortalities attributable to causes that are more likely versus less likely to be detected or reported. Among the former are Defense-of-life-and-property (DLP), collisions with vehicles, and mistaken ID. Among the latter are poaching and natural deaths.

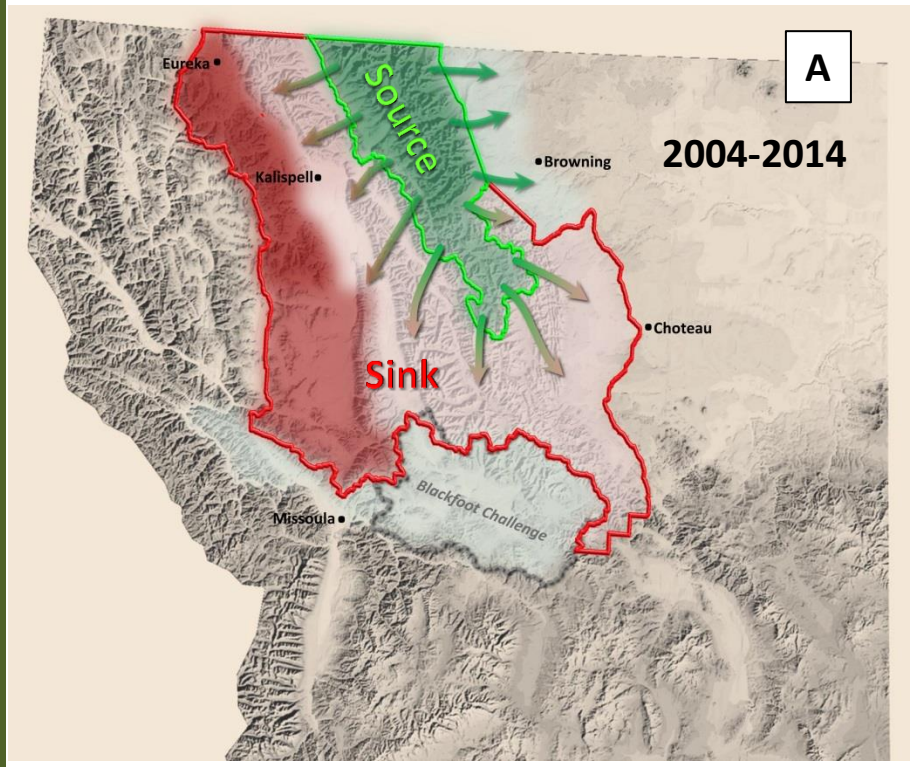
These methods using known fates of radio-marked bears produce coefficients that are used to multiply known-probable deaths from causes with high and low reporting rates to produce an estimate of total cause-specific mortality. These multipliers are summarized for various ecosystems and studies in B, ranging for a mean of 7 in the Canadian portion of the North Fork of the Flathead (pink square) to a mean of 2 in the Cabinet-Yaak ecosystem (pink diamond), with the NCDE in between at 2.6 (pink dot). The individual black dots represent the year-specific multipliers applied to mortalities in the NCDE over an 11-year period, excluding removals by managers and deaths of radio-marked bears.

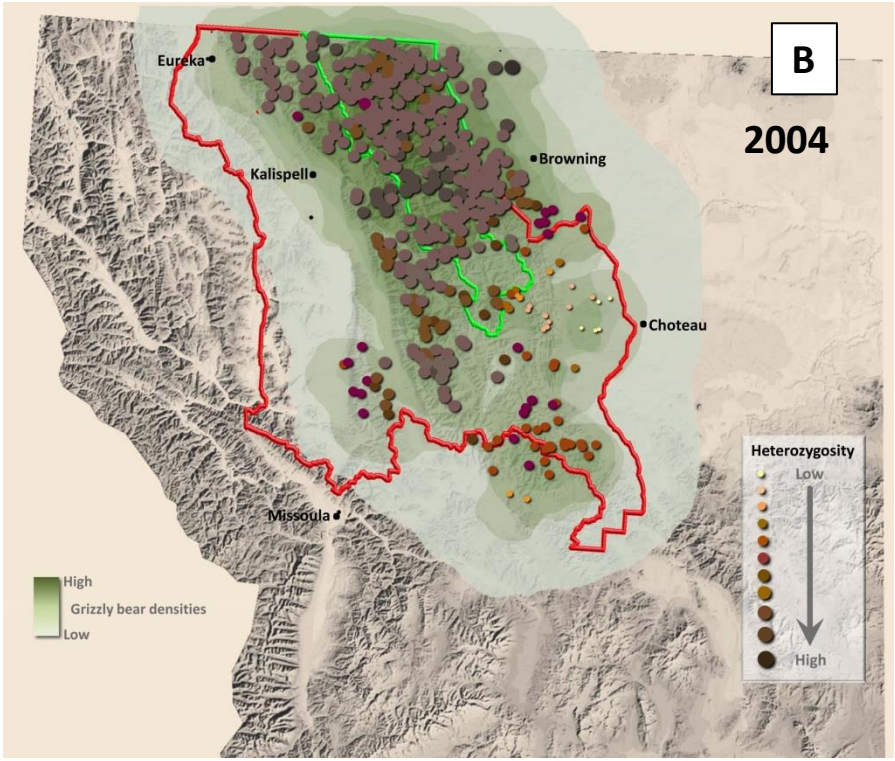
The upshot of adjusting cause-specific totals is a substantial increase in the relative fraction of deaths attributable to poaching. For example, in the NCDE, percentages attributable to malicious killing more than double, from 15-18% to 30-40%, making poaching the single most prevalent cause of grizzly bear deaths and, by implication, a major problem.



The Related Problem of Roads on Public Lands

The map in C overlays all known-probable grizzly bear mortalities from 2004-2014 (pink dots) on roaded public lands managed as being either suitable or potentially suitable for timber production (burgundy and dusky orange), along with the 'human footprint' defined primarily by croplands (to the east) and density of human residences (everywhere else). Not surprisingly, a strikingly disproportionate number of bear mortalities have occurred on lands with road access that are considered to be part of the timber base. Poaching is also, almost certainly, disproportionately concentrated in these areas. In short, there are good reasons for the on-going emphasis on limiting road access to public lands in management of grizzly bear mortality in the NCDE.





Source-Sink Structure

The consequences of concentrating lethal humans in remote portions of the southern NCDE during 1970-1990 (Page 36, Figs. A & B) was almost certainly to drive down the bear population in this area and establish what was probably a strong source-sink population structure that has persisted to the present, with Glacier National Park throughout this time being the most vigorous source area. Despite the termination of sport hunting, data on bear densities and mortalities broken out by NCDE subunits in Costello et al. (2016) show that a source-sink structure persists, as delineated in (A), with darker red denoting more extreme sink areas. Note the spatial match of the Blackfoot Challenge with a secondary source area defining southern portions of the NCDE Demographic Monitoring Area. The coexistence efforts undertaken by the Challenge (Page 35) probably account for this anomaly and related appearance of dispersing grizzly bears to the south and southwest (Page 50).

A long-duration source-sink structure is consistent with results of genetic analyses presented in Mikle et al. (2016) showing severely diminished genetic heterozygosity among bears residing in sink areas during 2004 (B), presumably as a consequence of a long preceding period of time during which a mere handful of male bears were responsible for most reproduction. Mikle et al suggest that there has been an infusion of reproductive adults into southern portions of the NCDE between 2004 and 2012 that has increased genetic heterozygosity and contributed to recovering this portion of the population.

Of more direct relevance to the demographic analyses presented in Costello et al. (2016), their failure to account for this source-sink structure inevitably leads to additional bias and impairs applications to management. At a minimum they should have estimated vital rates and population growth for the geographically-defined source and sink subpopulations as well as rates of exchange between the two.

Summary & Implications: Spatial Demography I

- Increases in grizzly bear distribution were uncoupled from increases in population size during the 1980s-2004 and 2009-2014 in the Northern Continental Divide Ecosystem (NCDE). Distribution increased by 3-4-fold more during these periods relative to any probable increases in numbers of bears, suggesting that changes in habitat, food availability, and diet played a major role.
- The comparatively rapid increase in distribution during the 1980s-2004 coincided with a dearth of fruit (the Berry Famine) in western portions of the ecosystem and terminal extirpations of whitebark pine as a food source in eastern portions.
- The comparatively rapid increase in distribution during 2009-2014 closely followed the rapid accretion of transient unproductive habitats generated by widespread wildfires during 1998-2007 in wildlands of the NCDE. This period was also marked by rapid restocking of rangelands with cattle to record high levels along the East Front in the aftermath of destocking driven by the epic 1998-2007 drought. This abundance of cattle coincided with a substantial decline in mule deer numbers at well as gut piles resulting from hunter kills, which no doubt drove bears to more often exploit cattle and thereby be drawn ever further into agricultural environments to the east.
- Natural and anthropogenic grizzly bear foods in agricultural landscapes of the eastern and southern portions of the NCDE are concentrated in riparian areas, with a resulting concentration of bears and bear-human conflicts in these lineated habitats.
- Concentration of foods in lineated riparian habitats of foothills and plains environments predictably accelerates the spread of grizzly bears out into such environments, no doubt contributing to the rapid expansion of bear distributions especially since 2009.

Summary & Implications: Spatial Demography II

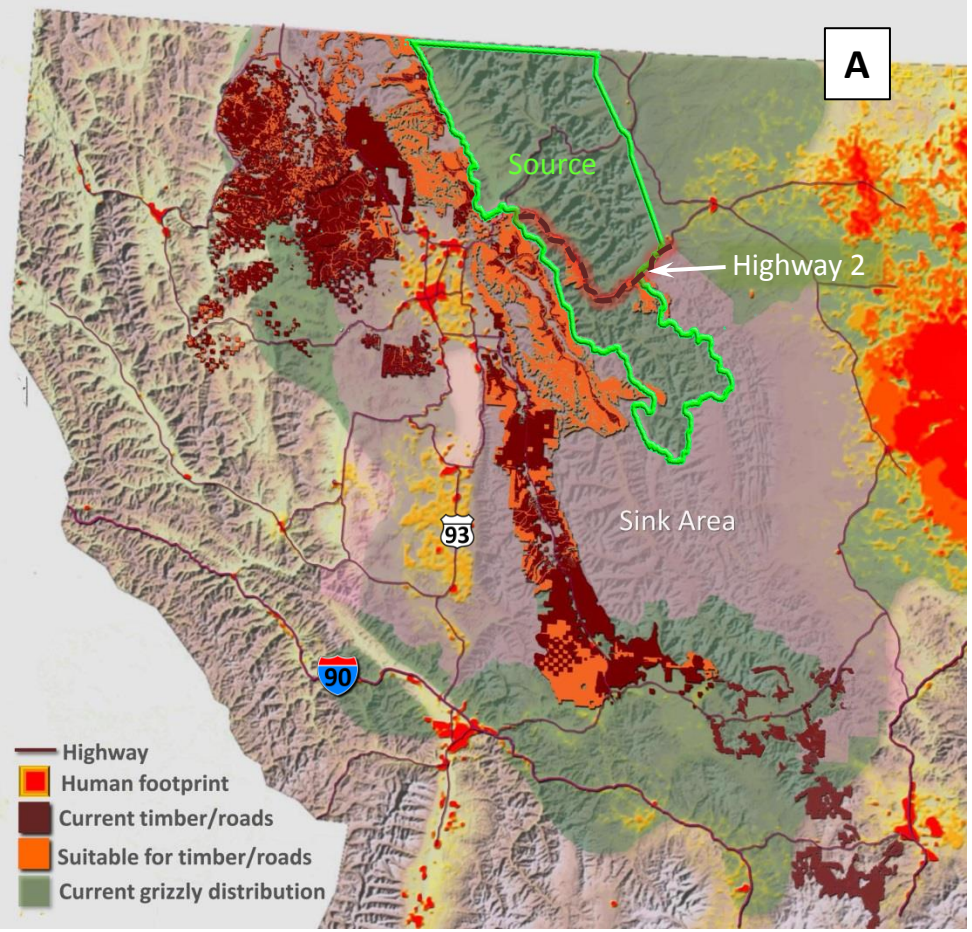
- Human causes account for roughly 90% of all mortality among grizzly bears >2 years of age, but the preponderance of different causes varies dramatically between eastern and western portions of the NCDE. This divergence in human causes reflects differences in environments, densities of livestock and people, and resulting sources of human-grizzly bear conflict.
- Meat-related conflicts and resulting bear deaths are proportionately much more common in agricultural landscapes to the east and south, in direct reflection of meat availability and the preponderance of meat in bear diets.
- Grizzly bears die much more often because of collisions with vehicles and because of conflicts over attractants concentrated around human residences in western portions of the NCDE, as a direct reflection of greater traffic and greater numbers of human residences. Defense-of-life-and-property (DLP) kills here are also much more common, partly as a result of much greater road access on lands devoted to production of timber.
- When adjusted to correct for much lower odds of detection compared to other human-causes, poaching emerges as the most important reason why adult grizzly bears die in the NCDE (roughly 30% of all deaths), with connections to the extent of road systems in landscapes supporting industrial-scale logging.
- Systems of secondary or industrial roads are much more extensive and dense in western portions of the NCDE, where proportionately much more land is devoted to timber production. As a result, management of human access along road systems is a more important management issue in western versus eastern parts of the NCDE.

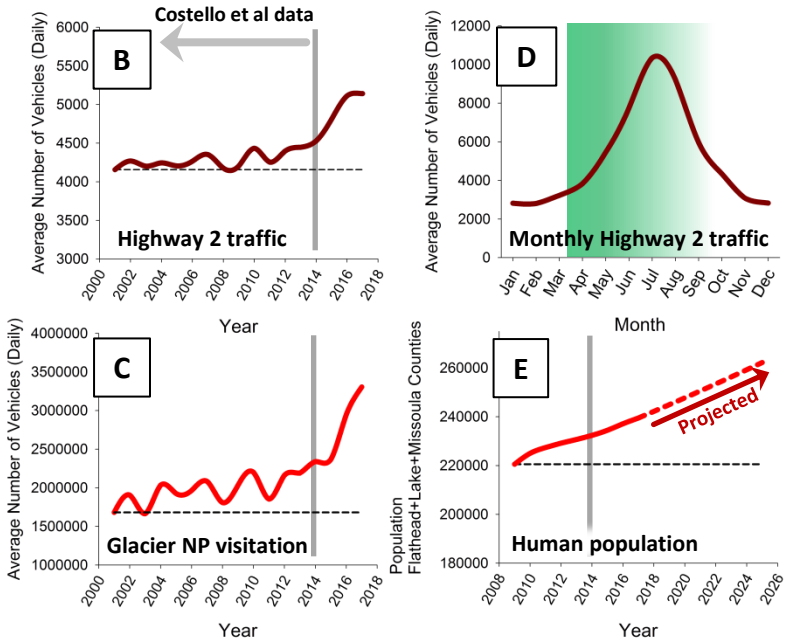
Summary & Implications: Spatial Demography III

- Between 1970 and 1997 grizzly bear mortalities were concentrated in remote portions of the NCDE, notably the Bob Marshall Wilderness Area, including almost all deaths from sport hunting.
- All available evidence suggests that this concentration of bear mortality in wildlands led to a virtual depopulation of especially male grizzly bears in the Bob Marshall Wilderness.
- The legacy of excessive mortality in non-Park wildlands prior to 1997 has been emergence and persistence of a source-sink population structure, with source areas centered on Glacier National Park and the Middle Fork of the Flathead River, and sinks most pronounced to the west in areas heavily impacted by human settlements, highways, and secondary road systems.
- Another legacy of excessive male-biased mortality in southern portions of the NCDE prior to 1997 was genetic impoverishment of grizzly bears living in these areas, primarily because most breeding was being done by a mere handful of wide-ranging males.
- Source-sink structures are an important feature of the NCDE grizzly bear population, especially in simulating population dynamics, managing grizzly bear mortality, and forecasting and addressing causes of mortality.

FRAGMENTATION

The Grizzly Bear Recovery Project





Human impacts have almost certainly increased since 2014, which is the end-point for data used in the analysis by Costello et al in support of delisting the NCDE bear population. Visitation to Glacier NP and associated traffic on Highway 2 both jumped sharply after 2014 (C & B), at the same time that human populations in Flathead, Lake, and Missoula Counties continued to steadily increase, with more increases projected for the near future (E). Highway 2 (labeled in A) is especially problematic because it potentially limits dispersal of bears from source to sink areas in the NCDE (see Page 38, Figures A).

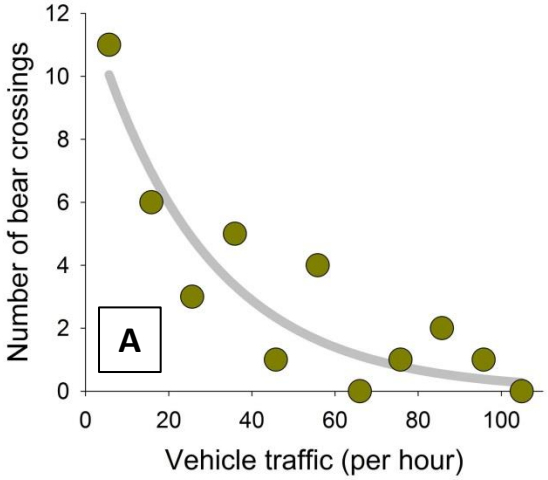
Fragmentation & Barriers

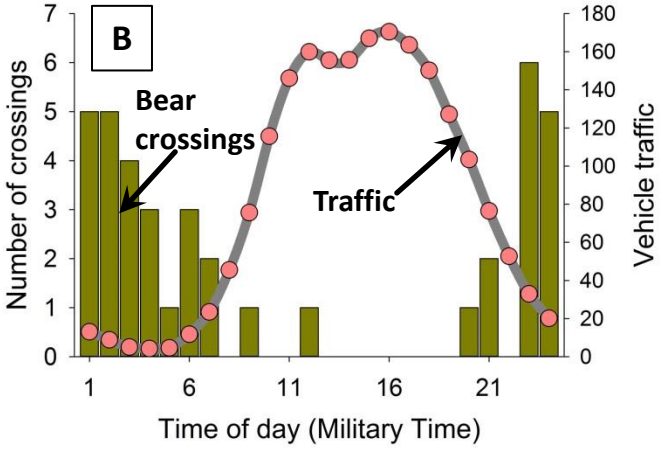
Dispersal of grizzly bears from the NCDE to areas west and southwest is impeded by formidable barriers in the form of the densely populated Flathead Valley and Missoula environs, denoted by red in the map above (A)—along with croplands to the east that also comprise areas most affected by the 'human footprint'. Impacts from shear numbers of resident people in the Flathead and Missoula environs is compounded by potentially lethal heavy traffic on I-90 to the south and US 93 to the west (Page 44, Figure C). There are also large areas of the Flathead and Kootenai National Forests in western portions of occupied grizzly bear habitat, shown in orange and burgundy, that are roaded and obligated to timber production, or likely to be roaded and logged in the next several decades. Human activity and associated poaching on these Forest Service roads introduce additional fragmentation of bear habitat, especially in the North and South Fork drainages of the Flathead River, the Swan Valley, and Salish Mountains (Page 37, Fig. C). It logically follows that much of the sink areas in the NCDE (in lavender above, plus see Page 38, Fig. A) coincide with these heavily-impacted areas. Failure by managers to limit or mitigate forest roads, private-lands developments, and high-speed high-volume highways will only perpetuate if not worsen existing levels of fragmentation.

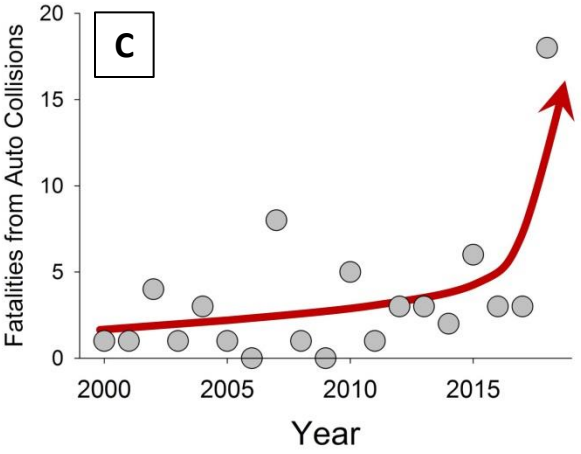
Fragmentation from Highways

Highway 2 and the associated BNSF railway along the south boundary of Glacier NP is an especially problematic fracture zone given that it sits astride much of the potential connectivity between the source area centered on the Park and sink areas to the south and southwest (see Page 43, Fig. A). Although not yet a barrier, Waller & Servheen (2005) documented already severe impacts of traffic on crossings by grizzly bears (A), which were concentrated at night when traffic was lightest (B). Crossings dropped dramatically during hours when traffic exceeded 20 vehicles per hour.

Fragmentation is caused not only by bears avoiding high-speed high traffic volume highways, but also, more tangibly, by lethal collisions with vehicles. Figure C shows the number of grizzly bears annually killed by such collisions during 2000-2018. Numbers of collision-related fatalities are clearly increasing and reached record levels during 2018.

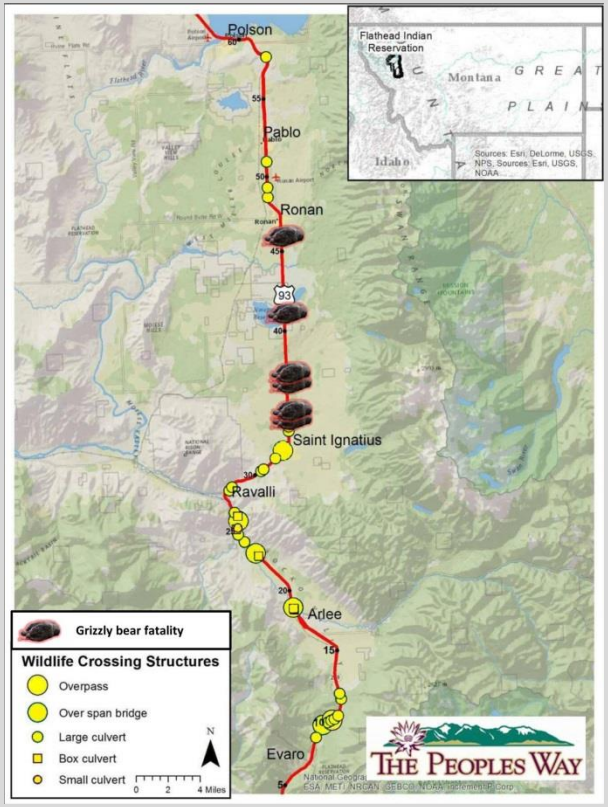






Highway Mitigation?

Some efforts have been made to reduce collisions between wildlife and vehicles on major highways, in Montana notably along 'The People's Way' on Highway 93 from Polson to Evaro. This collaborative effort resulted in the installation of crossing structures at 39 locations (shown as yellow dots at right), enhanced by nearly 9 miles of fencing to redirect wildlife. Although collisions declined by 70-80% in treated areas, collisions along the entire reconstructed highway actually increased due to higher traffic speeds and volumes. More important for bears, there was no indication that collision-related fatalities declined anywhere along the highway. A total of 6 grizzly bears were killed in collisions since 2002, five during 2010-2015 (shown at right). Despite heroic efforts, installation of crossing structures did not appreciably mitigate impacts of this highway on either black or grizzly bears.



Summary & Implications: Fragmentation

- A persistent source-sink population structure accentuates potential problems arising from fragmentation of sources areas to the north from sink areas to the west and south, primarily along heavily-trafficked transportation corridors. The most problematic of these corridors are centered on Highway 2 and the BNSF railway along the southern boundary of Glacier NP and Highway 93 to the west through the Flathead and Mission Valleys.

- The Highway 2 and 93 transportations corridors demonstrably impede grizzly bear movements. Even though an extensive system of wildlife crossing structures was installed along Highway 93, the infrastructure did not demonstrably benefit bears, primarily because the installations were not comprehensive along the full length of the Mission Valley.

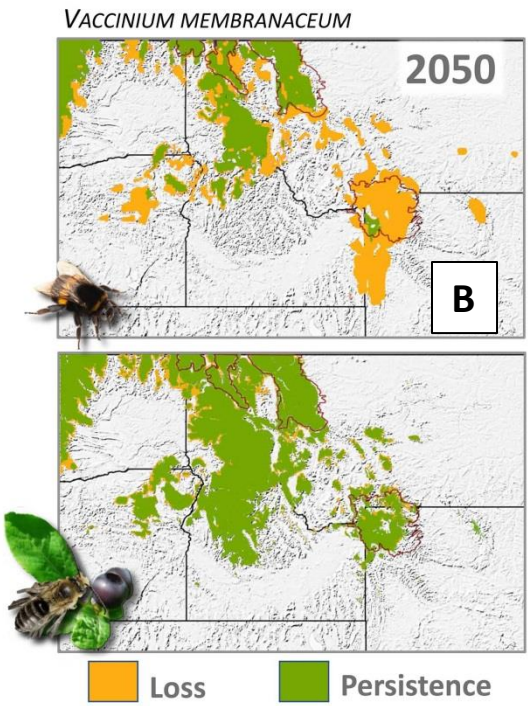
- The US Fish & Wildlife Service has not seriously addressed the inter-related issues of source-sink population structure and fragmentation in either its planning for or oversight management of the NCDE grizzly bear population. Both features have been altogether neglected in analyses and planning undertaken by the state of Montana.

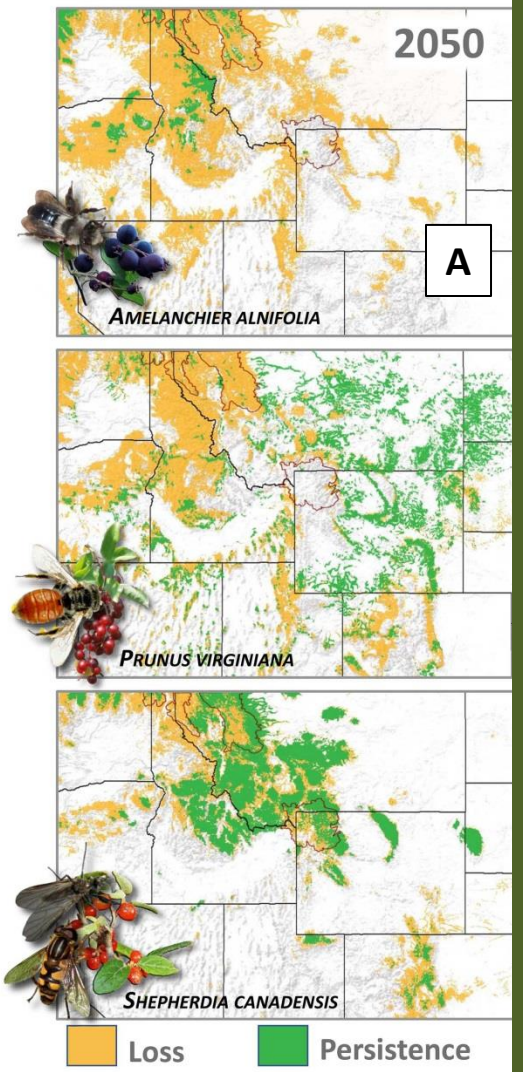
THE FUTURE

The Grizzly Bear
Recovery Project

The Future of Fruit-Bearing Species

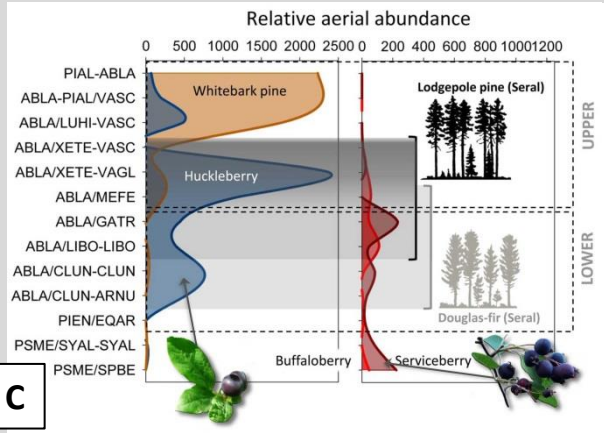
The state of Montana and US Fish & Wildlife Service have neglected the fundamentally important task of projecting changes in habitats and food abundance likely to transpire with foreseeable climate change in the NCDE. Nonetheless, it is almost certain that habitats will change substantially. The maps at right show changes in distributions of important fruit-producing shrubs in the northern Rockies according to one credible as yet unpublished projection. According to this analysis, we will likely see catastrophic declines in serviceberry and chokecherry (A). Modest losses of buffaloberry are also probable (A). Models for huckleberry are more variable, as shown in (B). One model fixed to static geomorphic and soil features shows little change (bottom in B). The other model emphasizing changes in climate shows substantial declines, especially in the south (top in B). Overall, abundance of key fruit-bearing species is likely to decrease—dramatically—by 2050 and even more so by 2100. The prospective effects of climate change on fruit-producing species is given further credence by the emphasis placed on this issue by Kasworm et al. (2017, 2018) for the Cabinet-Yaak Ecosystem immediately to the west.

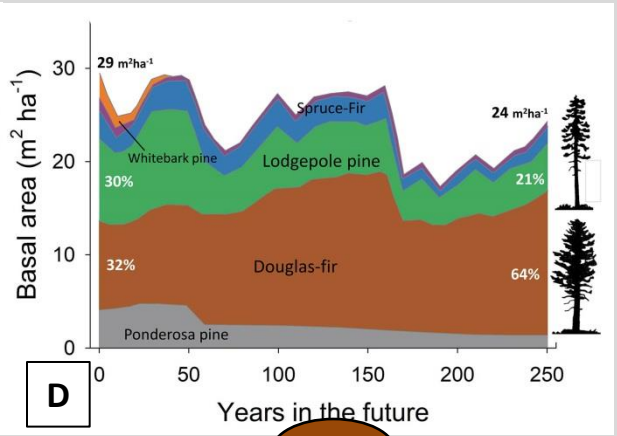




The Future of Fruit-Rich Habitats

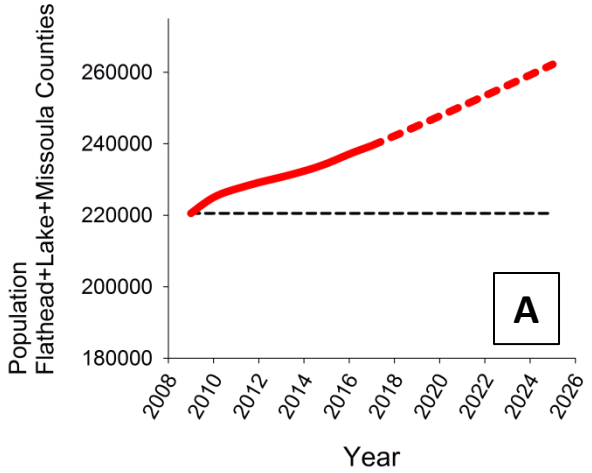
Several researchers have projected changes in wildfires and forest composition with climate warming in northwestern Montana. In general, areas dominated by lodgepole pine and subalpine forests are projected to decline substantially (as per D; Loehman et al. [2017]. This forecast is consistent with a projected decline of huckleberry based on a diminishing climate envelope given that huckleberry shrubs are closely identified with higher-elevation habitat types in which lodgepole pine is a dominant seral tree species (C; based on data in Pfister et al. [1977] and Aune & Kasworm [1985]).





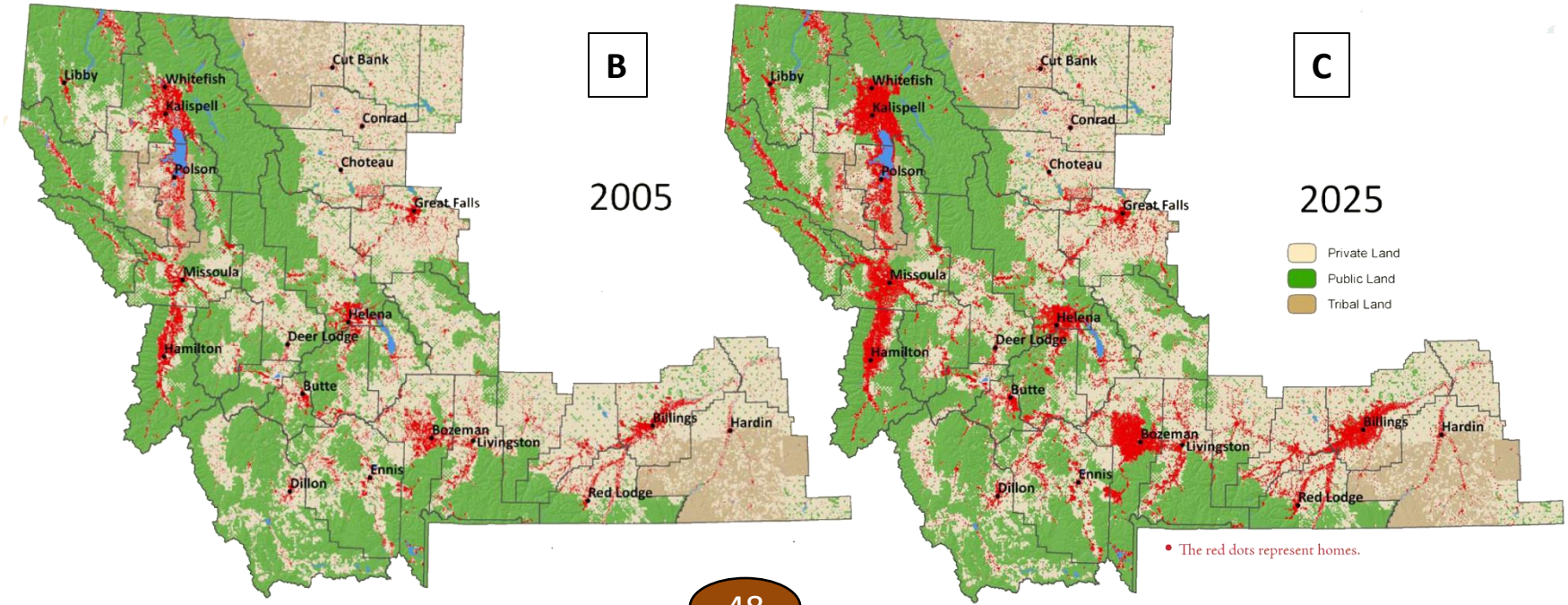
Human Populations West and Southwest of the NCDE Will Increase

Human populations have steadily grown in the Flathead, Mission and Clark's Fork Valleys to the west and southwest of the NCDE, especially since the turn of the last millennium, with demonstrable impacts on the NCDE grizzly bear population and prospects for regional recovery (Page 36, Fig. D, Pages 43 & 44). The best available projections suggest that human populations will grow by an additional 20,000 (or roughly 8% of the current total) during the next 8 years in Flathead, Lake, and Missoula counties (Figure A). Traffic on regional highways will predictably increase as a consequence, especially along Highway 93 and Interstate 90, which are major impediments to grizzly bear dispersal even now (Pages 43 & 44).



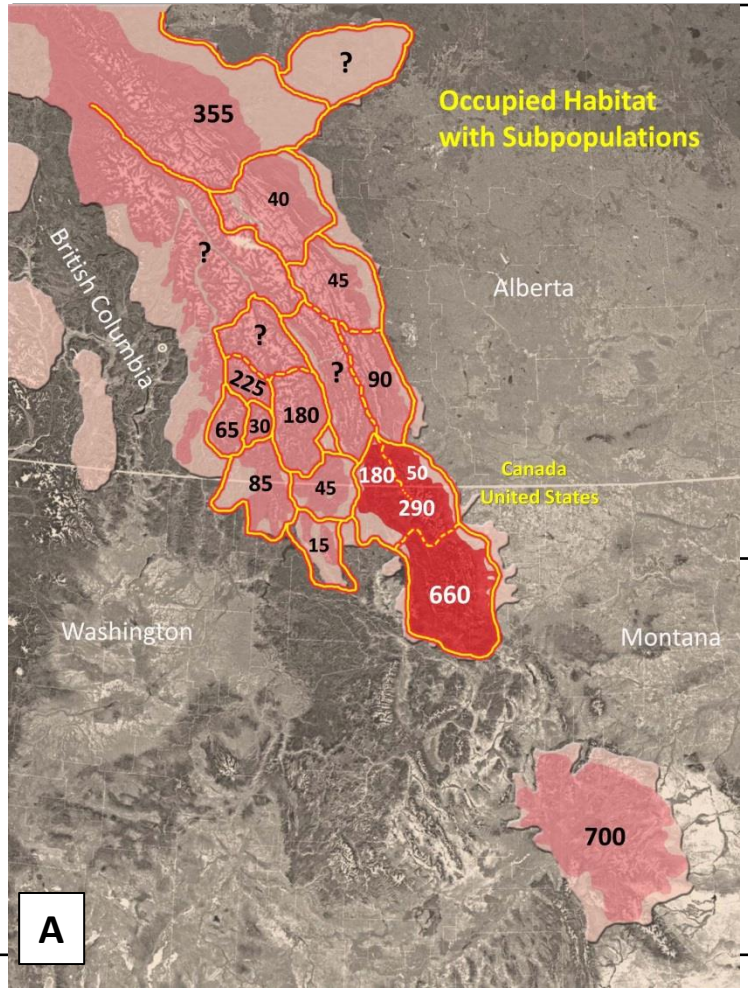
The Extent and Density of Human Residences Will Increase

Maps B and C, below, show the extent and density of human residences as of 2005 and projected for 2025—seven year in the future. The prognosis is for there to be many more residences in areas that are already problematic when it comes to human-grizzly bear conflicts, largely because of a burgeoning of attractants not only in the form of garbage, but also smaller domesticated animals such as chickens, pigs, and goats. Areas that are already an impediment to grizzly bear dispersal will predictably become even more of a gauntlet for bears, especially prospective colonizers of the Selway-Bitterroot Ecosystem in Idaho originating in the NCDE.



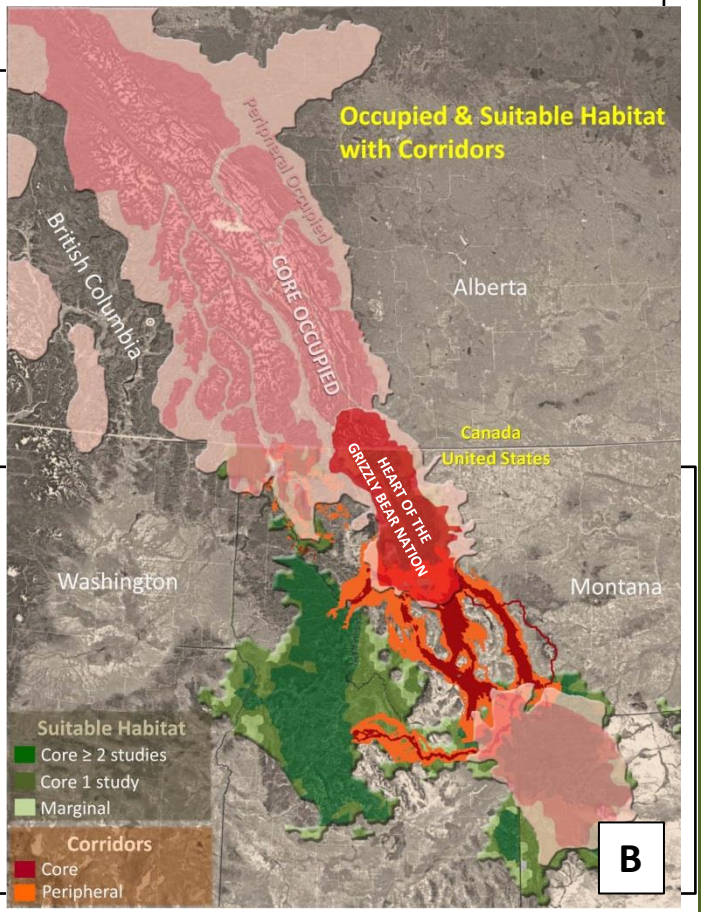
Fragmented and Endangered Populations

Grizzly bears in the Northern Continental Divide Ecosystem are contiguous with grizzly bear populations in Alberta and British Columbia. But, contrary to the inflamed imaginings of most people in the US, bear populations in adjacent parts of Canada are not in great shape. Alberta's grizzly bears are listed as Threatened under *Alberta's Wildlife Act* and number between 500 and 750 Province-wide (Festa-Bianchet 2010). Moreover, grizzly bear populations in Canada are highly fragmented. The map at left (A) summarizes the size of populations and nature of fragmentation (yellow lines) in Canada based on research by Proctor et al (2012) and Apps et al (2016). Of direct relevance to the NCDE, grizzly bear populations immediately to the north of the border number no more than 230-275, largely isolated from bears farther north by heavy traffic on Canadian Highway 3. Moreover, grizzlies to the west and northwest in the Yahk/Yaak are even more isolated, and number no more than 40-50. We can expect no rescue from bears in Canada. If anything, grizzly bears in the NCDE will rescue bears in Canada and, ultimately, in the Yaak, but only if the NCDE population is vigorous.



Ample Potential

Grizzly bears in the NCDE are vital to full recovery of grizzly bear populations in adjacent Canada as well as elsewhere in the United States. They constitute the *Heart of the Grizzly Bear Nation* at the southern limits of grizzly bear distribution in North America. Yet The Heart can only serve this purpose to the extent that there is potential for outward dispersal and colonization, as well as habitat suitable for supporting resident bears on the receiving end. This holds no more so than for the Selway-Bitterroot Recovery Area and central Idaho more broadly. The map at right (B) summarizes results of all the research done to date on potential dispersal corridors (notably, Walker & Craighead 1998, Servheen 2001, Proctor et al 2015, Peck et al 2017) as well the extent and location of suitable habitat (notably, Merrill et al 1999; Merrill & Mattson 2003; Mattson & Merrill 2004; Merrill 2005; Carroll et al 2001,2003). There is ample potential for dispersal and colonization, and ample potential for a grizzly bear population in central Idaho (>600 bears).

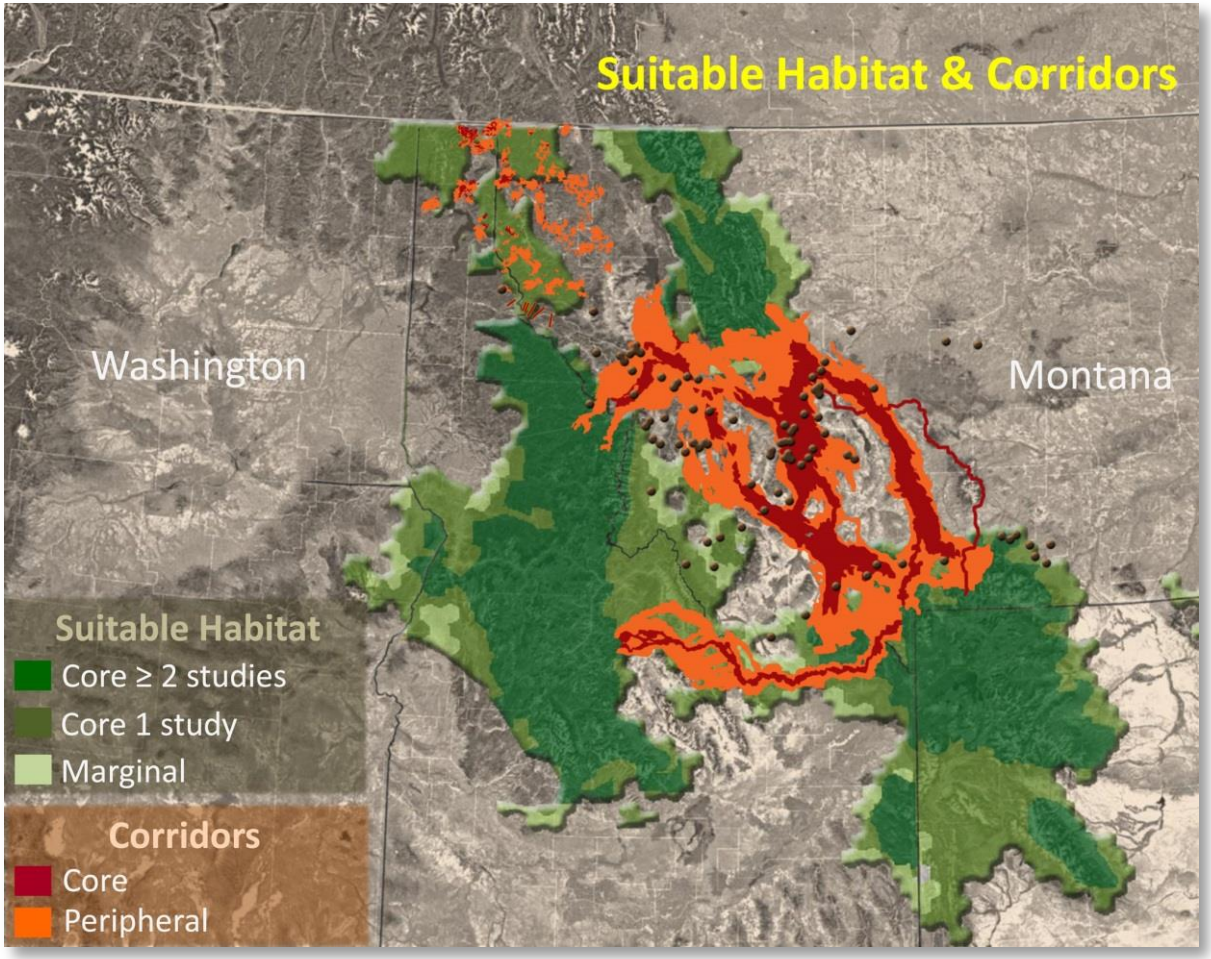


The Bears are Showing Us with Their Feet

The map at right distills what we know about potential suitable habitat, potential dispersal routes, and documented grizzly bear dispersers on the periphery of the northern US Rocky Mountains. The results are promising, but only if we protect the bears that are venturing beyond the bounds of established protections.

More specifically, the green depicts areas that have been shown by a number of researchers to be suitable for sustaining resident grizzly bears (see Page 49); the orange and burgundy, areas likely to support dispersers and colonizers; and the black dots, documented instances of grizzly bears venturing far afield into the areas modeled as being auspicious, but some in defiance of modelers and modelers.

When put together, these results suggest that grizzly bears could occupy much more of the northern Rockies than they currently do, but, again, only if colonizers and dispersers are not killed or trapped and relocated, as recently happened with a grizzly bear that had made it as far south and west as Stevensville, Montana. Removing ESA protections will obviate all of this potential, and relegate grizzly bears to current Recovery Areas, which are more an artifact of history than a reflection of existing potential.



Summary & Implications: The Future

- Climate warming is underway in the NCDE and will almost certainly accelerate during the next 50 years. Even though forecasts for precipitation are more uncertain, it is almost certain that any increases will be offset by warmer temperatures to produce more frequent and severe late summer and fall droughts.
- Recent history has shown that sustained drought leads to increased frequency and extent of wildfires, near across-the-board declines in berry crops, and declines in abundance of both native and anthropogenic sources of dietary meat for grizzly bears, with resulting deleterious consequences for the NCDE grizzly bear population.
- Projected climate change will likely result in loss of much of the berry-producing shrubs in most places, with resulting severe consequences for grizzly bears in portions of the NCDE where berries currently comprise a critical part of the bear diet.
- Projected climate change will almost certainly cause major changes in vegetation composition, directly, because of changing weather norms and extremes and, indirectly, because of increased frequency and extent of wildfires. Avalanche chutes and habitats that support huckleberry will very likely decline.
- Human populations and the extent of the human infrastructure will almost certainly increase, with related impacts on grizzly bears, especially in the Flathead and Mission Valleys and the environs of Missoula.
- The US Fish & Wildlife Service has failed to meaningfully assess foreseeable changes in habitats, foods, and mortality risks for NCDE grizzly bears, and thereby does not meaningfully address these changes in any planning or management.
- Even more problematic, the Service has failed to account for and capitalize on the ample potential suitable but unoccupied grizzly bear habitat in the Northern Rockies. If considered, this unrealized potential is the basis for robust regional recovery in the form of a single contiguous grizzly bear population of near 3,000 individuals.

The Grizzly Bear Recovery Project

SUMMARY OF CRITIQUE

The Grizzly Bear Recovery Project

SUMMARY OF CRITIQUE I

- The US Fish & Widlife Service does not recognize the modern scientific consensus on taxonomy and phylogeny of *Ursus arctos* that has emerged since the early 1990s, and instead relies on an outdated schematic produced during the 1960s and 1970s. As a consequence, the Service also ignores the current scientific consensus on paleogeography of *Ursus arctos*, including the unique evolutionary and more recent history of Clade 4 grizzly bears.
- In part because of these failings, the Service fails to conceive of or plan Recovery for grizzly bears in the contiguous United States as a unique and globally endangered genetic lineage with a distinctive shared history, ecological niche, and historical distribution.
- Variations in food availability and diet of grizzly bears in the Northern Continental Divide Ecosystem(NCDE), both geographically and temporally, have major ramifications for demography and distribution of this population.
- The Service dismisses these facts out of hand in its Recovery planning by invoking omnivory, claiming that, because grizzly bears are omnivores, environmental and dietary changes are inconsequential. As a presumed logical derivative, the Service then goes on to contend that it is relieved of any burden to monitor foods and habitats in the NCDE.
- Abundance of key foods has varied substantially during the last 40 years with demonstrable affects on demography and distribution of the NCDE grizzly bear population. A berry famine on the west side caused increases in bear mortality and distribution, coincidence with terminal losses of whitebark pine in mountains of the East Front. The frequency and extent of wildfires also increased substantially since the mid-1980s, with effects on habitat productivity. At the same time, stocking rates of cattle along the East Front declined and then recovered to record levels, coincident with substantial declines in mule deer populations.
- The Service fails to account for any of these changes in grizzly bear habitats, foods, and diets in its assessment of trends, threats, or projected future risks, and thereby fails to offer a realistic insightful context for management and recovery planning of the NCDE grizzly bear population.

The Grizzly Bear Recovery Project

SUMMARY OF CRITIQUE II

- Estimates of population growth for the Northern Continental Divide Ecosystem (NCDE) grizzly bear population are entirely retrospective and, with passage of time, tethered to increasingly aged and irrelevant data that thereby make these estimates progressively more insensitive to current population trend.
- Deficiencies in models and software (i.e., RISKMAN) being used by government biologists are compounded by problems with how population growth is being simulated, resulting in substantial unacknowledged risks of over-harvest engendered by methods being proposed by the Service for management of grizzly bear mortality.
- There is no credible basis for estimating current population size or recent growth rate for the NCDE grizzly bear population, and therefore no credible input into calculations that would presumably yield estimates of allowable mortality.
- Increases in grizzly bear distribution were uncoupled from increases in population size during the 1980s-2004 and 2009-2014 in the NCDE. Distribution increased by 3-4-fold more during these periods relative to any probable increases in numbers of bears, largely because of changes in habitat, food availability, and diet.
- The roles of habitat, food availability, and diet in driving changes in population distribution are unacknowledged by the Service, which fatally compromises any government analysis of distributional dynamics for the NCDE grizzly bear population.
- When adjusted to correct for much lower odds of detection compared to other human-causes, poaching emerges as the most important reason why adult grizzly bears die in the NCDE (roughly 30% of all deaths), in part driven by the extent of road systems in landscapes with industrial-scale logging.
- Systems of secondary or industrial roads are extensive and dense in western portions of the NCDE, where proportionately much more land is devoted to timber production. As a result, management of human access along road systems is an important management issue in western parts of the NCDE, with ramifications for recovery of the entire NCDE grizzly bear population.

The Grizzly Bear Recovery Project

SUMMARY OF CRITIQUE III

- Source-sink structures are an important feature of the NCDE grizzly bear population, especially in simulating population dynamics, managing grizzly bear mortality, and forecasting and addressing causes of mortality.
- The Service has not seriously addressed the inter-related issues of source-sink population structure and fragmentation in either its planning for or oversight management of the NCDE grizzly bear population. Both features have been altogether neglected in analyses and planning undertaken by the state of Montana.
- Projected climate change will likely result in loss of much of the berry-producing shrubs in most places, with resulting severe consequences for grizzly bears in portions of the NCDE where berries currently comprise a critical part of the bear diet.
- Projected climate change will almost certainly cause major changes in vegetation composition, directly, because of changing weather norms and extremes and, indirectly, because of increased frequency and extent of wildfires. Avalanche chutes and habitats that support huckleberry will very likely decline.
- Human populations and the extent of the human infrastructure will almost certainly increase, with related impacts on grizzly bears, especially in the Flathead and Mission Valleys and the environs of Missoula.
- The Service has failed to meaningfully assess foreseeable changes in habitats, foods, and mortality risks for NCDE grizzly bears, and thereby does not meaningfully address these changes in any planning or management.
- Climate warming is underway in the NCDE and will almost certainly accelerate during the next 50 years. Even though forecasts for precipitation are more variable, it is almost certain that any increases will be offset by warmer temperatures to produce more frequent and severe late summer and fall droughts.
- Even more problematic, the Service has failed to account for and capitalize on the ample potential suitable but unoccupied grizzly bear habitat in the Northern Rockies. If considered, this unrealized potential is the basis for robust regional recovery in the form of a single contiguous grizzly bear population of near 3,000 individuals, with the Heart of the Grizzly Bear Nation key to achieving this potential.

The Grizzly Bear Recovery Project

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In what follows I have assembled a list of references for the material I present here, organized by relevance to the various chapters. Some of this material is explicitly referenced; some drawn upon but not referenced; some consulted but not relied upon explicitly for information that I present; but all scrutinized for helpful insights. Regardless of the degree of reliance, what follows hopefully provides readers with a list of publications that they can consult for further information and insights.

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